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Report No. FAA-SS-72-41

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SST Technology Follow-On Program—Phase

NINTERS STREET, MARSH

JUN 27 1972

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A SUMMARY OF THE SST NOISE SUPPRESSION TEST PROGRAM

The Boeing Company Commercial Airplane Group P.O. Box 3707 Seattle, Washington 98124



D6-60241 February 1972

FINAL REPORT Task 4

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Prepared for

FEDERAL AVIATION ADMINISTRATION Office of Supersonic Transport Development 800 Independence Avenue, S.W. Washington, D.C. 20590

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SYMBOLS

A _B	nozzle base area = A_F (AR - 1)
A _{BID}	ejector inlet ventilating flow area
A _{BID} /A _B	ejector ventilation parameter
A _E	nozzle exit area (convergent-divergent nozzle)
A _F	nozzle flow area
AR	ratio of total nozzle area to flow area
AS	tube array physical ventilation flow area between outer-row tubes
A _S /A _B	ventilation parameter
A _T	ejector cross-sectional flow area at throat station
A ₈	nozzle area at the exit plane
A*	nozzle throat area
BID	ejector blow-in door to allow admission of ambient air
C _D	nozzle discharge coefficient (equals measured weight flow divided by ideal weight flow of physical flow area at prescribed nozzle total pressure and total temperature)
C _{Fg}	gross thrust coefficient (equals measured nozzle thrust divided by ideal thrust of <i>measured</i> weight flow at prescribed nozzle total pressure and total temperature $F/(W_{act}V_{IP}/g)$)
DB	nozzle base drag, lb
D _E	diameter of ejector exit or diameter of ejector for constant-area ejectors
D _P	nozzle-diameter to outside of baseplate
D _T	ejector throat diameter
EPNL.	effective perceived noise level, EPNdB
FI	ideal thrust of given nozzle weight flow at prescribed nozzle total pressure and total temperature, lb

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g	universal gravitational constant
L	ejector length excluding inlet lip
L _T	exposed tube length from baseplate to tube exit
M _e	tube exit Mach number
м _g	Mach number of the fully expanded flow
N _o	number of tubes in outer row
OASPL	overall sound pressure level (45 to 11,200 Hz, full scale), dB
OASPL (average)	averaged values of OASPL from two or more microphone locations, dB
P _B	average base pressure on baseplate
P_B/P_V	nozzle base pressure ratio for shrouded configurations
P_B/P_{∞}	nozzle base pressure ratio (no ejector installed)
P _{LIP}	static pressure acting on internal surface of ejector inlet lip
PNL	perceived noise level, PNdB
PT	nozzle total pressure
P_T/P_{∞}	nozzle pressure ratio
P _V	local ventilating air static pressure surrounding multitube array for shrouded configurations
P_{∞}	freestre:.m static pressure
R	gas constant
RC	round convergent (nozzle)
SPL	sound pressure level, dB re: $0.0002 \text{ dynes/cm}^2$
TSEN	two-stage ejector nozzle
T _T	nozzle gas total temperature, °F
T ₈	nozzle gas total temperature at the exit plane, °F

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v _{IP}	ideal fully expanded primary jet velocity at prescribed nozzle total pressure and total temperature, fps
W _A	measured primary airflow-rate, lb/sec
W _{act}	measured primary nozzle gas flow rate, lb/sec ($W_A + W_f$)
W _f	fuel flow rate, lb/sec
γ	gas specific heat ratio
θ	half angle of spoke apex, deg

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1.0 INTRODUCTION

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The supersonic transport jet noise reduction efforts described in this document encompass the period from February 1966 through March 1971. During these 5 years, The Boeing Company and the General Electric Company were developing two prototype-SST aircraft and engines under FAA contracts.

Both Boeing and General Electric conducted applied research on the problem of suppressing-SST propulsion radiated acoustic noise. Only the results of the Boeing program will be presented in this review.

Initially, the Boeing research program was divided into a low noise-suppression effort to investigate ways of obtaining at least 5 PNdB sideline suppression and a high noisesuppression effort to obtain 12 to 20 PNdB sideline suppression with 10% or less thrust loss. About 5 PNdB suppression was deemed necessary to meet 1966 requirements of ≤ 116 PNdB maximum noise levels at the 1500-ft sideline for the prototype SST. Higher noise suppression was considered necessary for the commercial version of the SST to:

- Achieve community noise standards under the flightpath comparable to subsonic intercontinental aircraft in the same production time period
- Achieve sideline noise reduction such that, at a distance of 1 nmi to the side of any international runway, the SST would be as quiet as the existing subsonic jets

It was believed that these objectives would be technically feasible by early 1978 and were consistent with proposed airport noise regulations and land use of 1966.

The Federal Aviation Administration (on November 3, 1969) issued Noise Standards: Aircraft Type Certification referred to as FAR 36. These noise standards became the goal for the production SST jet noise suppression effort. At takeoff, the perceived noise level at the 0.35-nmi sideline was not to exceed 108 EPNdB, cutback noise underneath the aircraft 3.5-nmi from the start of the takeoff roll was not to exceed 108 EPNdB, and approach noise at a point 1 nmi from the threshold was not to exceed 108 EPNdB.

The SST jet noise suppression program was a joint effort of the aircraft noise, aerodynamics, design, and propulsion staffs of the Commercial Airplane Group. The techniques of supersonic jet noise suppression had to be established, mindful of other considerations affecting aircraft reliability and economics. Any jet noise suppression hardware applied to the engines must be retracted when the aircraft is clear of the community to avoid penalizing flight efficiency during climb and cruising flight. Originally, suppressor nozzle hardware had to be subjected to an afterburner primary gas environment approaching 3000° F. This required an investigation into materials and methods of cooling. Nozzle thrust losses had to be determined and methods for minimizing these losses ascertained.

1.1 LOW NOISE-SUPPRESSION (5 PNDB) PROGRAM

The purpose of this test program was to develop a jet noise suppressor concept for the SST turbojet engine that would allow the prototype airplane to take off with maximumavailable thrust and not to exceed the 116-PNdB, 1500-ft sideline noise objective set by the FAA. It was ca. Lated that a minimum of 5 PNdB of noise suppression with respect to a standard nozzle configuration would be required.

The initial nozzle configurations considered to achieve the 5-PNdB suppression were determined from a review of past noise studies. Particular emphasis was placed on a review of model suppressor nozzle tests conducted by Boeing, General Electric, and P&WA, references 1, 2, 3, and 4. Nozzle noise suppressor systems were selected that were considered adaptable to the prototype SST engine and would provide the desired amount of noise suppression.

Suppressor nozzle hardware was designed and manufactured. Model-scale nozzle testing was conducted to determine noise-suppression characteristics, and the more promising configurations were modified to determine optimum relationships between physical parameters and jet noise suppression.

A parallel program to study the thrust, drag, and weight penalties associated with selected suppressor systems was conducted by the Propulsion staff (ref. 5). The suppressor nozzle configurations that provided at least 5 PNdB suppression and were best suited to current SST design were constructed and tested on a J-75 engine to confirm model-scale test results. The model-scale 5-PNdB test program is described in references 6 and 7. The large-scale 5-PNdB test program is described in references 8, 9, and 10.

1.2 HIGH NOISE-SUPPRESSION (20 PNDB) PROGRAM

The high noise-suppression program proposed to develop a jet noise suppressor concept that could be applied to the production (or commercial) SST airplane. It was predicted that 12- to 20-PNdB sideline jet noise suppression was necessary at the sideline measuring point during lift-off to meet FAA community noise requirements. The jet noise suppressor system shculd not exact more than 10% thrust loss and still be compatible with cruise stowage requirements. Jet noise suppressor nozzles attaining a PNdB suppression/percent-thrust-loss ratio greater than unity were considered candidates for a jet noise suppression system.

The applied research program to determine suppressor nozzle noise characteristics was primarily oriented to subjective considerations, e.g., PNdB levels at the 1500-ft sideline. A secondary consideration was the investigation of noise spectra, undistorted by atmospheric propagation anomalies, to determine the major influences of jet configuration on acoustic signatures. Initially, there was very little information available concerning jet noise suppression systems applicable to the SST and GE4 engine. The relatively high nozzle pressure ratio and total temperature of the primary flow common to the GE4/J5P engine was beyond the consideration of jet noise research programs conducted previously. At the onset of the SST high noise-suppression program, the groups involved in the development of a commercial version SST jet noise suppression system (e.g., Boeing Acoustics, Aerodynamics, Propulsion, Project Design, and Thermal Environment staffs) had to establish their particular technologies. This required development of facilities to acquire test data; construction of test hardware;

and establishment of the methods, computer routines, and other software items necessary. An integrated effort was established between the technical groups whenever development of a design concept was considered. Ť

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The general technical approach that was applied to solve the SST jet noise problem was as follows:

- Review previous noise suppressor data.
- Design, fabricate, test, and analyze new suppressor model configurations having high suppression potential.
- Establish suppressor acoustic and performance characteristics of basic suppressor concepts as a function of key variables.
- Conduct suppressor element thermal environment and cooling tests to establish required design criteria compatible with afterburning operation.
- Conduct design implementation studies to incorporate desired suppressor characteristics and define resulting installation penalties.
- Conduct engine-cycle and airplane-installation studies to define optimum compromise between noise level and airplane performance.
- Design, fabricate, test, and analyze suppressor configurations that reflect above study results.
- Conduct large-scale tests to verify small-scale results.
- Design, fabricate, and test large-scale demonstrator suppressor nozzles meeting program objectives and representing best overall compromise between noise level and airplane performance.

The first suppressor nozzle configurations tested were multitube and multispoke hardware from earlier test programs. These nozzles, designated MPP or MAE, were eighth-scale JT3/C4 (or C6) engine suppressor nozzle concepts. Testing was limited to a maximum total temperature of 1100° F. At a nozzle pressure ratio of 3.0, these nozzles provided 7 to 11 PNdB suppression at 1500-ft sideline. The results were encouraging enough to warrant a parametric study of spoke- and tube-type nozzle configurations to determine the prime variables associated with jet noise suppression.

2.0 JET MOISE TEST FACILITIES AND TECHNIQUES

Most of the SST jet noise suppression program model-scale testing was accomplished at the Boeing Annex D and hot-nozzle test facility (HNTF) in Seattle. Throughout the program, facilities and measurement techniques were improved for acquiring and reducing data, increasing the dynamic range of the gas generators, and controlling acoustic interference anomalies such as ground reflection interference and sources of noise-interference.

The same improvements occurred at the full-scale test facilities. Initial testing was done on an afterburning YJ-75 turbojet engine at the North end of Boeing Field in Seattle. The Bueing Company program to minimize noise for neighboring communities led to development of Boeing's Boardman, Oregon site as a research facility for the study of aircraft propulsion system noise reduction. Full-scale testing of SST jet noise suppressor concepts at Boardman used the YJ-75 and J-93 turbojet engines. Unfortunately, an engine capable of the high pressure ratios with high total temperatures equivalent to the proposed GE4 engine conditions at takeoff had never been developed. Therefore, full-scale testing was more representative of SST cutback engine conditions and was used more to verify the model-scale suppressor test results and scaling techniques employed. A 36-spoke nozzle tested both full scale and model scale showed very good agreement in jet noise characteristics (see ref. 11). Full-scale test anomalies, e.g., ground reflection interference and engine machinery noise interference, are much more difficult to control compared to model-scale tests when jet noise suppression is the object of investigation. As a research tool, the model-scale test facility at this time is more versatile and yields higher quality and quantity of data at lower cost. Full-scale testing of an engine/suppressor nozzle system is important to determine the conglomerate acoustic signature of the propulsion system from individual sound sources, e.g., jet noise, turbomachinery noise, fan noise, engine casing noise, etc., in the final analysis.

2.1 MODEL-SCALE

2.1.1 Annex D

The hot-gas test facility is located at Annex D in the Boeing Plant II complex at Seattle, Washington. The facility was designed to test eighth-scale nozzle hardware with a flow area of 13.2 sq in. Pressure ratios of 7.0 and temperatures of 2500° F are possible. A 6-in. flow duct and limited air supply of 16 lb/sec restricted the size of nozzles tested. The hot-gas equipment, similar to a scaled version of an afterburning J-47 engine, is mounted in an outdoor arena on the north side of Annex D. Controls for regulating gas temperature and total pressure, acoustic data recording equipment, and performance data recording equipment are located within Annex D.

Figure 1 shows the acoustic test arena. The arena is bounded by a slanted-wall fence to reduce the noise levels in adjacent work spaces. An anemometer/wind vane set in the test arena with a readout in the control room is monitored during the recording of acoustic data to keep wind-induced acoustic propagation anomalies within prescribed limits. A closed-circuit television system provides visual monitoring of test hardware. The floor of the acoustic test arena is paved with concrete resulting in a "hard" acoustical surface. The hot-gas flow pipe axis or jet axis is horizontal and 20 in. above the arena floor.



Initially, the microphones were placed 20 in. above the arena floor on a 25-ft arc centered at the nozzle exit. In eighth-scale nozzle tests, 25 ft was equivalent to 200 ft in full scale. This test setup introduced a ground reflection interference anomaly that distorted the measured spectrum.

Another microphone arrangement used the 25-ft polar arc layout except that the microphone was located close to the arena floor. This situation was designed to make use of pressure "doubling" at the air/ground interface. Theoretically, the noise spectrum measured at the acoustically hard ground surface will be 6 dB higher than the free-field noise levels. Subtracting 6 dB from the measured noise levels should provide the free-field spectrum level. This advancement facilitated spectrum analysis techniques. The irregularities of the arena floor relative to the wave length of the acoustic noise recorded introduced diffraction anomalies that caused some distortion, notably in the high-frequency portion of the spectrum.

An overhead or vertical-plane microphone arrangement was installed during 1968. Microphones were located at 10° intervals from 40° to 80° on a 25-ft polar arc. The jet turbulence was used to shield the microphones from the ground-reflected noise. This allowed direct measurement of the free-field jet noise with no adjustments to the spectrum necessary. Later it was determined that the low frequencies diffracted around the jet causing abnormally high noise levels in that portion of the spectrum. Installation of a 2-in.-thick fiberglass blanket on the ground underneath the jet eliminated the low-frequency ground-reflection interference.

2.1.1.1 Internal Flow and Performance Instrumentation

Nozzle gas pressures were set by the facility operator with an open mercury manometer indicator with an accuracy of ± 0.2 in. Hg. Gas total temperature was measured with a platinum, 10% rhodium thermocouple, accurate to within 60° at 3000° R. An ASME flow nozzle upstream of the burner was used to measure air weight flow. Fuel flow to the burner was measured by a Potter flow meter accurate to within $\pm 0.5\%$. A 1000-lb Baldwin loadcell was used to measure thrust. The accuracy of thrust measurements was never certified but is believed to be within $\pm 0.5\%$ to $\pm 2\%$. A schematic of the burner and thrust rig is shown in figure 2. Photographs of the burner, burner control panel, and scanner printout system are shown in figures 3, 4, and 5. The values printed out by the scanner instrument system were thrust, fuel flow, fuel pressure, fuel temperature, air temperature, flow nozzle pressures, exhaust nozzle total pressure, and exhaust nozzle total temperature.

A complete description of the Annex D, test cell 1 hot-gas supply system can be found in references 12 and 13.

2.1.1.2 Acoustic Instrumentation

A block diagram of the acoustic data acquisition system is shown in figure 6 (from ref. 7). Four to eight microphone systems were used, depending on the test requirements. Each microphone system was calibrated with an electrostatic actuator and a frequency recorder from 20 Hz to 200 kHz. An electrical insert voltage calibration was performed on the remainder of the data acquisition system using an automatic frequency response recorder from 20 Hz to 200 kHz.



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FIGURE 3.-ANNEX D HOT-GAS TEST FACILITY, BURNER AND THRUST RIG (1968)



FIGURE 4.-ANNEX D HOT-GAS TEST FACILITY, BURNER CONTROL PANEL (1968)



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FIGURE 5.—ANNEX D HOT-GAS TEST FACILITY, ACOUSTIC RECORDING AND SCANNER PRINTOUT EQUIPMENT (1968)

Tape recorder, 14 channels 14 monitor scopes 1 channel Selector switch 14 channels -Time code Headphones Vacuum tube voltmeter Scope channels 13 FIGURE 6.-DATA ACOUISITION SYSTEM 1 channel Scale-Model Test Facility (Annex D) Vacuum tube volt meter: Hewlett-Packard 400D Preamolifier assembly microphone Talk amplifier Time code generator/reader: EICO 858A Talk - 30-meter extension cable Adapter: B & K type UA 0035 Power supply: B & K 2801 Monitor scripes: EICO 270 12 channels – Power supply Cathode follower Microphone: Bruel & Kjaer type 4135 Extension Cable: B & K AO-0029 Adapter Cathode follower: B & K 2615 Tape recorder: Ampex Cp-100 Preamplifier: Dynamics 6764 **Reference 7** Micro-phones

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2.1.1.3 Test Procedure

Each day, prior to testing, an end-to-end calibration was made on each microphone system. In addition, background noise was recorded. The background noise data were reduced in octave bands in the same manner as the actual test data. If the signal-plus-noise-to-noise ratio was less than 10 dB, a correction was made; if it was less then 3 dB, the data were discarded. If more than one reel of tape was used on a given day the above procedure was repeated at the beginning of each-reel.

A. Sel

A suppressor nozzle was mounted on the model-scale test rig and set to the specified temperature/pressure condition, allowed to stabilize, and acoustic data were taken for a period of 20 sec. If more than one temperature was called for, the lower temperature was recorded first. If a number of pressures were specified, the lowest pressure was recorded first. Performance data were recorded during the same time interval that acoustic data were recorded. A round convergent nozzle with the same exit plane area as the suppressor was then tested under the same engine conditions to provide a baseline for comparison.

2.1.1.4 Acoustic Data Reduction

A block diagram of the acoustic data reduction system is shown in figure 7 (from ref. 7). The data were reduced in eight preferred octave bands with center frequencies of 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 32.0, and 64.0 kHz.

The end-to-end acoustical calibration was performed at the beginning of each reel of tape. The calibrator used was a pistonphone that generates a 124-dB sound pressure level (SPL) re: $0.0002 \text{ dynes/cm}^2$ at 250 Hz. In data reduction, octave-band corrections were determined for the calibration of the microphones and the frequency response of the electronic systems. Total system correction was the sum of the two corrections for each octave band. All corrections were made relative to 250 Hz. The sample length for data reduction was 10 sec. The output of this system is the n-ean-rectified average of the 10-sec sample for each octave band in octave-band sound pressure levels (OB-SPL) expressed in dB re: $0.0002 \text{ dynes/cm}^2$.

The acoustic instrumentation system has an accuracy of ± 1 dB for the first seven octaves and ± 2 dB for the eighth octave band.

2.1.2 Hot-Nozzle Test Facility

The hot-nozzle test facility (HNTF) is located in Building 3.326 in the Mechanical Laboratory test area, adjacent to the north end of Boeing Field, Seattle, Washington. The HNTF was designed to test eighth-scale GE4 engine suppressor nozzle hardware with a flow area of 28.6 sq in. The purpose of the facility was to provide accurate exhaust nozzle performance data simultaneously with the acquisition of free-field radiated acoustic noise data.

The HNTF incorporates a primary air supply and burner system capable of providing hot gas up to 3000° F at a nozzle pressure ratio of 4.0. A strain gage load cell provides reactive thrust measurement to 2000 lb with repeatability of 0.5% full scale. The original burner system at the HNTF included five burners in parallel that discharged into a watercoored mixing plenum and then into the duct section to which the model-scale nozzle was



mounted. The original system (fig. 8) provided the desired flat temperature profile at the nozzle exit, however the system presented problems in operation, i.e., difficulties in igniting the burners and frequent overhaul of the system because of plenum erosion resulting from 3000°F operation. A subsequent burner system was installed that combined one primary burner followed by an afterburner that discharged directly into the water-cooled duct.

The afterburner produces large temperature gradients (i.e., 300° gradient across the primary exit flow field at an average total temperature of 1500° F). Random temperature variations with time (at a fixed point) are ± 30 at 1500° F. To acquire average primary total temperatures, an area-weighted rake containing seven shielded chromel/alumel thermocouples is installed in the primary flow 4 in. upstream of the nozzle mounting flange. A seven-probe, area-weighted, total-pressure rake is located 180° from the temperature rake. Primary air weight flows and fuel flows are measured at ambient temperature for all run conditions. Area-weighted static-pressure pickups were installed on the nozzle baseplate when applicable.

Compressed air is supplied from a 300-psig source through a 160-psig regulator to the facility. A remotely operated control valve is used to regulate the air supply. The primary and secondary flow metering systems are designed to ASME standards and are located downstream of the regulator valves. These systems contain high-beta-series ASME flow nozzles. The primary air is ducted from the flow metering system to a cold-air plenum through two diametrically opposed thin-wall pipes. This plenum supplies air to the burner where JP-series fuel is introduced and ignited. The burner discharges into a water-cooled duct section to which the exhaust nozzle model is mounted. Nozzle reactive thrust is transmitted directly through the flexure-supported thrust rig to a strain gage load cell.

A 180° acoustically clear area is provided for a maximum 50-ft radius outboard of the nozzle exit station. This area is graded flat and covered with river rock. An arena fence and an acoustic baffle were constructed and installed, (figs. 9 and 10).

2.1.2.1 Internal Flow and Performance Instrumentation

Airflow was measured using a 3.5-in.-diameter ASME flow nozzle. Fuel flow was measured with a 5/8-in. Potter flowmeter. Nozzle reactive thrust was sensed with a 2000-lb Baldwin Lima Hamilton loadcell. Maximum available airflow is 35 lb/sec. Nozzle total pressure was measured with a single water-cooled probe approximately 63 in upstream of the nozzle exit.

Model and airflow measuring pressures were sensed with Consolidated Electrodynamics and Statham pressure transducers that were accurate and repeatable to $\pm 0.25\%$ full scale.

The force, temperature, and pressure 1^{-1} , were automatically scanned and recorded using the HNTF Dymec data system. The individual transducer outputs were conditioned and amplified using a Hewlett-Packard crossbar scanner (DY-2911A) and data amplifier



FIGURE 8.--HOT-NOZZLE TEST FACILITY

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FIGURE 9.-HOT-NOZZLE TEST FACILITY, ACOUSTIC ARENA LAYOUT

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These signals were fed through a digitizing voltmeter (DY-2401C) and stored in digital form on punched paper tape. The data-were then transferred to IBM cards using an IBM 047 tape-to-card converter.

2.1.2.2 Acoustic Instrumentation

A 14-channel tape recorder and associated electronics were used to record acoustic noise levels. The tape system had a usable frequency range from 150 to 80,000 Hz and included a voice channel and time sequence input. A level recorder was used to provide a direct readout of third-octave-band data. The entire acoustic data system was field calibrated (see fig. 11).

Five to twelve 0.25-in.-diameter condenser-type microphones, located on a radius 25 ft from the nozzle exit plane and at selected angles to the nozzle centerline, were used to measure the noise levels due to the jet efflux. These microphones were mounted at nozzle centerline height and pointed toward the nozzle exit plane.

2.1.2.3 Test Procedure

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The nozzle operating conditions (pressure and temperature) were monitored on digital voltmeters and manually controlled by varying air and fuel flow. After setting the desired exhaust temperature, a series of data points was taken at various nozzle pressure ratios. After stabilization of all parameters (approximately 15 sec), thrust, weight flow, and temperature values were recorded. All pressures were trapped (using cutoff values), scanned, and recorded sequentially. During this same period, acoustic data were being recorded on magnetic tape from the microphones in the acoustic arena.

A round-convergent reference nozzle with a 6-in. exit diameter was run periodically at the same suppressor nozzle operating conditions to ensure proper operation and repeatability of all systems and to provide a noise baseline for acoustic data.

2.1.2.4 Performance Data Reduction

The recorded digital performance data were combined with the IBM 290.08 data reduction program and processed on the CDC 6600 computer.

The reduced performance data included the following parameters:

- Measured primary air flow rate
 W_A
- Measured primary fuel flow rate W_f
- Primary gas flow rate $W_{act} = W_A + W_f$
- Nozzle pressure ratio P_T/P_c
- Nozzle gas average total temperature
 T_T
- Nozzle ideal fully expanded jet velocity
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٠	Calculated isentropic flow area	A [*]
•	Nozzle thrust	·F
•	Ideal thrust	FI
•	Nozzle cross thrust coefficient	$C_{Fg} = \frac{F_{measured}}{(W_{act} V_{I}/g)_{primary}}$
C	Nozzle velocity coefficient $C_V =$	$\frac{F_{measured}}{(W_{act} V_{I}/g)_{primary} + (W_{act} V_{I}/g)_{secondary}}$
•-	Nozzle_discharge coefficient	$C_{D} = \frac{\text{measured primary weight flow}}{\text{ideal primary weight flow}}$
•	Baseplate and ejector wall pressure ratios	$P_{\rm B}/P_{\infty}$; $P_{\rm S}P_{\infty}$
•	Average base pressure ratio	P_{Bavg}/P_{∞}
٠	Baseplate drag ratio	D _B /F _I

2.1.2.5 Acoustic Data Reduction

Acoustic data were reduced off magnetic tape on the same system described in section 2.1.1.4. During 1970, another data reduction system was employed at the CAG acoustic laboratory that provided true rms, third-octave band levels on 80-column IBM cards. The acoustic data reduced on IBM cards was used with existing CDC 6600 computer programs to provide extrapolated sideline perceived noise levels and with SC 4020 plotting routines to provide noise spectrum plots.

2.2 FULL-SCALE

2.2.1 B1 Test Pad at Boardman, Oregon

The bulk of full-scale suppressor nozzle testing prior to mid-1968 was accomplished at test pad B1. Boardman, Oregon. A portable thrust stand with a J-75 engine for a hot-gas generator was installed. The J-75 engine was oriented with the exhaust nozzle pointing northeast. A permanent blockhouse containing the engine performance instrumentation and acoustic recording equipment was located 650 ft southwest of the engine. The acoustic field was to the north of the engine (fig. 12, from ref. 10). The acoustic field had a natural ground floor composed primarily of sand and sparse vegetation.

2.2.1.1 Internal Flow and Performance Instrumentation

The performance characteristics checked are as follows:

Temperatures (3 sensors)
 Fuel inlet (1)
 Turbine Discharge (1)
 Outside air (1)



FIGURE 12.-B1 TEST PAD AT BOARDMAN, OREGON

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Pressures (59 sensors)

 Turbine discharge (1)
 High-pressure compressor discharge (1)
 Ejector wall statics (24)
 Ejector chute statics (14)
 Ejector inlet statics (3)
 Ejector inlet statics (3)
 Engine inlet statics (12)
 Ambient (1)

• Engine component speeds (2 sensors)

• Weight flows (1 sensor)

• Thrust measurement (1 sensor)

• X-Y plots (1 senser)

• Vibration (3 sensors)

A simplified block diagram of signal paths only is shown in figure 13 (from ref. 10).

An environmentally controlled instrumentation trailer was located approximately 40 ft south of the engine test stand. The equipment located in the trailer included chromel-alumel 150° F reference junctions, pressure transducers, scanivalves and associated driver, chop valves, and power supply for the driver.

All engine controls and indicating devices for control of the engine were located in the control trailer approximately 120 ft south of the engine stand. Of the instrumentation requirements, only the three vibrations were read out manually in the control trailer.

The recording instrumentation system and the remainder of the signal conditioning equipment were located approximately 600 ft southwest of the engine stand in the blockhouse.

All temperature readouts were derived from chromel-alumel thermocouples and appeared as millivolt outputs in digital display. Engineering units were derived either manually or from a computer using standard 150° reference millivolt-to-temperature conversion charts. These charts also provided the means for system checks. By imposing a given millivolt level at the output of the reference junction, it was possible to read directly the impressed voltage at the system output. The millivolt source used was a Leeds and Northrup millivolt potentiometer, model 8686.

With the exclusion of the ambient pressure, all pressures were trapped simultaneously in volume chambers by automatically operated chop valves. These pressures were then sampled either through the use of scanivalves and scanivalve transducers or by individual transducers in the case of P_{T7} and P_{S4} . All of the transducers were calibrated from a



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calibration panel in the control trailer with the use of a controlled external pressure from a dry nitrogen bottle. Pressures so applied were monitored by Wallace and Tiernan pressure gages, calibrated in inches of mercury, to an accuracy of $\pm 0.1\%$.

All system calibration frequencies for tachometer and flow meter outputs were calculated using the following equation:

f = gear ratio x teeth x rpm x min/60 sec = cps

 N₁-Low-Pressure Rotor Speed Gear ratio = 0.62 Tachometer teeth = 143 RPM = 10.000

Therefore,

 $f = 0.62 \times 143 \times 10,000/60 = 14,777 \text{ cps}$

Applying this frequency to the Vidar frequency-to-voltage converter enabled the voltage output of the Vidar to be divided through a potentiometer to yield a reading of 10,000 counts on the data system equal to 10,000 rpm.

 N₂-High-Pressure Rotor Speed Gear ratio = 0.481 Tachometer teeth = 143 RPM = 10,000

Therefore,

 $f = 0.481 \times 143 \times 10,000/60 = 11,464 \text{ cps}$

The same calibration procedure used for N_1 was also used for N_2 .

• WF-Fuel Weight Flow

The same calibration procedure was used for W_F as for N_1 and N_2 with the frequency extracted from the laboratory calibration sheet for gallons per minute. 554 cps yielded 102.50 gpm.

Engine thrust measurements were calibrated with the aid of a Baldwin-Lima-Hamilton standard load cell ad indicator with digital readout in pounds. The calibration cell was placed between the stand and a fixed "dead man" and a load was pulled hydraulically. By recording the outputs of both the engine load cell and the standard cell, a correction curve was resolved for the combination of engine stand and load cell. These "thrust pulls" were generally carried out prior to each series of runs or whenever deemed necessary by test or instrumentation engineers.

The accuracy of the measurements were as follows:

F	<u>+</u> 60 ⁻ 1b
P _{T7}	<u>+</u> 0.2 in. of Hg
P _{AMB}	<u>+</u> 0.08 in. of Hg
T _{T7}	<u>+</u> 10° F
ΟΑΤ	<u>±</u> 4° F
Ť _{FI}	<u>+</u> 4° F
N ₁	<u>+</u> 20 rpm
N ₂	<u>+</u> 25 rpm
P _{T2}	±0.01 in. of Hg
W _F	±0.03 lb/sec
P _{S4}	±1.6 in. of Hg

Tertiary air static and total pressure (P_{IS} , P_{IT}) were used to find the tertiary airflow. There were two sets of probes. One set had three static-pressure probes while the other had three total-pressure probes. The total-pressure probes were manifolded together to give one reading. When the blow-in-door (BID) simulator was used, the probes were in the doors of the simulator. When the BID was not used, the set of total-pressure probes was at the 10 o'clock position and the set of static-pressure probes at the 2 o'clock position. (The position is determined by standing at the rear of the engine and looking forward.)

2.2.1.2 Acoustic Instrumentation

Microphones were placed along a circular arc of 200-ft radius from the engine nozzle at 10° intervals from 30° to 80° and set up at grazing incidence to the centerline height of the engine nozzle. The microphones measured the sound pressure levels (SPL) created by the J-75 engine (with an afterburner) for various hardware configurations and power settings. Microphone outputs were recorded on magnetic tape for later data reduction.

Altec model 21BR-180-1 microphones were used for the entire test. These capacitortype microphones were attached directly to cathode follower preamplifiers (Altec model 165A). Six cables 200 ft long carried the signals from the six-cathode followers to six microphone power supplies (Altec model 526B). Cable 500 ft long carried the signals from the output terminals of the power supplies to the recording system located in the blockhouse. Due to the long distances between the microphones and the recording system, impedance matching systems were set up between the microphone power supplies and the preamplifiers of the tape recorder. The impedance matching systems consisted of stepdown transformers

(50,000 to 50 ohms) from the power supply's output through 500 ft of instrumentation cables into step-up transformers (50 to 50,000 ohms), mounted on the instrumentation rack in the blockhouse. A block diagram of the instrumentation system is attached (fig. 14, from ref. 10).

The microphones were calibrated by the comparison method in an acoustic pressure coupler. A Western Electric model 640AA microphone with calibration traceable to the National Bureau of Standards was used as a standard. This pressure coupler was designed to operate from 40 to 8000 Hz.

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An end-to-end calibration was performed on each microphone before each test. The calibrator used was a Bruel and Kjaer pistonphone model 4220, which generates a 124-dB SPL re: 0.00C2 dynes/cm² at 250 Hz. The SPLs, as indicated on a VTVM, were then related to the preamp code tone, 400 Hz at 1.0 volt rms = +2.2 dB at 0 dB gain. The reference SPLs at 400 Hz, therefore, came out differently for each microphone, depending on the gain setting of the preamplifier and the level read on the VTVM when the pistonphone was applied to the microphone. This technique made possible the direct calibration of all channels in one step by recording the code tone at 1 volt rms on magnetic tape for 30 sec.

Once a week, a frequency response check of the microphone system was performed. A Bruel and Kjaer random noise source, type 4240, which generates 108 dB overall SPL for 15 sec, was applied to each microphone, and the signals were recorded on magnetic tape set aside for this purpose. The data acquired were later analyzed and the results checked against the previous week's results for repeatability. Comparisons showed maximum deviations of ± 1.0 dB, which is well within the specified tolerance.

The output voltages of the fixed-position microphones were amplified by preamplifiers and the amplified signals recorded on a 14-channel Singamo 3500 tape recorder. The tape recorder was operated at 30 ips in the FM and direct-record modes. Channels 1 through 6 recorded data in FM mode, while channels 13 and 14 recorded voice and time code, respectively, in the direct mode. This was considered the most favorable mode for the test since the tape recorder had a flat frequency response from 50 Hz to 10 kHz, as indicated when a frequency sweep 20 Hz to 10 kHz was run through every channel and the response plotted by a Bruel and Kjaer model 3304 automatic frequency response recorder. The tape recorder frequency response was down 0.5 dB from 20 to 50 Hz, which was compensated for during data reduction.

Once a week, the limiting frequencies (64.8 and 151.2 kHz) and the center frequency (108 kHz) of the FM record cards were checked (and adjusted when necessary) by inserting ± 1.4 Vdc and 0 Vdc signals, respectively, into the input of each channel and feeding the output into a Dymec frequency counter. (The dc voltage supply was checked and adjusted for the above values on a Dana digital voltmeter.)

The data reduction system consisted of the Sangamo tape recorder, a Hewlett-Packard VTVM, and a General Radio octave-band analyzer, model 1558A. Before data analysis, the playback cards were checked and adjusted when necessary to give 1 volt rms (measured by the VTVM) response to the calibration signal as reproduced by the tape recorder.


Reference 1(.

FIGURE 14.—BLOCK DIAGRAM OF ACOUSTIC DATA ACQUISITION AND REDUCTION INSTRUMENTATION AT BOARDMAN

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The calibration signal (400 Hz) of a specific magnitude SPL, as identified on voice channel and noted on log sheet for a particular channel, was played back directly into the octave-band analyzer with the octave-band filter set at 300 to 600 Hz. The calibration potentiometer was adjusted for the given SPL, thus calibrating the octave-band analyzer for the data recorded thereafter.

Data samples were then played back into the calibrated octave-band analyzer and, by manually switching the octave-band filter, the SPLs for the standard octave bands were read off the meter directly. The octave-band corrections for the whole system, as determined by the sum of the deviations from the ideal flat frequency response for the microphones, the tape recorder, the electronic system, and the cables , were then added to the data obtained and the corrected data tabulated as octave-band SPL versus test point and run number. All test-data were analyzed in this fashion for all microphones.

The maximum day-to-day microphone calibration repeatability using the Bruel and Kjaer pistonphone for all microphones used for the test was ± 0.5 dB. The frequency response checks, using the Bruel and Kjaer noise source, type 4240, on all microphones showed a maximum deviation of ± 1.0 dB in some octave bands. Manufacturer's specification on noise source is ± 1.0 dB repeatability. Data reduction was slow, tedious, and possibly inaccurate for data recorded in windy weather (8 mph and over). High winds created disturbances in the sound propagation path and caused meter fluctuations ranging from 3 to 10 dB on the octave-band analyzer level indicator. In such cases, the average value was taken.

2.2.1.3 Meteorological Instrumentation

Meteorological data obtained for these test series were air temperature at five levels, humidity at one level, and wind speed and direction at two levels, all from one tower. A tripod-mounted wind unit was mounted at another location for a remote measurement of wind speed and direction. All data were recorded in chart form as ink traces of a data analog.

Beckman and Whitley 15-64 and 15-65 wind speed and direction sensors are the industry standard and are common at research stations of all governmental agencies and armed services. This point is important, because it allows close comparisons to be made among many data sources.

Wind speed was sensed by a lighweight three-cup anemometer which begins turning at speeds of about 0.5 mph. The cups are used to rotate a plotted disc acting as a light chopper between a light source and a phototransistor producing pulses that are converted to an analog current.

Horizontal wind direction was sensed by a vane, connected to a precision potentiometer that was one arm of a voltage divider network. The resultant output was converted to a current analog linear with direction. Vertical components were not available.

On the west face of the tower near the blockhouse, there was one of each sensor at 3 and 33 meters above the ground surface. A similar vane was mounted on a tripod near the 30 microphone with the sensor height at 3 meters.

Data were recorded on Esterline Angers strip-chart recorders, model AW, located in the blockhouse. Chart speeds were normally 3-in./hr, except during test periods when 3-in./min were used for better resolution. Accuracy for the low-wind conditions of the test was better than 1 mph of speed and 2° to 3° in azimuth.

All of the humidity values were from measurements made with a wet bulb-depression thermocouple psychrometer. The resultant wet- and dry-bulb values were converted to relative humidity, accurate to within 5%.

Thermocouples of copper-constantan were used entirely for temperature measurements. These were referenced against a 1-meter-deep ground thermocouple that was, in turn, calibrated against an ice bath once or twice each week. Variations in the ground reference temperature of less than 1° F were usual, which is comparable to the variation in methods of measuring air temperature under these conditions. The thermocouple emf was fed into a Leeds and Northrup model-G potentiometer-type recorder that amplifies and records as a 0.5-sec mean value once or twice each minute.

Electrically powered aspirators with a high degree of solar and infrared radiation shielding house the air-sensing thermocouples. These were also of Beckman and Whitley manufacture and were mounted to sense air from a layer less than 10 cm deep at heights of 0.25, 2, and 32 meters. Thermocouples were also mounted at 1 meter in the sand and on or near the sand surface. The former was sealed and insulated to-damp out transients of less than 1 day duration, and the latter was part of a 1-in.-square plate of copper usually covered with a half millimeter or so of fine sand.

2.2.1.4 Test Procedure

The following procedure was followed when testing a suppressor nozzle configuration:

- Bring engine up to desired engine pressure ratio.
- Allow engine to stabilize for 3 min to ensure correct performance data.
- During this 3-min period, monitor the acoustic field with an on-line octave-band analyzer.
- At the 3-min point, record performance data, weather data, and : Justic data for 30 sec.
- At the 4-min point, obtain recorded performance data again.
- Shut down.

2.2.2 B2 Test Pad at Boardman, Oregon

The B2 test pad at Boardman. Oregon was established to facilitate the acquisition of free-field acoustic data of supersonic jet radiated noise. This test pad was operational in

mid-1968. A YJ-93 turbojet engine installation was used as the hot-gas generator. This engine was able to attain a higher nozzle pressure ratio at afterburning temperatures than the J-75 engine used in earlier tests.

The engine was mounted on a thrust stand with the engine centerline 7.3 ft above the local ground plane. The bellmouth inlet faced in a west-south-westerly direction (239° true).

The northeast quadrant was paved with concrete out to a radius of 250 ft from the center of the exhaust nozzle. This concrete pad was machine finished to within 0.25 in. of flat. The area immediately surrounding and under the engine was covered with steel plate. A strip of large rocks extended beyond the steel plates under the jet wake to reduce erosion. These rocks protruded randomly about i ft above the level of the concrete.

The engine-was controlled from a blockhouse located about 500 ft south of the engine. All engine and nozzle performance data were monitored and recorded in the blockhouse. All acoustic data were recorded in the acoustic trailer.

A maximum (nonafterburning) nominal nozzle pressure ratio of 2.8 and temperature of 1600° F was available when the nozzle area was properly matched to the engine.

2.2.2.1 Internal Flow and Performance Instrumentation

Appropriate instrumentation was used to supply performance-related data, such as:

- P_{amb} Barometric pressure
- T_{amb} Atmospheric temperature
- P_{T2} Total pressure at compressor inlet

P_{S2} Static pressure at compressor inlet

RPM Rotor speed

W_{fuel} Fuel flow rate

- F_N Measured engine thrust
- P_{T5} Total pressure at turbine exit
- T_{T5} Total temperature at turbine exit
- P_{T7} Total pressure at nozzle entrance
- T_{T7} Total temperature at nozzle entrance
- P_{SB} Suppressor nozzle static base pressure

Instrumentation was similar to that used on the B-1 test pad, section 2.2.1.2.

2.2.2.2 Acoustic Instrumentation

Noise data were acquired through six Altec 21 BR microphones. These were placed 200 ft from the center of the exhaust nozzle at angles of 30°, 40°, 50°, 60°, 70°, and 80° from the jet exhaust axis at a height of 7.5 ft above the concrete pad and oriented with the diaphram of the microphone facing upward. Another set of six microphones was set at the same angles about 1 in. above the concrete ground floor. This provided measurements that were 6 dB above the free-field levels due to pressure doubling at the concrete/air interface. The reduced acoustic data were adjusted by -6 dB to arrive at free-field spectrum levels.

Signals from the microphones passed through a transformer to match impedance with an 800-ft transmission line leading to an Ampex ES 100FM magnetic tape recorder. The transformers and power supplies were buried in a double-walled box to avoid microphonics and extraneous reflections. Thirty-second data samples from the magnetic tapes were recorded on magnetic tape loops and replayed into an automatic third-octave-band analyzer. The third-octave-band levels were recorded on punch tape. These punch tapes, along with data acquisition parameters, were fed into a card puncher. The corrected third-octave- and full-octave-band levels were calculated by computer (IBM 360) and punched onto cards for further processing.

The sensitivity of the system was determined by a pistonphone calibration at 124 ± 2 dB and 250 Hz made before or after each run. The frequency response was determined by an insert calibration made within 48 hr of each test. This consisted of a sweep of 1 + 0.01 V pure tone signals at frequencies ranging from 20-to 20,000 Hz. The signals were applied at the cathode follower input with button loading included.

The total data scatter (based on OASPL) including variations in the noise source, atmosphere, and the data acquisition and reduction systems was observed to be less than 2 dB maximum to minimum. The data acquisition and reduction systems have an accuracy of ± 3 dB and a 1.6-sigma deviation of ± 1 dB (i.e., 90% of all data points will deviate from the mean by less than 1 dB). The above apply only in cases where noise floor interference is absent or insignificant.

2.2.2.3 Meteorological Instrumentation

The data from three instruments were used for the acoustic and performance analyses. The instruments (an anemometer, a psychrometer, and a thermocouple) were mounted on a tower located 700 ft from the engine test stand. The anemometer was mounted 10 ft above the ground and the remaining instruments 6 ft above the ground. Additional instruments were placed at other levels on the tower and on stands at other locations on the test site, but the data from these were used only as a check. The accuracy of the anometer data is within 2 mph and 10° of arc, the thermocouple is within 2°F, and the psychrometer is within 5% relative humidity. Meteorological instrumentation was similar to that described in section 2.2.1.3.

2.2.2.4 Test Procedure

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Prior to each run, all acoustic and performance instrumentation was set up and calibrated, and the engine and suppressor received a thorough visual inspection. The engine was then started and idled for 5 min while another check of instrumentation and engine hardware was conducted. After completing the above engine checkout procedure, the engine was brought to the first test condition and allowed 2 min to stabilize. After stabilizing, two scans or separate sets of acoustic and performance data were recorded. The total engine time required to set a condition, stabilize, and record data was about 5 min. After running all of the conditions listed below, the engine was idled fc. 5 min and shut down.

Turbine exit total pressure P_{T5} was used as a guide in setting all engine conditions except the highest condition where the engine limits were used. The P_{T5} levels used were computed from the desired nozzle pressure ratio, ambient pressure, and afterburner pressure drop.

Test runs were made if weather conditions were within the following limits:

Temperature	32° to 80° F
Relative humidity	Greater than 30%
Wind speed	Less than 8 mph
Precipitation	None
Fog	None

2.3 EXTRAPOLATION OF ACOUSTIC DATA

The Boeing SST Aircraft Noise unit used an integrated noise extrapolation procedure based on the following Society of Automotive Engineers (SAE) publications, references 14, 15, and 16.

The procedure has been computerized and is described in detail in reference 17. Effects considered in sound propagation between the source (jet engines) and observer follow:

Spherical divergence	AIR 876 (ref. 14)
Number of engines and engine shielding	AIR 876 (ref. 14)
Atmospheric absorption	ARP 866 (ref. 15)
Extra ground attenuation	AIR 923 (ref. 16)

The sum of all these effects was used to extrapolate ground-static acoustic data to flight conditions for noise-suppressor evaluation.

Boeing was conducting eighth-scale model suppressor nozzle tests in the design/ development of a noise suppressor that could be used on the SST. The eighth-scale acoustic test data were scaled up to full-scale conditions by use of the Strouhal number relationship described in AIR 876 and then extrapolated to flight conditions.

The Strouhal number scaling technique consists of dividing the model noise data frequencies (Hz) and multiplying *all* model linear dimensions by a scale factor determined from the following equation:

Scale factor =
$$[A_1/A_2]^{\frac{1}{2}}$$

where (A_1, A_2) are the nozzle discharge areas, respectively, for full-scale and model-scale burners or engines operating with *identical* primary gas conditions of pressure ratio, total temperature, and gas composition.

The scale factor was also applied to the distance relationship between the sound source and the microphone station. For instance, in eighth-scale acoustic tests, a microphone distance of 25 ft is equivalent to 200 ft full scale. The air absorption loss in dB was assumed to be negligible for the test distance employed between microphone and jet. The assumption is naive when considering the extreme high-frequency end of the spectrum in model-scale data: however, there was little effect on perceived noise level calculations. More information is required concerning air propagation anomalies in the ultrasonic range before model-scale jet noise data can be successfully adjusted to a standard-day condition.

Measured acoustic data were extrapolated to the observer position by applying propagation loss factors (e.g., spherical divergence, atmospheric absorption, extra ground attenuation, etc.) given in ARP 866, AIR 876, and AIR 923.

The adjusted acoustic signatures were transformed into perceived noise levels (PNdB) using the procedures outlined in ARP 865 (SAE). The observer reference position considered prior to the establishment of FAR 36 was the 1500-ft sideline parallel to the jet axis. After 1969, the 2128-ft sideline (0.35 nmi) was used as the observer reference position and the propagation loss factors adjusted accordingly. Typical ground-to-ground sound propagation losses, including spreading loss, employed in extrapolating 200-ft polar arc acoustic data to the 1500-ft sideline are given in table 1 for preferred octave bands. These propagation losses are for standard-day conditions of 59.0° F and 70% RH. Table 2 lists sound propagation losses used in extrapolating from the 200-ft polar arc to 2128-ft sideline. It should be noted that the current SAE standards do not predict accurately the sound propagation losses for 1500- and 2128-ft sideline distances. Measurements taken at Boardman, Oregon at the 800and 1500-ft sideline indicated that large standard deviations (approximately 10 dB) of sound pressure levels exist for all octave bands (ref. 18). It is suspected that ground reflection interference and ducting of radiated acoustic noise affects sound propagation loss significantly in ground-to-ground measurements. Air-to-ground sound propagation loss anomalies are probably less severe.

-	Preferred octave bands							
Angle to jet axis (deg)	1 63 Hz	2 125 Hz	3 250 Hz	4 500 Hz	5 1 kHz	6 2 kHz	7 4 kHz	8 8 kHz
30	28.4	30.2	32.8	35.4	39.1	44.9	58.1	76.8
40	25.5	27.3	24.5	32.0	34.8	39.7 -	49.7	64.0
45	24.0	26.0	27.5	30.5	33.0	38.0 ⁻	47.0	60.0
50	23.6	25.2	27.1	29.5	31.8	36.2	44.4	56.2
60	22:3	23.7	25.4	27.5	29.7	33.6	40.8	51.1
70	21.2	22.5	24.0	26.0	28.3	31:8	38.3	47.7
80	20.6	21.8	23.4	25.1	27.3	30.7	36.9	45.8
90	20.5	21.7	23.1	24.9	26.9	30.4	36.5	45.2

TABLE 1.—SOUND PROPAGATION LOSS IN DB (GROUND TO GROUND) 200-FT POLAR ARC TO 1500-FT SIDELINE

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TABLE 2.-SOUND PROPAGATION LOSS IN DB (GROUND TO GROUND)200-FT POLAR ARC TO 2128-FT SIDELINE

1	·····	······	·····	· · · · ·				
	Preferred octave bands							
Angle to	1	2	3	4	5	6	7	8
jet axis (deg)	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
					· · · · · · · · · · · · · · · · · · ·			
30	31.6	34.3	37.3	40.7	45.6	52.9	72.2	98.9
35	30.7	33.0	35.8	38.9	43.4	49.9	66.5	89.6
40	29.6	, 31.9	34.5	37.5	41.5	47.4	62.2	82.6
45	28.7	30.8	33.3	36.2	39.9	45.4	58.8	77.2
50	27.9	30.0	32.3	35.1	38.5	43.8	56.0	72.9
55	27.2	29.2	31.5	34.1	37.3	42.4	53.7	69.5
60	26.6	28.5	30.7	33.3	36.4	41.2	51.9	66.7
65	26.1	28.0	30.1	32.6	35.5	40.2	50.4	64.5
70	25.7	27.5	29.6	32.1	34.9	39.5	49.2	62.8
75	25.4	27.1	29.2	31.6	34.4	38.9	48.4	61.5
80	25.1	26.9	28.9	31.3	34.0	38.4	47.7	60.6
85	25.0	26.9	28.7	31.1	33.8	38.2	47.4	60.1
90	25.0	26.9	28.7	31.1	33.8	38.1	47.3	59.9
1	1		1	1				1

3.0 A SUMMARY OF TEST RESULTS

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The SST jet noise program was divided into two parts: a low noise-suppression effort (>5 PNdB suppression) and a high noise-suppression effort (12 to 20 PNdB suppression). The low noise-suppression effort and results are covered only briefly in this section because this information is already well documented elsewhere (refs. 6, 7, 8, 9, and 10). Full-scale tests of the GE4/J5P engine with the two-stage ejector-nozzle (TSEN) installed indicated that the prototype SST could meet the FAA objective of 116 PNdB peak noise level at the 1500-ft sideline during takeoff. This obviated the need to continue on with the low noise-suppression effort. In 1968, the full resources of the SST jet noise staff were applied to the problem of developing a 12- to 20-PNdB jet noise suppressor for use on the commercial version of the SST. More emphasis has been placed on results of the 12- to 20-PNdB suppression effort in this section because the results have not been well documented at this date.

3.1 LOW NOISE-SUPPRESSION (5 PNdB) PROGRAM

3.1.1 Model-Scale Testing

Model-scale nozzle acoustic testing was conducted at the Boeing Annex D jet noise facility located in the Boeing Plant II area complex in Seattle. Model-scale nozzle testing was based on the premise that jet noise characteristics can be scaled on a dimensional basis. This hypothesis had been fairly well established by considerable acoustic data acquired by many independent jet noise research programs (see ref. 11 for an example). Most nozzle configurations tested were eighth-scale replicas of candidate jet noise suppressor systems for the GE4/J5P turbojet and P&WA 17A-21B turbofan engines proposed as the propulsion units for the prototype supersonic transport. For eighth-scale acoustic tests, the 25-ft polar arc microphone layout was representative of a 200-ft polar arc layout full scale. The jet noise spectrum has to be adjusted in frequency by a factor of eight to be representative of fullscale nozzle test results (e.g., 8 kHz for eighth-scale nozzle corresponds to 1 kHz for full-scale nozzle).

Model-scale testing was an economical method of testing a large number of suppressor nozzle configurations. The desired primary flow conditions could be obtained on the model nozzle test facility, whereas an actual turbojet engine capable of approaching the engine conditions proposed for the SST did not exist. A disadvantage in the initial model test program was the lack of suppressor nozzle performance data to relate nozzle propulsion values with acoustic noise suppression results. Later in the SST jet noise program, a facility to acquire accurate thrust values simultaneously with acoustic data was developed to overcome this deficiency.

Three categories of nozzles were tested in 1966 at the Annex D jet noise test facility. The first group of nozzles was selected from previous jet noise test programs to ascertain jet noise characteristics under supersonic jet flow conditions. These nozzles were various multitube and multispoke configurations described in appendix A, section A.1. The tube nozzles tested (9, 21, and 37 tubes) showed perceived noise suppression values greater than 5 PNdB; however, these nozzle systems would exact a large performance penalty during supersonic cruise unless they could be retracted and stowed after the airplane cleared the community. A jet noise suppressor system of this type was considered to be impractical for the prototype SST.

Tests of spoke nozzie configurations, where the number of spokes was four, six, or eight and spoke penetration of the flow was 20%, 50%, or 75%, indicated that perceived noise level (PNL) suppression improved as the number of spokes increased and as the spoke depth of penetration of the primary flow increased (ref. 19). The resolution of these early tests was not very good since only three microphone positions were used 30°, 45°, and 60° relative to the jet axis and nozzle exit). Subsequent testing indicated that 5° or 10° increments between microphone positions was necessary to attain maximum perceived noise levels with 1-2 PNdB accuracy. Acoustic measurement techniques evolved during the 5-year jet noise suppression program resulted in good data resolution and better control of sound propagation anomalies.

Emphasis was placed on testing of various "lobed" primary nozzles with ejectors outfitted with different types of "chutes" or "scoops" (see app. A). The primary nozzle was designed to provide the initial suppression of jet noise, while the chuted ejector surrounding the fully expanded flow would provide an additional stage of suppression.

Primary nozzles applicable to the proposed GE turbojet and P&WA turbofan engines were tested. These nozzles varied from four-lobe to 16-lobe configurations with flow penetrations of 12% to 50% (see app. A, sec. A.1). The primary nozzles tested provided 0.5 to 3 PNdB suppression at the maximum nonaugmented power settings (see ref. 20).

The chuted ejector configurations tested showed higher suppression values. Jet noise suppression up to 6-8.5 PNdB was demonstrated. Chutes in the ejector penetrated into the fully expanded flow to induce jet mixing with ambient air pumped into the inlet of the ejector by the jet. This increased mixing concept was designed to lower the velocity of the exposed jet beyond the ejector exit.

Scoops were different from chutes in that the scoops enabled ambient air from openings in the ejector sidewall to mix with the jet as well as ambient air from the ejector inlet. Scoops did not prove as effective as chutes in suppressing jet noise.

The model-scale 5-PNdB suppressor program during 1967 was an intensive effort to determine the parametric relationships pertinent to chuted-ejector noise suppression and to determine near-optimum configurations. Five primary nozzle types, 15 ejector types, and 28 chute types were tested in about 70 different combinations (see app. A, sec. A.2). Test conditions were generally $T_T = 3000 \text{ R} (2540^\circ \text{ F})$ with pressure ratios ranging from 2.0 to 3.3. Acoustic data were recorded on a 25-ft polar arc in 10° increments from 40° to 80° relative to the jet axis.

Model-scale testing indicated little difference in noise suppression in the use of chutes of different shapes, i.e., conical chutes performed as well as flat chutes. Jet noise suppression increased with an increase in chute angle of attack and blockage ratio. Suppression decreased as primary gas pressure ratio-increased when the ejector-to-primary-nozzle area ratio was small ($A_E/Ap < 2.0$), see figure 15 (from ref. 7). Suppression tends to be independent of chute penetration when angle of attack and blockage ratio were held constant. Longitudinal positioning of the chutes indicated chutes were more effective when positioned nearer to the primary nozzle, see figure 16.

The chuted ejector configuration considered to have the best noise suppression characteristics tested attained the following PNL suppression values, referenced to the 1500-ft sideline with a primary gas temperature of 2540°F.

Pressure Ratio	PNL Suppression (Δ PNdB)		
2.7	8.0		
3.0	10.1		
3.3	10.1		

This configuration had a 4.1-in.-diameter primary nozzle. The cylindrical ejector (designated E9) had a diameter of 6.35 in. and length of 9.1 in., see figure 17. The ejector inlet diameter was 7.3 in. Eight flat chutes 0.45 in. wide and 1.5 in. long were set 1.5 in. upstream of the ejector throat, e.g., 0.75 in. downstream of the primary nozzle exit plane. The chute angle of attack was 37.4°. Chute penetration was 40% of the jet flow, see references 21 and 22.

3.1.2 Full-Scale Testing

Full-scale nozzle testing used the YJ-75 engine since acoustic information concerning jet noise suppressors was needed at afterburning turbojet engine conditions. Unfortunately, the primary gas conditions achieved by the YJ-75 engine did not approach the conditions anticipated for the SST propulsion system. The nozzle pressure ratio in particular fell considerably short of the desired primary gas conditions.

Initial tests were conducted at the North Boeing Field (Seattle), Mechanical Laboratory test area. The jet noise suppression hardware items tested were largely full-scale equivalents of promising configurations tested at the model-scale test facility. A round convergent primary nozzle and a 16-pointed star nozzle were tested with various chuted (or scooped) ejector configurations. Also, a four-lobe primary nozzle was tested without an ejector. Primary gas conditions at the nozzle were total temperatures of 1020° and 2880° F and pressure ratios of 2.5 and 2.2 (see app. A, sec. A.3). Acoustic data were recorded at angles of 30° to 90° (in 10° increments) relative to the nozzle exit and jet axis. Microphones were located on a 200-ft polar arc. Engine performance data were recorded simultaneously with acoustic data. A description of the tests performed, together with the recorded acoustic and performance data, can be found in reference 8.



FIGURE 15.—EFFECT OF PRESSURE RATIO ON SUPPRESSION, FLAT CHUTES WITH SIDES Scale Model Test Facility (Annex D)



FIGURE 16.--CHUTE POSITION STUDIES



FIGURE 17.-4.1-IN. ROUND CONVERGENT NOZZLE WITH E9 EJECTOR

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At the afterburning engine conditions, where PR = 2.2 and $T_T = 2880^{\circ}F$, the following PNL suppression and thrust loss values were determined:

Nozzle Configuration	PNL Suppression (PNdB)	Thrust Loss (%)
Four-lobe primary nozzle	5.0	0.0
Ejector ^a	1.0	0.8
Ejector ^a eight chutes 30% penetration	4.0	4.4
Ejector ² eight chutes 44% penetration	7.0	7.6
Ejector ^a eight scoops 37% penetration	5.0	6.7

^aRound convergent primary nozzle used.

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Other acoustic results are discussed in references 23 and 24. All Boeing SST program full-scale nozzle testing after 1966 was conducted at the Boardman facility.

The next series of full-scale nozzle tests was more involved in ejector and chute (and scoop) parametrics. Several chute widths were tested with penetration of the jet as a variable-e.g., 30%, 40%, and 50% penetration of the flow. Primary flow conditions were total temperatures of 2910° to 3190° F and pressure ratios of 1.9 to 2.2. The YJ-75 engine was used for these tests. The configurations tested are listed in appendix A, section A.4.

The noise-suppressor configuration that yielded the best results during this test series used eight chutes 3.6 in. wide installed in the ejector so as to achieve 40% penetration of the jet flow. Test results are:

PR	$T_{T}(^{\bullet}F)$	V _J (ideal)(fps)	PNL Suppression (PNdB)	Thrust Loss (%)
1.9	2910	2640	8.5	5
2.0	3080	2800	8.0	6
2.2	3190	3020	5.0	7

Scoops tended to provide less PNL suppression for an equal amount of thrust loss than did chutes. A complete account of noise and performance characteristics is contained in reference 25.

The third series of full-scale tests used a round convergent nozzle, a 16-pointed star nozzle, and a four-lobe nozzle with ejectors of several different sizes. Various kinds of chutes were tested—flat chutes with sides, conical chutes, box chutes, and wing chutes. Chute lengths were either 17.3 or 27.8 in. Chute flow penetration was 40% in most cases. The YJ-75 engine was used in the afterburning power settings with total temperatures of 2900° to 3200° F and nozzle pressure ratios of 1.84 to 2.20. Configurations tested are listed in appendix A, section A.5.

Chute shape did not influence_noise suppression. When chute angle of attack was increased from 15.6° to 25.5° with 40% flow penetration, there was a 1.5-PNdB improvement in noise suppression; however, thrust loss increased. PNL suppression and thrust loss decreased almost linearly as the number of chutes in the ejector was decreased.

A divergent ejector provided 3 PNdB more suppression than a cylindrical ejector, however static thrust loss increased 2%. A 1-in.-thick fiberglass-lined ejector did not enhance PNL suppression values because of low-frequency dominance in the spectrum. However, from 710 to 11,200 Hz there was a 3- to 9-dB decrease in spectrum level due to the acoustic absorptive lining.

The 16-point star nozzle with 12% penetration of the primary flow showed no value as a suppressor nozzle. The four-lobe nozzle with 50% flow penetration attained 4 PNdB suppression with 0.5% to 1% thrust loss. Descriptions of the third series of full-scale, 5-PNdB program testing with test results have been reported in reference 9.

The fourth series of full-scale tests used contoured ejectors; chute length, penetration, longitudinal positioning, and angle of attack were varied. A YJ-75 engine with afterburner was used with total temperatures of 3010° to 3220° F and nozzle pressure ratios of 1.93 to 2.28. Configurations tested are listed in appendix A, section A.6.

The contoured E1 ejector $(D_E/D_T = 1.00)$, with eight chutes mounted at the throat and with a nominal chute penetration of 40%, gave suppression values on the order of 4 to 5 PNdB. Variations of chute orientation (angle of attack or penetration) produce. I changes in the suppression on the order of 1.5 PNdB. While no general correlation appeared between changes in angle of attack and changes in suppression, increases in chute penetration resulted in suppression increases. Thrust loss, on the other hand, showed a definite increase as either penetration or angle of attack increased. With the chute mounted at a nominal penetration of 40%, thrust loss (based on a round convergent reference nozzle) varied from about 3.5% for a 16° angle of attack to about 12.5% for a 36° angle of attack.

As a result of the behavior of suppression and thrust loss relative to changes in chute orientation, the ratio of PNL suppression to thrust loss decreases as either chute penetration or angle of attack increases.

The contoured, divergent, E2 ejector ($D_E/D_T = 1.15$) gave suppressions that ranged from 7 to 9.5 PNdB, while thrust loss ranged from about 10% to nearly 25%. With eight chutes mounted at the throat and with a nominal penetration of 40%, suppression ranged from about 7 PNdB for an angle of attack of 16°, to 8 PNdB for an angle of attack of 24°. The corresponding change in thrust loss varied from 10% to 13%.

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Those configurations in which the chutes were mounted forward of the ejector throat at 40% penetration yielded suppression values of 9 to 9.5 PNdB, while thrust loss varied from 16.5% to 20%.

Changing the orientation of the chutes mounted forward of the throat produced suppression changes on the order of 1 PNdB, but the change appearing in thrust loss were severe. As an example eight chutes at 30% penetration and 79° angle of attack gave 14% thrust loss, while eight chutes at 50% penetration and a 38° angle of attack gave a 25% thrust loss.

There was negligible effect on suppression when two of the chutes mounted forward of the ejector throat, E2, were removed. Thrust loss decreased from 20% with eight chutes to 16% with six chutes.

The use of the blow-in-door simulator had little effect on the suppression or thrust loss obtained with ejector E1. No study was conducted to determine the effects of a blow-in-door simulator with ejector E2.

In addition to the studies made with the engine operating in the afterburning mode at high nozzle pressure ratios (1.93, 2.11, and 2.28), a study was carried out to investigate the suppression and performance characteristics of chuted ejectors at low nozzle pressure ratios (1.1, 1.2, and 1.5). It was found that suppression decreased sharply to less than 2 PNdB at the lower pressure ratios. Thrust losses generally did not show correspondingly great reductions, so that the ratio of PNL suppression to thrust loss was less at the three low pressure ratios than at the three high pressure ratios.

3.2 HIGH NOISE-SUPPRESSION (12-20 PNdB) PROGRAM

3.2.1 Model-Scale Testing (Chronicle)

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Model-scale suppressor nozzles tested in 1967 at the Boeing Annex D facility (Plant II complex) are included in appendix B, section B.1. Spoke nozzles were tested with number of spokes, spoke penetration, area ratio, and exit cant angle among the variables investigated. Multitube nozzle configurations were oriented toward 37-tube arrays where equal spacing between adjacent tubes was maintained. Area ratios tested varied from 3.33 to 8.0. Some configurations had tubes with round convergent terminations while others had 12-spoke ends on each tube. At pressure latios of 3.0 or higher, the multitube suppressor nozzles tended to maintain good PNI, suppression values whereas spoke nozzle suppression tended to deteriorate significantly. Since there was so little information available concerning the suppression of supersonic jet noise, several novel design concepts were tested using the "shotgun" approach to the problem. One nozzle, designated HM-AP-6, had six radial arms with 20 parallel slots in each arm. A maximum suppression of 12.5 PNdB was attained with this nozzle; however, the static thrust loss was excessive. Another nozzle tested had seven tubes coupled to the atmosphere and surrounded by the primary flow (HM-AP-23). The HM-AP-23 nozzle attained 6.5 PNdB suppression with 1% thrust loss, relative to a round convergent reference nozzle. This transposition of flow elements provided good noise characteristics at high pressure ratios and with a low area ratio (AR = 1.8). The results of performance testing conducted during this time period on annular and multitube annular suppressors (HM-P-1 through -9) are shown in reference 25.1 and summarized in appendix D.

The 1968 model-scale suppressor nozzle test program continued the multispoke and multitube parametric studies initiated in the previous year. During this period, the hot nozzle test facility (HNTF) at the Boeing Mechanical Laboratory complex (north end of Boeing Field) was completed. This facility provided accurate static thrust data-simultaneously with the jet noise measurements. The thrust information was invaluable by providing a check onmean indicated total temperature and other gas conditions. A method eliminating ground reflection interference introduced at the HNTF provided free-field acoustic data. Previously, ground reflection interference seriously hampered spectrum analysis and affected the accuracy of extrapolated PNL values.

The suppressor nozzles tested at Annex D during 1968 are listed in appendix B, section B.2. Some of the nozzles of interest tested during this period.were: annulus slot with center plug shaped for attached flow (HM-AP-20), 60 radial siots with annular configuration (HM-AP-36), combination tube and spoke nozzles, 37 tubes for tertiary air surrounded by primary flow (HM-AP-56), rectangular multitube arrays and ejector configurations.

Suppressor nozzles tested at the HNTF during 1968-69 are listed in appendix B, section B.3. The multitube nozzle parametric study was broadened by testing 126-tube (HM-AP-85) and 330-tube (HM-AP-86) hexagonal arrays. Also, the 37-tube nozzle study was extended into the augmented flow total-temperature region 1500° to 3000° F in the testing of Cr-Ti-Si coated columbium nozzles (HM-AP-55).

A 36-spoke nozzle (HM-AP-45) with an area ratio of 2.06 was tested at the HNTF. A full-scale version of this nozzle, designated HL-AP-9, was tested at Boardman, Oregon on the J-93 engine. The model-scale and full-scale nozzle test data showed very good agreement (see ref. 11). Several propulsion-design nozzle systems were tested-at the HNTF, notably a combination array of 16 spokes and 16 clusters of tubes (HM-AP-78), a 97-tube array (NSC-82), and a 61-tube array (NSC-119B). The propulsion and acoustic data acquired from testing the NSC-119B nozzle indicated that this concept would meet FAR 36 requirements when applied to the production version of the SST.

Jet noise characteristics of the various suppressor nozzle configurations tested in the SST jet noise program emphasized supersonic flow with conditions ranging from $0.85 < M_J < 1.56$, e.g., pressure ratios from 1.6 to 4.0. Gas total temperatures investigated varied from ambient to 3000° F, although very limited data were obtained at the extreme conditions of temperature. The gas condition of prime interest was $T_T = 1500^\circ$ F and PR = 3.0, which represented, approximately, the maximum dry-engine (nonafterburning) power setting for the GE4/J5P engine.

Later in the program, increasing emphasis was placed on higher bypass ratio turbojet engine configurations such as the GF4/J6G and then the GE4/J6H2 proposed engines. At takeoff aircraft velocities of 200 to ³30 kn, higher pressure ratios (3.4 to 3.8) were important, and suppressor nozzles deemed adequate for the original maximum dry-engine conditions turned out to be inadequate in obtaining the desired noise levels at the later imposed conditions.

3.2.1.1 Research Technique

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The research technique used almost exclusively during the SST jet noise program was the testing of many different kinds of suppressor nozzle configurations (both model scale and full scale) and measuring the jet-radiated acoustic noise in the far field. The acoustic data acquired were extrapolated to the 1500-ft sideline (later to the 2128-ft sideline) and perceived noise levels (PNdB) were determined using SAE-approved methods.

The main objective of the SST jet noise program was to determine the subjective efficacy of suppressor nozzle concepts. This information determined whether the propulsion and noise-suppressor system, as installed on the SST, would meet established subjective acceptance levels. Evaluation of jet noise suppressor concepts in subjective units of PNdB provides no information concerning the mechanisms of noise generation. The secondary goal of the program was to conduct an evaluation of jet suppressor nozzle noise characteristics using unextrapolated, measured data.

Analyses of radiated far-field acoustic noise spectrums, noise beam patterns, and perormance results using such variables as primary gas conditions; number, size, and shape of flow elements; relative distance between flow elements (variations in area ratio); jet crosssection configuration, etc.; provided the methods to inductively determine the characteristics of multijet noise generation. The mechanized model of jet noise generation established by these inductive methods provided the general rules and guidelines for developing suppressor nozzle concepts.

The generalizations set forth in this document warrant further investigation. There are other research tools and methods available that can be applied to further delineate the mechanized model of suppressor nozzle jet noise generation.

3.2.1.2 Noise Suppression Rationale

There are two relationships in jet noise research that serve as guides in understanding suppressor nozzle noise generation. One relationship derived from the Lighthill equation is where

Acoustic power =
$$\frac{K\rho^2 AV^8}{\rho_0 a_0^5}$$

where

 ρ = density of fully expanded jet

 ρ_0 = density of surrounding medium

 a_0 = speed of sound in surrounding medium

A = cross-sectional area of jet

V = efflux velocity of jet

K = dimensionless constant

Although this equation was meant to describe simple subsonic jet noise generation, the factors of gas density (ρ), flow area (A), and jet velocity (V) were recognized to be key variables in jet noise research when atmospheric conditions are held relatively constant. The other relationship used was the Strouhal number, which is equal to fD/V. The Strouhal number relationship served as a guide in understanding the frequency content in acoustic noise spectrum analyses. The dimension (D) is considered to be directly related to the width of the jet mixing region. The peak frequency observed in the spectrum of a simple jet is generally recognized as being equal to 0.22 V/D when sound pressure levels are expressed in terms of constant percentage bandwidths, i.e., octave or third-octave band levels. In subsonic flow, the peak levels are considered to be radiated from the mixing region adjacent to the end of the jet potential core. In supersonic jets, the peak level occurs some distance beyond the potential core, this distance being related to the Mach number (M₁) of the primary flow.

Multitube and multispoke suppressor nozzles were observed to have a random noise spectrum that had a low-frequency peak and a high-frequency peak. This spectrum was considered to be a composite spectrum. Noise generated in the jet mixing region prior to the coalescence of the individual jets into a single jet is considered to be responsible for the high-frequency peak. This conclusion was derived by evidence compatible with the Strouhal number relationship to the exit diameter of individual tubes in a multitube array. An example is shown in figure 18 (see ref. 26).

Since multielement nozzles significantly shorten the jet mixing region relative to the jet efflux from an equivalent-area round nozzle, the mixing region can be completely surrounded by an ejector. The inner wall of an ejector can be treated to absorb noise radiated from the jet mixing region. Tests of ejectors lined with acoustically absorbent material and installed on various multielement nozzles have consistently shown significant suppression of the high-frequency peak portion of the spectrum. This supports the hypothesis that high-frequency noise emanates mainly from the jet mixing region.

The low-frequency peak in the multielement nozzle acoustic spectrum was also thought to be compatible with the Strouhal number relationship. The coalesced jet contains a considerable amount of secondary flow entrainment from the mixing process; therefore, the relatively large, low-velocity coalesced jet would be expected to have a noise spectrum that peaks at the low-frequency end of the spectrum.

Figure 19 shows schematically the relationship believed to exist in the composite multielement nozzle jet noise spectrum. The high frequencies are dominated by noise radiated from the jets prior to coalescence. The low frequencies are dominated by noise radiated from the coalesced jet. The existence of another defined mixing region in the coalesced jet has been hypothesized and could be verified by determining the velocity profile in this region experimentally.

Various types of suppressor nozzles tend to attain peak PNL suppression values at jet velocities between 2100 and 2600 fps. This trend is evident in figure 20. There also was a tendency for suppression to fall off rapidly at jet velocities below 2100 fps, approaching 0 PNdB suppression at jet velocities between 1200 and 1600 fps. Not many measurements were taken at ideal jet velocities less than 1600 fps during the SST program, and jet noise characteristics in this velocity region were ill-defined by this program.



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Breakdown of Noise from Multielement

FIGURE 19.-MULTIELEMENT NOZZLE JET NOISE SPECTRUM



 $T_T = 1500^{\circ}F$ except where noted otherwise

FIGURE 20.—EFFECT OF JET VELOCITY ON PNL SUPPRESSION FOR VARIOUS SUPPRESSOR NOZZLE TYPES

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The improvement of noise suppression with an increase in jet velocity may be due to the change in physical properties of eddies in the jet mixing layer. The turbulence at the outer periphery of flow appears to "mask" or "shield" the noise generated by flow elements within the array. This "masking" effect has been attributed to (1) a redirection of acoustic energy by scattering, (2) absorption of acoustic energy, or (3) inhibition of the generation of acoustic energy.

Figure 21 (from ref. 27) shows the amount of suppression attained with multitube nozzle arrays at primary gas conditions of $T_T = 1500^\circ$ F and PR = 3.0 [V_J (Ideal) = 2550 fps]. The number of tubes in these nozzle arrays varied from 37 to 330. The overall sound pressure levels were integrated over a polar arc from 40° to 80° relative to the jet axis and compared with the integrated SPL from an equivalent-area round convergent nozzle jet (ref. 27). Although the propulsion power is approximately the same, there is a definite decrease in radiated acoustic energy as the number of tubes in the array is increased. A relationship is shown in figure 21 where OASPL suppression is proportional to the ratio of the total number of tubes in the array to the number of tubes occupying a 60° sector in the outer row of tubes. This curve approximates the results obtained from the tests, lending support to the hypothesis that the outer jet elements provide the radiated acoustic power and substantially shield the noise generated within a multitube nozzle array.

The OASPL (average) suppression reaches an optimum value at some jet velocity then diminishes as shown in figure 22 for 126-tube arrays. The drop in OASPL suppression at the higher jet velocities is largely due to an increase in the low-frequency part of the acoustic spectrum. Arrays that have a close spacing of tubes (small area ratios) will peak in suppression at a lower jet velocity than those that have tubes spaced further apart. The jet coalescing noise (low frequencies) is believed to be a function of shear when adjacent jet flows combine, and it is not difficult to see that tubes with close spacing will permit adjacent jets to merge earlier where there is considerable kinetic energy, relatively speaking, left in the flow.

The hypothesis that jet shielding of mixing noise and low-frequency noise is a product of jet coalescence was applied to the NSC-119B nozzle. The outer two rows of tubes were spaced relatively far apart (equivalent to an area ratio of 4.0) while the inner tubes were placed relatively close together (equivalent to an area ratio of 2.5). This resulted in an overall area ratio of 2.9, which would hopefully provide satisfactory jet noise suppression characteristics equivalent to an area ratio 4.0 nozzle at the high pressure ratio and jet velocity engine conditions necessary for SST takeoff. The test results were positive lending some credence to our original suppositions (see ref. 28).

A popular belief during the initial part of the SST jet noise program was that good ventilation was necessary with a multielement suppressor nozzle to attain the best jet noise suppression values. This belief was not substantiated in subsequent testing conducted under supersonic flow conditions. Tube and spoke lengths of several models were effectively varied in length by blocking secondary (ambient) flow. There was very little noticeable effect on radiated noise spectrums or beam patterns when the elements were completely blocked or unblocked (see refs. 29, 30, and 31). Large variations in nozzle thrust performance were observed by blocking secondary airflow.



FIGURE 21.-MULTITUBE NOZZLE SUPPRESSION

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Jet noise tests of a 126-hole, area-ratio-2.3, flat plate, resembling a manhole cover and a 126-tube, area-ratio-2.8, suppressor-nozzle yielded similar results in noise characteristics (ref. 30). However, the difference in thrust loss varied between 15% and 20% for the two nozzles. The range of gas conditions that could be employed using a flat plate multijet nozzle to simulate a multitube array was not determined. The results of this test are sufficiently encouraging to warrant future investigation of the use of flat-plate nozzles in supersonic flow tests. In parametric studies of multielement, coplanar, nozzles, the flat-plate configuration has the potential of supplying the desired acoustic data at substantial savings in nozzle development costs.

Round convergent ends on multitube nozzles did not affect jet noise characteristics when compared to round, straight, nonconvergent ends (ref. 32). Elliptical tube cross sections (major to minor axis ratio of 2) had noise characteristics nearly identical to those of a multitube array comprised of round tube cross sections (ref. 33). The elliptical tubes had their major axes situated in a radial direction reducing the spacing between adjacent jets, radially. This did not result in an increase in low-frequency jet coalescing noise. The peripheral spacing between jets appears to have a more pronounced effect on low-frequency noise generation than does the radial spacing for multitube arrays.

A distinct advantage of multitube nozzles over spoke- or lobe-type nozzles was structural integrity. The high temperatures and pressure ratios used in testing suppressor nozzles, necessitated by GE4 engine conditions, resulted in using materials near the limit of their ultimate tensile strength. Multitube nozzles with their round cross sections invariably survived the extreme gas conditions used in testing with little or no deformation apparent. Two-dimensional configurations, such as spoke, love, or slot nozzles, experienced a high failure rate at the same gas conditions. Spoke elements tended to bow out resulting in deformed exit configurations. Increasing material thickness to resist deformation or failure resulted in severe blockage of secondary flow and an increase in thrust loss due to base drag.

A parametric study was conducted with several spoke nozzles where the number of spokes was 12, 24, or 36. Area ratio varied from 2 to 6. A slight decrease in maximum PNL suppression occurred as area ratio increased from 2 to 6 with the 24-spoke configuration. A 4- to 6-PNdB increase in maximum noise suppression was noted as the number of spokes was increased from 12 to 36. Figures 23, 24. and 25 summarize the results of the spoke parametric study. Nozzle deformation and ground reflection interference affect the accuracy of these results.

A 36-spoke, area-ratio-2.06 nozzle designated as HM-AP-45 was tested at the HNTF where free-field acoustic data could be measured under carefully controlled gas conditions. The results of these tests were reported in references 34 and 35. A large-scale 36-spoke nozzle was tested at Boardman, Oregon, on the J93 turbojet engine. There was good correspondence between model- and full-scale nozzle acoustic data. Noise characteristics showed agreement within 2 dB or 2 PNdB (see figs. 26 and 27). Full-scale test results are given in reference 11.

Multitube suppressor nozzle parametric studies tended to yield higher PNL suppression values with less thrust loss as compared to spoke-type nozzles. Hexagonal multitube arrays with 37, 126, and 330 tubes were tested. Area ratios varied from 2.8 to 8.0. Suppression as



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1500°F 1000°F

2000°F

Full scale

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FIGURE 24.-VARIATION IN PNL SUPPRESSION WITH JET VELOCITY

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24 26

20 22

Ideal jet velocity (ft/sec x 100)

16 18



Thrust loss relative to round convergent nozzle (%)

FIGURE 25.—SUMMARY OF 1500-FT SIDELINE PNL SUPPRESSION AND THRUST LOSS FOR MULTISPOKE NOZZLES

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FIGURE 27.-COMPARISON OF FULL-SCALE AND MODEL OASPL SUPPRESSION

a function of jet velocity (ideal) is shown in figure 28. The highest suppression values 17 PNdB) were attained by 37-tube configurations that had 12-spoke-type ends on each tube. The 12-spoke ends resulted in 7% to 11% more thrust loss than round convergent ends.

Figure 29 shows the effect of PNL suppression on thrust loss characteristics for the 126-tube, area ratio-2.8 nozzle for various tube lengths. There is not much change evident in noise suppression values as tube lengths are varied from 0 to 56 in. (full-scale equivalent dimensions); however, thrust loss is significantly affected (see pages D277-D283). The multijet configuration primarily determines the noise characteristics of a suppressor nozzle without much dependence on thrust loss due to base drag shown.

Appendix C includes the PNL suppression values (PNdB) as a function of thrust loss (percent) for most of the eighth-scale suppressor nozzles tested in the SST high noise-suppression program. The range of gas conditions shown are $T_T = 500^\circ$, 1000° , and 1500° F with PR = 1.8, 2.2, 2.6, 3.0, and 3.4. The 126-tube nozzle series was tested extensively over the full range of test conditions. Many of the nozzles were tested briefly only near gas conditions representing the GE4/J5P maximum dry-engine power setting.

Several model-scale design suppressor nozzles were tested during the noise program. These nozzles were expected to provide between 12 and 20 PNdB sideline suppression at takeoff power settings with no more than 10% thrust loss. The length of the nozzle elements had to be kept short so that the suppressor nozzle could be stowed in the engine nacelle or ejector during cruise flight.

Figure 30 shows the relative noise-suppression and thrust-loss characteristics of the design nozzles tested. Installation of an ejector with an acoustically absorbent lining would improve these noise suppression values by at least 1 or 2 PNdB above those shown. The initial design concept was the HM-AP-6 nozzle, and the final concept was the NSC-119B nozzle. Techniques were developed during the SST jet noise suppression program to improve nozzle performance by reducing base drag without sacrificing noise suppression. The noise-suppression characteristics of low-area-ratio nozzles at high pressure ratios was improved upon. The NSC-119B nozzle represents an applicable design nozzle for a GE4-type turbojet engine (see ref. 28).

A compendium of model-scale suppressor nozzles tested during the 12- to 20-PNdB noise-suppression program appears in appendix D. This compendium includes a description of the nozzles, acoustic results, and propulsion performance results.

3.2.1.3 Normalization of Jet Noise Data

The SAE procedure for estimating jet noise levels (ref. 14) from a simple jet nozzle uses a normalization procedure to express overall sound pressure level as a function of ful' i expanded relative jet velocity. The SAE description of jet noise characteristics is limited to the overall sound pressure level (OASPL) at 45° relative to the jet axis and presented at the 200-ft sideline. Jet noise nominally peaks at 45° for jet engines operating without afterburner (e.g., gas temperature range of 800° to 1300°F).

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FIGURE 28.--EFFECT OF JET VELOCITY ON HEXAGONAL MULTITUBE NOZZLE ARRAY SUPPRESSION

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The SAE normalization procedure is based on a dimensional analysis of the original Lighthill equation

Acoustic power =
$$\frac{K^{o2} A V^8}{\rho_0 a_0^5}$$

Jet noise data taken under relatively constant atmospheric conditions can be assumed to have a constant ambient air density (ρ_0) and speed of sound (a_0); therefore, for a simple subsonic jet, the above equation becomes

Acoustic power =
$$K' \rho^2 A V^8$$

Assuming that the sound pressure level (SPL) at the angle where peak noise radiation occurs is proportional to the total acoustic power radiated, the variables as a function of jet velocity can be expressed as

SPL -
$$10 \log \rho^2 A = 10 \log f(V)$$

The velocity exponent is approximately 9 for subsonic jets in the direction of peak radiation (ref. 14).

Recent research has indicated that the velocity exponent may be different at the very low jet velocities (below 800 fps). Also, the gas density exponent may be less than 2 at these lower velocities. At jet velocities approaching 4000 fps, the velocity exponent has decreased to 3, see figure 31 (from ref. 14). This relationship is a valuable aid in predicting jet noise levels and as a check on baseline acoustic noise data acquired at the test facility.

Multispoke nozzle acoustic test data tend to "normalize" well with jet velocity by subtracting $\rho^2 A$ from the sound pressure level. Figure 32 is an example of normalized acoustic data from tests of the HM-AP-45 suppressor nozzle (36 spokes, area ratio 2.06). Multitube nozzle acoustic data do not normalize by subtracting $\rho^2 A$, as evidenced by the stratification of data for different total temperatures shown in figure 33 for the HM-AP-85-2 (126 tubes, area ratio 5.2) test data.

The original Lighthill equation from which the normalizing parameter $\rho^2 A$ was derived was based on early subsonic flow theory. Ffowcs-Williams in 1963 (ref. 36) suggested that radiated acoustic noise from a supersonic jet was proportional to

$$\frac{[1/2(\rho+\rho_0)]^2}{a_0^5 \rho_0} \frac{D^2}{X^2} V_R^7 V (1-M\cos\theta)^{-5} (1+N\cos\theta)^{-1}$$

where

D = jet diameter

X = distance from jet in far field



Jet noise = maximum passby OASPL at 200 ft off-axis normalized for $P = 1 \text{ lb/ft}^3$, A = 1 ft²

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FIGURE 31.-EFFECT OF JET RELATIVE VELOCITY ON NORMALIZED JET NOISE FOR A SIMPLE JET

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FIGURE 32.–NORMALIZED JET NOISE LEVELS FOR A 36-SPOKE, AREA RATIO-2.06 NOZZLE



FIGURE 33.–SPL NORMALIZED BY 10 LOG p²A FOR A 126-TUBE, AREA RATIO-5.2 NOZZLE AND A ROUND CONVERGENT NOZZLE

- V_R = jet exhaust speed relative to atmosphere
- V = jet exhaust speed relative to aircraft
- M = Mach number of eddy convection velocity
- N = Mach number of aircraft
- θ = angle to jet axis

For static tests, the sound intensity will be proportional to $(\rho + \rho_0)^2 \text{ AV}^n$. When 10 $\log (\rho + \rho_0)^2 \text{ A}$ is subtracted from sound pressure levels in dB-obtained from tests of a round convergent nozzle and plotted against jet velocity, a stratification of data occurs at different jet total temperatures.

For static jet noise testing with near-constant atmospheric conditions and removing the directionality factors in the equation, radiated acoustic power will be very nearly proportional to $K(\rho + \rho_0)^2 A V^n$ under conditions of supersonic flow. A normalizing parameter of $(\rho + \rho_0)^2 A$ is indicated here.

This normalizing parameter was applied to sound pressure levels in dB measured from a round convergent nozzle by subtracting $10 \log (\rho + \rho_0)^2 A$ and plotting the results against jet velocity. A stratification of data thus normalized occurred as a function of temperature.

When the $(\rho + \rho_0)^2 A$ normalizing parameter was applied to multitube nozzle acoustic data, a good correspondence of data was apparent when plotted against jet velocity (ideal), provided the noise spectra were dominated by high-frequency mixing noise. Figure 34 is an example of multitube nozzle noise levels normalized by subtracting 10 log $(\rho + \rho_0)^2 A$. The 126-tube, area ratio-5.2, normalized overall sound pressure levels show good agreement, while the round convergent nozzle data stratify with temperature.

The $(\rho + \rho_0)^2 A$ normalizing parameter was applied to the acoustic data from the following multitube nozzle tests:

<u>Tubes</u>	<u>Area ratio</u>
37	3.33
61	2.9
97	2.85
126	2.8
126	3.33
126	5.2
330	4.0

This particular study was not completed and the range of application was not determined. The $(\rho + \rho_0)^2 A$ normalizing parameter applies well to multitube nozzle acoustic data under supersonic primary flow conditions, provided jet-coalescence-generated noise does not dominate the spectrum. Very few acoustic data were acquired in the subsonic primary flow region during the SST program, and it has not been determined how well $(\rho + \rho_0)^2 A$ applies for this case.



FIGURE 34.—SPL NORMALIZED BY 10 LOG (P + P_O)²A FOR A 126-TUBE, AREA RATIO-5.2 NOZZLE AND A ROUND CONVERGENT NOZZLE

Figure 35 shows 37-tube, area ratio-3.33 suppressor nozzle average OASPL normalized by 10 log $\rho^2 A$ and 10 log $(\rho + \rho_0)^2 A$, respectively. Neither method provides good correspondence of sound pressure levels over the complete range of gas conditions tested. For this nozzle the acoustic data acquired at pressure ratios greater than 2.6 are normalized by -10 log $\rho^2 A$. and data acquired at pressure ratios less than 2.6 are normalized by -10 log $(\rho + \rho_0)^2 A$. Good correspondence of test data occurs as shown in figure 36. The jet coalesc .nce noise dominates over the jet mixing noise at pressure ratios greater than 2.6 for this particular multitube nozzle, and the coalesced jet has characteristics similar to a simple jet where $\rho^2 A$ applies best as the normalizing factor. When jet mixing noise dominates, $(\rho + \rho_0)^2 A$ is the better normalizing term.

Changes in overall sound pressure levels (dB) have been observed to change perceived noise levels (PNdB) by approximately the same amount. Therefore, perceived noise levels may often be normalized by the same factors even though a tenuous relationship exists between dB and PNdB.

SAE predicted noise levels at the 1500-ft sideline for a range of engine conditions where $T_T = 500^\circ$, 1000°, 1500°, 2000°, 2500°, and 3000° F and PR = 1.8, 2.2, 2.6, 3.0, and 3.4 were normalized by subtracting 10 log $\rho^2 A$. The normalized PNL values as a function of velocity (fig. 37) showed close correspondence, being within ±0.5 PNdB of the mean (ref. 37). Normalized PNL values are useful in making quick estimates of jet noise levels in engine cycle studies and may provide a relationship to account for relative velocity effects.

Figure 38 shows examples of normalized PNL values for a 37-tube, area ratio-3.33, suppressor nozzle. Estimates of suppressor nozzle noise levels can be made easily from normalized PNL relationships for engine cycle studies that fall within the range of gas conditions shown. Noise predictions from normalized PNL relationships have provided results that are within ± 0.5 PNdB of predictions obtained by conventional methods. This degree of accuracy is well within the accuracy of the original measured data.

It should not be construed that $\rho^2 A$ and $(\rho + \rho_0)^2 A$ are the final answers to jet noise normalization. As knowledge about jet noise generation processes improves, normalization terms will become more complete in their scope.



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Fully expanded jet velocity (ft/sec)

FIGURE 37.—NORMALIZED 150()-FT SIDELINE PNL VALUES FOR A ROUND CONVERGENT NOZZLE

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4.0 CONCLUSIONS

Model-scale nozzle jet noise characteristics appear to agree with full-scale nozzle test results. Control of ground reflection interference is especially important to obtain free-field acoustic data. In this way, acoustic data acquired at one facility are more likely to compare with acoustic data from another facility.

Model-scale nozzle testing provides acoustic and propulsion data-over a wide range of gas conditions, economically. It is advisable to test suppressor nozzles at ambient total temperature to acquire accurate coefficients of discharge. This information, together with accurate thrust values during acoustic testing at hot-flow primary gas conditions, is imperative in checking indicated total-temperature data. A mean value of total temperature is very difficult to obtain by direct measurement, yet jet velocity (and noise) is very sensitive to gas temperature.

Multitube nozzle configurations have shown greatest potential for attaining high jet noise suppression with low thrust loss under supersonic flow conditions. Multitube nozzle designs have greater structural integrity under conditions of high temperature and high engine pressure ratios.

The radiated acoustic spectra of multielement nozzles contain high-frequency energy attributed to noise generated by the elemental jet mixing region. Low-frequency acoustic energy is attributed to shear as the elemental jets coalesce and to the fully coalesced jet. Increasing the spacing between elemental jets causes a reduction in low-frequency noise levels. There appears to be an optimum spacing ratio between elemental jets to reduce highfrequency noise levels. Increases of pressure ratio tend to increase low-frequency noise with relatively little effect on high-frequency noise.

A hard-wall ejector surrounding the elemental jet mixing region has little effect on suppressor nozzle jet noise characteristics unless the ratio of ejector diameter to nozzle array diameter approaches unity. Suppression of 1 to 2 PNdB is possible with a tight-fitting hardwall ejector.

Ejectors lined with fiberglass batting have provided 5 to 12 dB suppression of jet mixing noise in the high-frequency portion of the spectrum. It has not been determined how well model-scale ejector lining acoustic characteristics compare with full-scale performance.

Suppressor nozzles tend to reach maximum values (PNJB) of suppression at fully expanded jet velocities between 2100 and 2600 fps. At jet velocities of 1100 to 1600 fps, these same nozzles may exhibit no suppression value, although further study is needed in this range.

The noise characteristics of multielement suppressor nozzles are not significantly affected by element length. A change in element length does affect thrust coefficient by changing nozzle base static pressures (base drag).

The SAE method of predicting jet noise levels declines in accuracy when extraordinary engine conditions are involved. In engine-cycle studies involving supersonic or high-temperature flow conditions, it was prudent to verify predicted acoustic noise values with model-scale nozzle test data.

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5.0 RECOMMENDATIONS

Radiated jet acoustic noise should be measured under far-field and free-field conditions so that noise spectra can be better interpreted and test results made more concise. The length of the jet over which the sound is generated should be determined, especially at supersonic flow conditions, to ensure that microphone locations are satisfactory for measuring the noise field with no parallax problems. Techniques for controlling ground reflection interference, especially in full-scale testing, need to be developed.

Investigations of ultrasonic sound propagation anomalies (e.g., air absorption loss and wind-induced turbulence) should be initiated to improve scaling relationships between model-scale and full-scale jet noise testing. It is desirable to express measured acoustic data in terms of standard-day conditions, and propagation loss values must be clearly defined.

Test facilities should be developed to measure jet noise and nozzle performance in the presence of forward velocity conditions. The methods for extrapolating static measured noise data to account for in-flight effects are not defined at this time. The relative velocity effect on noise generation is needed, especially for suppressor nozzle and ejector research. Improved temperature monitoring and stabilizing techniques are also required.

Measured acoustic data should be extrapolated from a predicated aircraft altitude of 1000 ft because propagation losses to the 2128-ft sideline are minimal at this altitude when using SAE extrapolation procedures. The actual propagation loss to the 2128-ft sideline needs to be determined by sound propagation studies under a wide range of meteorological conditions and locations. There is reason to believe that long-range propagation losses are ill defined at this time.

Noise levels in buildings (dwellings) should be considered when evaluating suppressor nozzle concepts. Currently, only out-of-doors annoyance levels are considered. Typical sound transmission loss values through building structure need to be used and indoor noise annoyance standards established.

A matrix of primary gas conditions is necessary in testing suppressor nozzle concepts for future engine developments. A wide range of engine conditions should be considered so that acoustic data can be interpolated conveniently for takeoff, cutback, and approach conditions as well as for engine-cycle studies.

Retest of some suppressor nozzle concepts is warranted, since current improvements in measurement techniques will provide better acoustic data. Many suppressor nozzles were tested over a very limited range of conditions, and retesting will fill gaps in the parametric studies already initiated.

Far-field acoustic data can only provide superficial answers to the noise-suppression problem. If the techniques of jet noise suppression are to progress, many methods have to be used to more completely define the multielement jet flow and noise generation processes and to clear up the suppositions currently espoused. Relations must be established evaluating the relative importance of changes in noise generation, redirection, or control of noise once generated, and attenuation of noise once radiated from the flow. These must be correlated with changes in nozzle geometry and fluid flow parameters. Techniques now exist to conduct such studies.

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APPENDIX A SST 5 PNdB SUPPRESSION PROGRAM

This appendix lists most noise suppression hardware tested during the SST low-noisesuppression (5 PNdB) program. The test configurations and upstream flow conditions are included as well as available test references.

A.1 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1966

Facility: Boeing Annex D, Seattle

Acoustic Data Reference: Boeing Test Report T6A10341-1, "SST Engine Noise Suppression Study-Scale Model Tests," September 1966

Performance Data Reference: None

A.1.1 Test Hardware

A.1.1.1 Nozzles

Designation	Description
C-6	Round convergent nozzle with short conical plug equivalent to 1:8 scale of JT3C-6 turbojet engine nozzle; $D_T = 3.10$ in. ($A_T = 7.07$ in. ²)
DP	Eight-lobe "daisy petal" exit configuration with 75% lobe penetration of the primary flow; $A_T = 7.07$ in. ²
MAE-2	Six-lobe spoke configuration with 30% lobe penetration of the primary flow; $A_{T} = 7.07 \text{ in.}^{2}$
MAE-5	Six-pointed star configuration with 50% penetration of the primary flow; $A_T = 7.07 \text{ in.}^2$
MPP 164	10 rounded lobe configuration with 12% penetration of the primary flow; $A_T = 7.07 \text{ in.}^2$
7 tubes	Seven round convergent tubes of equal size; area ratio < 2.0, $A_T \simeq 7.07$ in. ²
21 tubes	21 round convergent tubes (10 tubes in first row, 10 tubes in second row, and one center tube), three different tube sizes; area ratio ≈ 2.4 , $A_T \approx 7.07$ in. ²
37 tubes	37 round convergent tubes 12 tubes in first row, 12 tubes in second row, 12 tubes in third row, and one center tube), four different tube sizes; $A_T \approx 7.07$ in. ²
820-STD	Round convergent nozzle; $D_T = 3.4$ in., $A_T = 9.079$ in. ²

Designation	Description
820-1	Six-spoke configuration with 20% lobe penetration of the primary flow; $A_T = 9.1$ in. ²
820-2	Six-spoke configuration with 50% lobe penetration of the primary flow; $A_T = 9.1$ in. ²
820-3	Four-spoke configuration with 50% lobe penetration of the primary flow; $A_T = 9.1$ in. ²
820-4	Eight-spoke configuration with 50% lobe penetration of the primary flow; $A_T = 9.1$ in. ²
820-5	Six-spoke configuration with 75% lobe-penetration of the primary flow; $A_T = 9.1$ in. ²
GE-I STD	Round convergent nozzle; $D_T = 4.25$ in., $A_T = 14.2$ in. ²
GE-2 STD	Round convergent nozzle; $D_T = 5.25$ in., $A_T = 21.6$ in. ²
GE-I	16-point star configuration, 12% penetration of the primary flow; $A_T = 14.2 \text{ in.}^2$
GE-2	Eight-point star configuration, 30% penetration; $A_T = 21.6$ in. ²
GE-3	Eight-point-reverse star configuration, 30% penetration; $A_T = 21.6$ in. ²
GE-4	Eight-point star configuration, 50% penetration; $A_T = 21.6$ in. ²
GE-5	16-point star configuration, 30% penetration; $A_T = 21.6$ in. ²
GE-6	16-point star, 50% penetration; $A_T = 21.6$ in. ²
GE-7	Four spokes, 30% penetration; $A_T = 21.6$ in. ²
GE-7A	Four spokes, 30% penetration, 1/8-in. step in ventilation gutter; $A_T = 21.6$ in. ²
GE-8	Four spokes, 50% penetration; $A_T = 21.6 \text{ in.}^2$
GE-9	Four-lobe Maltuse Cross, 30% penetration; $A_T = 21.6 \text{ in.}^2$
GE-10	Four-lobe Maltese Cross, 50% penetration; $A_T = 2^{\circ}.6 \text{ in.}^2$
GE-11	16-point star, 12% penetration; $A_T = 21.6$ in. ²
PW-P1	Round convergent nozzle; $D_T = 3.80$ in., $A_T = 11.33$ in. ²

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Designation	Description
PW-P1B	Round nonconvergent nozzle; $D_T = 3.80$ in., $A_T = 11.33$ in. ²
PW-P2	Eight-point-star, 30% penetration; $A_T = 11.3$ in. ²
PW-P3	Eight-point star, 50% penetration; $A_T = 1.1.3$ in. ²
PW-S1	Round convergent secondary-flow nozzle; D _T = 6.08 in.
PW-S2	Eight-point-star-secondary-flow-nozzle, 30% penetration: $A_T = PW-S1$
PW-S3	Eight-point-star-secondary-flow-nozzle, 50% penetration; A _T = PW-S1
PW-S4	Four-lobe-Maltese-Cross-secondary-flow-nozzle; $A_T = PW-S1$
PW-S5	J-85 round nozzle with steps; A _T =PW-S1

A.1.1.2 Ejectors

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Designation	Description
GE-E1	Round ejector; $D_{I} = 5.20$ in., $D_{T} = 4.75$ in., $D_{E} = 5.6$ in., $L = 7.1$ in.
GE-E2	Round ejector; $D_1 = 8.38$ in., $D_T = 7.625$ in., $D_E = 7.56$ in., $L = 10.75$ in.
GE-E3	Round ejector fitted with four or eight chutes; $D_{J} = 8.38$ in., $D_{T} = 7.625$ in., $D_{E} = 7.56$ in., $L = 10.75$ in.
GE-E4	Round ejector fitted with eight scoops 0.7 in. wide; $D_{j} = 7.00$ in.
GE-E5	Contoured four-lobe ejector; $D_{\tilde{I}} = 4.20$ in., $D_{\tilde{T}} = 4.00$ in., $D_E = 4.20$ in., $L = 11.00$ in.
PW-E1	Round ejector with 12 blow-in doors installed (BIDE); $D_1 = 9.25$ ln., $D_T = 7.60$ in., $D_E = 8.55$ in., $L = 9.40$ in.
PW-E1A	12-blow-in-door round ejector, plain "clamshell"- with eight scoops 0.7 in. wide; $D_I = 9.15$ in., $D_{\overline{T}} = 7.62$ in., $D_{\overline{E}} = 8.62$ in., $L = 9.35$ in.
PW-E1B	12-blow-in-door round ejector, "scallop clamshell" with eight scoops 0.7 in. wide; dimensions same as ejector PW-E1A
PW-E1C	12-blow-in-door round ejector, no "clamshell," with eight scoops 0.7 in. wide; dimensions same as $PW-E1A$
PW-E4	Round ejector with eight scoops; $D_{\bar{I}} = 10.95$ in., $D_{\bar{T}} = 10.00$ in., $D_{\bar{E}} = 10.45$ in., $L = 10.50$ in.
No. 5	This ejector was not identified in the acoustic data reference.

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A.1.2 Test Configuration Index

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	Primary	Secondary-	-	Ej	ector flow	elements	Flow
Configuration	nozzle	nozzle	Ejector]	Туре	Quantity	Penetration	conditions
T	·C-6	None	None		None		GE: 1,2
	C- 6	None	No. 5		None	-	GE: 1,2
3	5-6	None	GE-1		None		GE: 1,2
4	C-6	None	GE-E1	-	None		GE: 1,2
5	DP .	None	None		None		GE: 1,2
6	D₽	None	No. 5	-	None		GE: 1,2
7	D₽	None	GE-1		None	-	GE: 1,2
8	MAE-2	None	None	-	: None	Ξ	GE: 1,2
Q	MAE-2	None	No. 5		None		GE: 1,2
10	MAE-2	None	GE-1		None		GE: 1,2
11	MAE-5	None	None		None		GE: 1,2
12	MAE-5	None	°No. 5	-	None		GE: 1,2
13	MAE-5	None	GE-1		None		GE: 1,2
14	MPP 164	None	None		None		GE: 1,2
15	MPP 164	None	No. 5	. 1	None		GE: 1,2
16	MPP 164	None	GE-1	-	None		GE: 1,2
17	7 tubes	None .	None		None		GE: 1.2
18	7 tubes	None	No. 5		None		GE: 1,2
19	7 tubes	None	GE-1		None		ĠE: 1,2
20	21 tubes	None	None	u .	None		GE: 1,2
21	21 tubes	None	No. 5		None		GE: 1,2
22	21 tubes	Note	GE-1		None		GE: 1,2
23	3) tubes	None	None		None		GE: 1,2
24	37 tubes	None	No. 5		None		GE: 1,2
15	at luluea	None	GE-1		None		GE: 1,2
26	820-STD	None	None		None		GE: 1.2
27	820-STD	Nalla	No. 5		None		GE: 1,2
28	820 - STD	None	GE-1		None	94 A	GE: 1,2
29	820-1	None	None		None	-	GE: 1,2
30	820-1	None	No. 5		None		GE: 1,2
31	820-1	None	GE-1		None		GE: 1,2
11	810-1	None	None		None	- -	GE: 1,2
33	820-2	None	No. 5		Nong 🕴	Ę	GE: 1,2
34	820-2	None	QE-1		None		GE: 1,2
35	820-3	None	None		None		GE: 1,2

	Primary	Secondary		Eje	ctor flow	elements	Flow
Configuration	nozzle	nozzle	Ejector	Туре	Quantity	Penetration	conditions
36	820-3	None	No. 5		None	-	GE: 1,2
37	820-3	None	GE-1		None -	۰.	GE: 1,2
38	820-4	None	None		None		GE: 1,2
39	820-4	None	No. 5		None		GE: 1,2
40	820-4	None	GE-1		None		GE: 1,2
41	820-5	None	None		None	:	GE: 1,2
42	820-5	None	No. 5	-	None		GE: 1,2
43	820-5	None	GE-1		None		GĒ: 1,2
44	GE-1 STD	None	None		None		GE: 2,3,4,5
45	GE-1 STD	None	GE-E1		None		GE: 2,3,4,5
46	GE-2 STD	None	None		None		GE: 2,3,4,5
47	GE-2 STD	None	GE-E2		None		GE: 2,3,4,5
48	GE-2 STD	None	GE-E3	Chutes	8	30%	GE: 2,3,4,5
49	GE-2 STD	None	ĞE-E4	Scoops	8	50%	GE: 2,3
<u>\$0</u>	GE-2 STD	None	GE-E4	Scoops	4	50%	GE: 2,3
51	GĒ-2 STD	None	GE-E4	Scoops	8	0%	GE: 2,3
52	GE-2 STD	None	GE-E4	ⁱ Scoops	-8	30%	GE: 2,3
53	GE-2 STD	None	GE-E4	Chutes	8	50%	GE: 2,3,4,5
54	GE-2 STD	None	GE-E4	Scoops Čhutes	. 8 4	50% 50%	GE: 2,3
55	GE-2 STD	None	ĢE-E4	Scoops Chutes	' 4 8	50% 50%	GE: 2,3
56	GE-2 STD	None	GE-E4	Scoops Chutes	8 8	50% 50%	GE: 2,3
57	GE-2 STD	Noñe	GE-E4	Scoops Chutes	8 . 8	0% 50%	GE: <u>2</u> ,3
58	GE-2 STD	None	GE-E3	Chutes	8	50%	GE: 2,3,4
59	GE-2 STD	None	GE-E3	Chutes	4	50%	GE: 2,3
60	GE-2 STD	None .	GE-E3	None	None		GE: 2,3
61	GE-2 STD	None	GE-E3	Chutes	8	20%	GE: 2,3
62	GE-2 STD	None	GE-E3	Chutes	4	20%	GE: 2,3
63	GE-2 STD	None	GE-E3	Chutes	4	30%	GE: 2,3
64	GE-2 STD	None	GE-E3	Scoops	4	50%	GE: 2,3
65	GE-2 STD	None	GE-E3	Scoops	8	0%	GE: 2,3
66	GE-2 STD	None	GE-E3	Scoops	4	<u>3</u> 0%	GE: 2,3
67	GĖ-2 STD	None	GE-Ē3	Scoops	8	30%	GE: 2,3
68	GE-2 STD	None	GE-E3	Chutes	8	30%	GE: 2,3,4
69	GE-1	None	None		None		GE: 2,3,4,5

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	Primary	Secondary	-	Ejector flow elements			Flow
Configuration	nozzle	nozzle	Ejector	Type	Quantity	Penetration	conditions
70	GE-1	None	GE-E1		None		GE: 2,3,4,5
71	-GE-2	None	None		None	×	GE: 1-,2.3
72	GE-2	None	GE-E2		None		GE: 1,2,3
73	GE-3	None	None		None		GE: 2,3
74	GE-3	None	GE-E2	-	None	-	GE: 2,3
75	GE-4	None	None		None -	-	GE: 2,3
76	GE-4	None	GE-E2		None	-	GE: 2,3
77	GE-4	None	GE-E3	⁻ Chutes	8	50%	GE: 2,3
.78	GE-5	None	None		None	-	GE: 2,3
79	GE-5	None	ĠE-E2		None	-	GE: 2,3
6.0	GE-5	None	GE-E3		None		GE: 2,3
81	GE-5	None	GE-E3	Chutes	8	60%	GE: 2,3
82	G Ŀ- 6	None	None		None		GE 1.2,3
83	GE-6	None	GE-E2		None		GE: 2,3
84	GE-6	None	GE-E3		None		GE: 1,2,3
85	GE-7	None	None		None		GE: 2,3
86	GE-7	None	GE-E2		None		GE: 2,3
87	GE-7A	None	None		None		GE: 2,3
88	GE-7A	None	GE-E2		None		GE: 2,3
89	GE-7A	None	GE-E3	Chutes	8	30%	GE: 2,3
90	GE-7A	None	GE-E3	Chutes	4	30%	GE: 2,3
91	GE-7A	None	GE-E3		None		GE: 2,3
92	GE-8	None	None		None		GE: 1,2,3
93	GE-8	None	GE-E2		None		GE: 2,3
94	GE-8	None	GE-E3	Chutes	8	30%	GE: 1,2,3
95	GE-8	None	GE-E5		None		GE: 2,3
96	GE-8	None	GE-E3	Chutes	8	50%	GE: 2,3,4
97	GE-9	None -	None	-	Nóne		GE: 2,3,4
98	GE-9	None	GE-E2		None		GE: 2,3,4
99	-GE-10	None	None		None		GE: 2,3,4
100	GE-10	None	GE-E3	-	None		GE: 2,4,5
101	GE-10	None	GE-E3	Chutes	4	30%	GE: 2,3
102	GE-11	None	None		None		GE: 2,3
103	GE-11	None	GE-E2	-	None		GE: 2,3
104	GE-11	None	GE-E3	Chutes	8	30%	GE: 2,3,4
105	GE-11	None	GE-E4	Chutes	8	50%	GE: 2,3
106	GE-11	None	GE-E4	Chutes	4	50%	GE: 2,3

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	Primary	Secondary	-	Ejector flow elements			'Zlow
Configuration	nozzle	nozzle	Ejector	Туре	Quantity	Penetration	conditions
107	GE-11	None	GE-E4	_	None		GE: 2,3
108	GE-11	None	GE-E4	Scoops	8	50% ·	GE: 2,3
102	GE-11 -	None	GE-E4	Scoops	4	50%	GE: 2,3
110	-GE-11	None	GE-E4	⁻ Chutes	: 4	85%	GE: 2,3
111	GE-11-	None	GE-E4	Chutes	· 2	85%	GE: 2,3
112	PW-P1	PW-S1	- None		None		PW: 1,2,3
113	PW-P1	PW-S3	None	-	None	-	PW: 1,2,3
114	PW-P1	PW-S2	PW-E1	-	None	-	PW: 1,2
115	PW-P1	PW-S1	PW-E4	Scoops	8	0%	•PW: 2,3
1.16	PW-P1	PW-S1	PW-E4	_ Scoops	4	74%	-PW: 2,3
117	PW-P1	PŴ-S1	PW-E4	Scoops	8 -	74%	PW: 2,3
118	PW-P1	PW-S3	PW-E4	Scoops	4	74%	PW: 2,3
119	PW-P1	PW-S3	PW-E1	Scoops	8	74%	PW: 2,3
120	PW-P1	PW-S3	PW-E1	Scoops	4	74%	•PW: 2,3
123	PW-P1	PW-S3	PW-E1		None		PW: 2,3
124	PW-P1	PW-S3	PW-E1	Scoops	4	22%	PW: 2
125	PW-P1	PW-S1	PW-E4	Scoops	4	30%	PW: 2,3
126	PW-P1	PW-S1	PW-E4	Scoops	8	58%	PW: 2,3
127	PW-P1	PW-S1	PW-E1B	Scoops	8	50%	PW: 2,3
128	PW-P1	PW-S5	None		None		PW: 2,3
129	PW-P1	PW-S5	PW-E1C	Scoops	8	50%	PW: 2,3
130	PW-P1	-PW-S5	PW-E1C	Scoops	4	50%	PW: 2,3
131	PW-P1	PW-S5	PW-E1C	Scoops	4	0%	PW: 2,3
132	PW-P1	PW-S5	PW-E1A	Scoops	8	0%	PW: 2,3
133	PW-P1	PW-S5	PW-E1A	Scoops	4	0%	PW: 2,3
134	PW-P1	PW-S5	PW-E1A	Scoops.	8	50%	PW: 2,3
135	PW-P1	PW-S5	PW-E1B	Scoops	8	50%	PW: 2,3
136	PW-P1	PW-S5	PW-E1B	Scoops	4	50%	PW: 2,3
137	PW-P1	PW-S5	PW-E1B	Scoops	8	0%	PW: 2,3
138	PW-P1	PW-S1	GE-E4	Chutes	8	50%	PW: 2,3
139	PW-P1	PW-S1	GE-E4	Scoops	8	60%	PW: 2,3
140	PW-P1	PW-S1	GE-E4	Scoops	8	100%	PW: 2
141	PW-P1	PW-S1	GE-E3	Chutes	4	50%	PW: 2,3
142	PW-P1	PW-S1	GE-E3		None		PW: 2,3
143	PŴ-P1	PW-S1	GE-E3	Chutes	8	50%	PW: 2,3
145	PW-P1	PW-S5	GE-E3	Chutes	4	50%	PW: 2,3
146	PW-P1	PW-S5	GE-E3	Chutes	2	50%	PW: 2,3

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	Primary	Secondary		Eje	ctor flow	elements	Flow
Configuration	nozzle	nozzle	Ejector	Туре	Quantity	Penetration	conditions
147	PW-P1	PW-S5	GE-E3		None	-	PW: 2,3
148	- PW-P1 -	PW-S1	PW-E1A	Chutes	8	50%	PW: 2,3
149	PW-P1	PW-S1	PW-E1A	Chutes	- 4	50%	PW: 2,3
150	PW-P1	PW-S1	PW-E1A		None		PW: 2,3
151	PW-P1	PW-S1	PW-E1A	Scoops	4	50%	PW: 2 3
152	PW-P1	PW-S1	PW-E1A	Scoops	8	50%	PW: 2.3
153	PW-P1	PW-S1	PW-EIC		None		PW: 2,3
154	PW-P1	PW-S1	None		None		PW: 2,3 (secondary
155	PW-P1	PW-S1	None		None		PW: 2,3 (primary flow only)
156	PW-P1B	None	None		None		PW: 2
157	PW-P1B	PW-S4	None		None		PW: 2,3
158	PW-P1B	PW-S4	PW-E1		None		PW: 2,3
159	PW-P1B	PW-S1	PW-E1		None		PW: 2.3
160	PW-P1B	PW-S1	None]	None		PW: 2,3
161	PW-P1B	PW-S5	PW-E1		None		PW: 2,3
162	PW-P1B	PW-S5	None		None		P₩: 2,3
163	PW-P1B	PW-S1	PW-E4	Scoops	8	58%	PW: 2,3
164	PW-P1B	PW-S1	PW-E4	Scoops	8	30%	PW: 2,3
165	PW-P1B	PW-S1	PW-E4	Scoops	8	0%	PW: 2,3
166	PW-P1B	PW-S1	PW-E4	Scoops	4.	30%	PW: 2.3
167	PW-P1B	PW-S1	PW-E4	Scoops	4	58%	PW: 2,3
168	PW-P1B	PW-S1	PW-E4	Scoops	4	0%	PW: 2,3
169	PW-P1B	PW-S4	PW-E1B	Scoops	8	50%	PW: 2,3
170	PW-P1B	PW-S4	PW-E1B	Scoops	4	50%	PW: 2,3
171	PW-P1B	PW-S4	PW-E1B	Scoops	8	0%	PW: 2,3
172	PW-P1B	PW-S4	None		None		PW: 2,3
173	PW-P1B	PW-S5	PW-E1A	Scoops	8	0%	PW: 2,3
174	PW-P1B	PW-S5	PW-E1A	Scoops	4	50%	PW: 2,3
175	PW-P1B	PW-S1	GE-E3	Chutes	8	50%	PW: 2,3
176	PW-P1B	PW-S1	GE-E3	Chutes	4	50%	PW: 2,3
177	PW-P1B	PW-S4	GE-E3	Chutes	8	50%	PW: 2,3
178	PŇ-P1B	PW-S4	GE-E3	Chutes	4 :	50%	PW: 2.3
179	PW-P1B	PW-S4	GE-E3		None		PW: 2,3
180	PW-P1B	PW-S4	GE-E3	Chutes	2	50%	PW: 2.3

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	Primary	Secondary	-	Eje	ctor flow	elements	Flow
Configuration	nozzle	nozzle	Ejector	Туре	Quantity	Penetration	conditions
181	PW-P2	PW-S2	None		None		PW: 1,2
182	PW-P2	PW-S1	PW-E1	-	None	•	PW: 1,2
183	PW-P2	PW-S2	PW-E1	-	None		-PW: 1,2
184	PW-P3	PW-S3	None	-	None	-	'PW': 2
185	-PW-P-3	PW-S3	PW-E4	Scoops	8-	74%	PW: 3

A.1.3 Upstream Flow Conditions

A.]	.3.1	GE N	lozzles	(Primary	Flow	Only)
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Reference number	Pressure ratio	Total temperature (°F)
1	1.88	900
2.	3.14	1,600
3	3.01	2,100
4	3.01	2.500
5	3.01	2,785

A.1.3.2 P&WA Nozzles

	Pri	mary flow	Seco	ondary flow
Reference number	Pressure ratio	Total temperature (°F)	Pressure ratio	Total temperature (°F)
1	1.88	1,560	2.67	Cold
2	2.14	1,590	2.35	2,000
3	2.14	1,590	2.32	2,500
4	2.14	1,590	2.67	2,250
5	2.14	1,590	2.67	3,150

A.2 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1967

Facility: Boeing Annex D, Seattle

Acoustic Data Reference: Boeing Test Report T6A11035-1, "Scale Model Jet Noise Suppression Program," March 1968

Performance Data Reference: None

A.2.1 Test Hardware

A.2.1.1 Nozzles

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Designation	Description
1	Round convergent nozzle; $D_T = 4.10$ in., $A_T = 13.2$ in. ²
3	16-pointed star configuration with 12% penetration of the primary flow; $A_{T} = 12.5$ in. ²
4	16-pointed star configuration with 12% penetration of the primary flow; $A_T = 14.1$ in. ²
6	Four-lobe nozzle configuration with 50% penetration of the primary flow, the lobes having parallel sides.
7	GE-2 standard, round convergent nozzle; $D_T = 5.31$ in., $A_T = 21.6$ in. ²
TSEN-2	Round convergent nozzle used in conjunction with TSEN-2 ejector; $D_T = 4.67$ in., $A_T = 17.35$ in. ²

A.2.1.2 Ejectors

			Description			
	· · · · · · · · · · · · · · · · · · ·	Diameter (in.)		Length	(in.)	
	FRi	-		Inlet		
Designation	Throat	Inlet_	Exit	to_throat	Total	
- 1	4.90	6.46	5.40	2.60	7.65	
2.	4.95	6.86	4.95	2.80	8.50	
4	4.90	6.46	6.86	2.60	7.65	
5	4.95	6.86	4.95	2.80	8.44	
		Fibergla	iss lined			
6	6.35	7.30	6.35	Length (in.) Inlet Total it to throat Total 0 2.60 7.65 25 2.80 8.50 26 2.60 7.65 25 2.80 8.44 25 2.98 9.10 25 2.56 10.5 0 2.20 10.50 0 2.70 8.07 0 2.70 8.07 th modified tips 0 2.70 4 1.60 7.37 rgent-divergent-convergent) 5 1.60 5 1.60 7.37 vergent-divergent) 0 2.70 0 2.70 8.07 15.6% 1.60 7.37 vergent-divergent) 0 2.70 0 2.70 8.07 16 5 1.60 7.90 8.07 15 1.60 7.37 0 2.70 8.07		
8	6.35	7.30	6.35	3.00	9.10	
		Fibergla	ss lined			
В	7.45	8.35	7.85	2.56	10.5	
C	10.05	10.95	10.70	2.20	10.50	
D	5.33	6.95	_6.40	2.70	8.07	
E	5.33	6.95	ნ.40	2.70	8.07	
	Tail feath	er penetration	30% with mod	lified tips		
F	5.33	6.95	6.40	2.70	8.07	
	1	ail feather pen	etration 15.6%	6	7	
G	5.04	7.28	5.04	1.60	7.37	
	GE 1/8-scale pro	ototype ejector	(convergent-d	livergent-converger	nt)	
H	5.04	7.28	6.05	1.60	7.37	
	. GE 1/8-scale	prototype ejed	tor (converger	nt-divergent)		
Ι	5.33 .	6.95	6.40	2.70	8.07	
	Tail featl	per-penetration	30% with stra	light tips		
TSEN-2	. 5.60	7.24	5.60	2.50	7.06	

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A.10

A.2.1.3 Chutes

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	Description	<u> </u>	-
		Dimen	sions (in.)
Designation	Туре	Width	Length
1	Cone chutes	0.31	2.16
2	Cone chutes	0.45	2.16
3	Cone chutes	0.51	2.16
5	Flat chutes	0.45	2.16
6	Flat chutes	0.90	2.16
7	Flat chutes •	1.80	2.16
8	Flat chutes with sides	0.45	2.95
9	Flat chutes with sides	0.45	2.68
10	Flat chutes with sides	0.45	2.16
11	Tapered box chutes	NIA	2.95
12	Rectangular box chutes	0.45	2.16
13	Wing chutes	0.50	2.16
14	Flat chutes with sides	0.45	3.48
15	Rectangular box chutes	0.45	3.48
16	Wing chutes	0.45	3.48
17	Aerodynamic cone chutes	0.7	3.50
18	U-shaped scoops	1.0	3.75
19	Aerodynamic cone chutes	0.5	2.52
20	Ejectorless chute cluster	0.45	2.00
21	Flat chutes with sides	0.45	2.23
22	Flat chutes with sides	0.378	2.66
23	Flat chutes with sides	0.325	3.09
24	Flat chutes with sides	0.285	3.52
25	Flat chutes with sides	0.254	3.95
32	Flat chutes with sides	0.45	1.94
Special	Flat chutes with sides Quantity (8) 40% penetration 22.4% area blockage Nozzle exit plane to throat distance (2-1/4 in.)	0.45	Various .
TSEN-2	Flat chutes with sides	0.54	2.95
TSEN-2	Triangular chutes without sides	1,10 (Base)	2.98 (Quier edge)

	<i>b</i> ,								
				Ejector 1	Tow element	s		Elon 20	
	Nozzle	Ejector	Chute			Angle		Total	enonion .
Configu- ration	identification	identification	identification number	Quantity	Penetration (%)	attack (deg)	Blockage (%)	temperature (°F)	Pressure ratio
I	1	1	-	4	40	30	7.7	2,540	2.2, 2.5, 2.7
7	I	1	1	8	40	30	1.5.4	2,540	2.2, 2.5, 2.7
ю			7	8	30	23	16.8	2,540	2.2, 2.5, 2.7, 3.0
4]	1	7	8	40	30	22.4	2,540	2.2, 2.5, 2.7
ŝ	1	1	0	8	50	36	27.9	2,540	2.0, 2.2, 2.7, 3.0
9	1	1	0	C 1	40	30	5.6	2,540	2.7
٢	Ļ	1	61	4	40	30	11.2	2,540	2.7
8	1	Ŧ	n	8	30	23	19.0	2,540	2.0, 2.2, 2.7, 3.0
6	متتع	1	m	8	40	30	25.3	2,540	2.0, 2.2, 2.7, 3.0
10	I	1	ω	8	50	36	31.7	2,540	2.0, 2.2, 2.7, 3.0
11	÷		n	4	40	30	12.7	2,540	2.7
12	÷	1	ω	5	40	30	6.3	2,540	2.7
13	щ.	1	S	8	30	23	16.8	2,540	2.2, 2.5, 2.7
14	1	1	S	8	40	30	22.4	2,540	2.2, 2.5, 2.7
15	-	1	S	8	50	36	27.9	2.540	2.2, 2.5, 2.7
16		1	5	4	40	30	11.2	2,540	2.2, 2.5, 2.7
17	-	1	5	6	40	30	5.6	2,540	2.7
1.8	1	1	6	4	40	30	22.4	2,540	2.7
19		I	6	(L)	40	30	11.9	2,540	2.7
20	÷	I	7	6	40	30	22.4	2,540	2.7
21	1	2	8	8	30	17	16.8	2,540	2.0, 2.7, 3.0
				Blow-in	doors		-		
22	-	6	8	8	30	17	16.8	2,540	2.0, 2.7, 3.0
			Cylindrical ext	tension on	ejector, blow	v-in doo	rs		_

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Test Configuration Index

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-		riow conditions Tetal Pressure (F) ratio	2.540 2.0: 2.7. 3.0	2,540 2.0, 2.6, 3.0	2,540 2.0, 2.7, 3.0		2,540 2.0, 2.7		2,540 2.0, 2.7, 3.0	2,540 2.0, 2.7, 3.0	1	2,540 2.0, 2.7, 3.0	2,540 2.0, 2.7, 3.0		2,540 2.0, 2.7, 3.0		2,540 2.0, 2.7, 3.0	2,540 2.0, 2.7, 3.0	2,540 2.0, 2.2, 2.5, 2.7, 3.0		2,540 2.2, 2.5, 2.7	-
		Blockage tem	16.8	16.8	16.8	S	16.8		22.4	22.4	S	22.4	27.9		27.9	s	27.9	27.9	27.9	-	27.9	
ied)		Angle of attack (deg)	81	17	18	v-in door	18		<u> </u>	20	v-in door	22	26		26	/-in door	26	26	26		26	lined
dex (continu	w elements	Penetration (%)	30	30	30	cjector, blov	30	oors .	40	40	cjector, blov	40	50	oors	50	ejector, blow	50	50	50	hard-lined	50	or wall herd-
guration Ind	Ejector f.o	Quantity	×	8	8	tension on	8	Blow-in d	8	×	tension on cj	8	బ	Blow-in d	8	tension on	8	8	8	jector wall	8	alf of ejecte
Test Confi		Chute identification number	×	8	8	Cylindrical ex	∞		∞.	8	Cylindrical ex	8	8		×	Cylindrical ex	8	8	ø	E	8	Forward h
		Ejector identification number	Q	3	6		ġ		2	2		6	2		3		ŷ	5	ŝ		5	
		Nozzle identification number	ω	4	4		4					3			-	-	ω	4	4		4	
	<u></u>	Configu- ration	23	24	25		26		27	28		29	30	-	31		32	. 33	34		35	

	hanner herrende		Sirence very		יייי ייייווווווווווווווווווווווווווווו	(n)			
				Ejector fl	low elements			į	
Configu- ration	Nozzle identification number	Ejector identification number	Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow co Tota! temperature (°F)	nditions Pressure ratio
у У	T	v	•	c	ດ ນ	ć			
0	ŀ	¢.	0		0C	07	6.17	4,040	2.2, 2.1, 3.0
-	-		Aft hal	If of ejecto	r wall hard-li	ned	-	11	-
37	4	5	∞	8	50	26	27.9	2,540	2.2, 2.5, 2.7
-			ũ	jector wall	hard-lined		-	-	
38	. 1	4	. 9	8	30	19	16.8	2.540	2.0, 2.7, 3.0
39	1	.4	6	8	30	19	16.8	2,540	2.0, 2.7, 3.0
-			Cylinc	irical exten	ision on eject	or	-	and the second	111
40	-	0	6	8	30	19	16.8	2,540	2.7, 3.0, 3.3
	-	-	-	No eje	ctor				-
41	1	4	6	∞	40	24	22.4	2,540	2.0, 2.7, 3.0
42	1	4	6	∞	40	24	22.4	2,540	2.0, 2.7, 3.0
-			Cylind	Irical exten	sion on eject	or	-	-	-
43	Ι	Ď	Ó	∞	40	24	22.4	2,540	2.7, 3.0, 3.3
			Chutes in li	ne with per	netrating tail	feather		-	-
44		ш	e	∞	40	7 t	22.4	2,540	2.7, 3.0, 3.3
r		-	Chutes in li	ne with per	net rating tail	feather	-	-	<u> </u>
45	-	ш	6	∞	40	24	22.4	2,540	2.7, 3.0, 3.3
			Chutes out of	line with p	benetrating to	uil feathe	ir		

Test Configuration Index (continued)

A.14

(continued)	
Index	
Test Configuration	

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	Flow conditions Total temperature (°F) ratio	2,540 2.7, 3.0, 3.3	-	2,540 2.7, 3.0, 3.3	-	2.540 2.7, 3.0, 3.3	-	2,540 2.7.3.0,3.3		2,540 2.0, 2.7, 3.0	2,540 2.0, 2.7, 3.0	-	2,540 2.0, 2.7, 3.0	2,540 2.0, 2.7, 3.0	2,540: 2.0, 2:2, 2:7, 3:0	2,540 $2.0, 2.2, 2.7, 3.0$	2,540 $2.0, 2.2, 2.7, 3.0$	2,540 2.0, 2.7, 3.0	2.540 2.0, 2.7, 3.0	2,540 2.0, 2.7, 3.0		2,540 2.0, 2.6, 3.0	1 1
	Blockage (%)	22.4	S	22.4	rs	22.4	_	22.4	ts	27.9	27:9		16.8	22.4	22 4	22.4	22.4	27.9	26.1	26.1		26.1	
ts	Angle of attack (deg)	24	ul feather.	24	tail teathe	24	il feathers	24	ail feathe	28	28	tor	19	24	30	31	31	30	17	1-7	tor	17	
ow clemen	Penetratior (%)	40	netrating to	40	enetrating 1	40	letrating tai	40	enetrating 1	50	50	tion on ejec	30	40	40	40	40	50	30	30	ion on ejec	30	doors
Ejector fl	Quantity	∞	ine with pe	8	line with po	8	ne with pen	8	line with po	8	8	rical extens	8	8	8	8	8	8	8	8	rical extens	8	Blow-in
	Chute identification number	6	Chutes in 1	6	Chutes out of	6	Chutes in li	6	Chutes out of	6	6	Cylind	10	10	10	10	10	10	11	11	Cylind	11	
-	Ejector identification number	ſĽ		لی		Ι		Ţ.		4	4		Ι	I	7	6	6	1	2	5		0	
	Nozzle identification number			- •		-		****			-		-			1	4	-	-			4	
	Configu- ration	46		47		48		49		50	51		52	53	54	55	56	57	58	59		60	

Test Configuration Index (continued)

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1410.00	Pressure	2.0, 2.6, 3.0		2.0, 2.7, 3.0		2.0, 2.7, 3.0	-	2.0, 2.7, 3.0	-	2.0, 2.7	2.0, 2.2, 2.7, 3.0	3.0		2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	2.0, 2.2, 2.7 3.0	-	2.0, 2.7, 3.6	2.0, 2.2, 2.7, 3.0	3.0	
	Total Total temperature (°F)	2,540	_	2,540	-	2,540		2,540 2		2,540 2	2,540 2	2,540 3		2.540 2		2,540 2	2,540 2		2,540 2	2,540 2	2,540 3	
	Blockage (%)	26.1	LS	34.8		34.8	rs	43.5		16.8	16.8	16.8		16.8	-	22.4	22.4		22.4	22.4	22.4	
s	Angle of attack (deg)	. 17	oop ui-w	20		20	w-in doo	26		19	24	24	chutes	24		30	20	ector	24	25	30	chutes
low element	Penetration (%)	30	ejector, blo	40	doors	40	ejector, blo	50	doors	30	30	30	ection into	30	nto chutes	40	40	ension on ej	40	40	40	ijection into
Ejector f	Quantity	∞.	tension on	8	Blow-in	∞	tension on	8	Blow-in	8	8	8	d water inj	8	orced air i	8	8	idrical ext	∞	8	8	ed water in
	Chute identification number	11	Cylindrical ext	11		11	Cylindrical ext	11	-	12	12	12	Force	12	Ę	12	12	Cylin	12	12	12	Force
-	Ejector identification number	0		7		2		2		-	2	5		5		4	4		1	2	2	
	Nozzle identification number	4				-		ľ		1	1	1		1		1			 1	1	1	
	Configu- ration	61	-	62		63		64	-	65	66	. 67	~	68	Ţ	69	· 20 [.]	-	71	72	73	

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			Test Config	uration Ind	ex (continue	(pc			
				Ejector fl	ow elements		-		
Configu- ration	Nozzle identification number	Ejector identification number	Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Total temperatur (°F)	onditions c Pressure ratio
74	1	6	12	×	40	30	22.4	2,540	2.0, 2.2, 2.7, 3.0
	τ.		1-1	² orced air ii	nto chutes				
75		-	12	8	50	30	27.9	2,540	2.0, 2.7, 3.0
76		I	13	8	40	30	24.8	2,540	2.7
							÷	1,600, 1,70(1,800, 1,900) 2.5) 2.5
								2,000, 2,100 2,200, 2,300 2,400, 2,500 7,600	2550
77	1	-	13	ø	50	36	31	2,540	2.2, 2.5, 2.7
78]	1	13	4	40	30	12.4	2,540	2.7
79	1	-	13	6	40	30	6.2	2,540	2.7
80	1	0	14	8	40	18	22.4	2.540	2.0, 2.2, 2.7, 3.0
81	1	6	14	∞	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
			Nozzi	le exit plan	e to throat d	listance ((coplanar)	-	-
82		ų	14	∞	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
			Nozzle exit	plane to th	roat distance	o: 3/4 in		-	
83	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
			Nozzle exit	plane to th	roat distance	:: 1-1/2	in.		-
84		Ó	4 1	80	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
			Nozzle exit	plane to th	roat distance	e: 2-1/4	ìn.	-	

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			Test Config	uration Ind	lex (continue	(p:			
				Ejector	flow elemen	ts		Elo 202	ditione
onfigu- ration	Nozzle identification number	Ejector identification number	Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Total temperature (°F)	Pressure
85		6	14	∞	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
			Nozzle exit	plane to the	hroat distanc	e: 3 in.	-		-
86		9	14	∞	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit plan	ne to throat dist	lance: copl:	anar; chute le	ocation:	1/2 in. do	wnstream	-
87	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit plai	ne to throat dist	tance: 3/4 i	in.; chute loc	ation: 1	/2 in. dow	nstream	
88	_	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit pl	ane to throat di	stance: 1-1	/2 in.; chute	location	i: 1/2 in. d	ownstream	
89	-	6	14	∞	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit pl	ane to throat di	stance: 2-1	/4 in.; chute	location	n: 1/2 in. d	ownstream	-
90	1	6	14	×	40	<u>2</u> 0	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit	plane to throat	distance: 3	in.: chute lo	cation:	1/2 in. dov	wnstream	_
91		6	14	ø	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit pl	ane to throat di	stance: col	olanar; chute	location	n: I in. dov	wnstream	-
92	-	6	14	8	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit p	lane to throat d	istance: 3/-	4 in.; chute le	ocation:	l in. dow	nstream	-
93		6	14	œ	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit pl	lane to throat d.	istance: 1-1	l/2 in.; chute	location	n: 1 in. do	wnstream	

Test Configuration Index (continued)

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	Pressure ratio	2.0, 2.2, 2.7, 3.0	_	2.0, 2.2, 2.7, 3.0		2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0		2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	
Ē	r low co Total temperature (°F)	2,540	nstream	2.540	stream	2,540	ownstream	2,540	wnstream	2,540	ownstream	2,540	ownstream	2,540	mstream	2,540	pstream	2,540	metream
	Blockage (%)	22.4	: î in. dow	22.4	l in. down:	22.4	l-1/2 in. de	<u>Ž</u> 2.4	-1/2 in. do	22.4	l-1/2 in. do	22.4	l-1/2 in. do	22.4	/2 in. dow	22.4	: 1/2 in. պ	22.4	n: 1/2 in
	Angle of attack (deg)	22	ocation	22	ation: 1	23	ation:	23	ation: 1-	23	ation:]	23	ation: 1	23	ion: 1-1	61	ocation	61	e locatic
w clements	Penetration (%)	40	4 in.; chute l	40	in.; chute loc	40	nar; chuíe loc	40	ance: 3/4 in.; chute loca	40	in.; chute loc	40	nce: 2-1/4 in.; chute loc	40	; chute locat	40	4 in.; chute l	40	1/2 in - chute
Ejector flo	Quantity	∞	tance: 2-1/	œ	listance: 3 i	8	nce: coplan	8		8	nce: 1-1/2 i	8		ŝ	stance: 3 in	∞	distance: 3/	8	listance: 1-
	Chute identification number	. 14	ne to throat dis	14	plane tr throat	14	to throat dista	14	ie to throat dist	14	to throat dista	14	to throat dista	14	ne to throat dis	14	lane to throat d	14	lane to throat d
	Ejector identification number	9	Nozzle cxit pla	6	Nozzle exit p	6	ozzle exit plane	6	Nozzle exit plan	. 6	ozzle exit plane	6	ozzle exit plane	6	Nozzle exit plan	6	Nozzle exit p	6	Nozzle exit p
	Nozzle identification number	_		1			Ź	*	I		Ź	1	Ź	-			-	I	
	Configu- ration	94	_	95		96		97		98	-	66	-	100	-	101		102	
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				Ejector fl	ow elements			Ē	- - (
Configu- ration	Nozzle identification number	Ejector identification number	Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Total temperature (°F)	Pressure Pressure
103	-	9	14	∞	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit pla	ne to throat di	stance: 2-1,	/4 in.; chute	location	: 1/2 in. u	pstream	-
104	I	6	14	8	40	61	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit p	lane to throat	distance: 3	in.; chute lo	cation:]	l/2 in. ups	tream	-
105	1	6	14	8	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit p	lane to throat d	listance: 1-	1/2 in.; chut	e locatio	n: l in. ur	stream	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
106	1	6	14	œ	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit p	lane to throat d	listance: 2-	1/4 in.; chute	e locatio	n: 1 in. ur	stream	
107	1	6	, 14	∞	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit]	plane to throat	distance: 3	l in.; chute lo	cation:	l in. upstr	cam	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
108	1	6]4	.∞	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit plar	ne to throat dis	tance: 1-1/	2 in.; chute l	ocation:	1-1/2 in.	upstream	-
109	-	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit plar	ne to throat dis	tance: 2-1/	4 in.; chute l	ocation:	1-1/2 in.	upstream	
110	1	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit pl	ane to throat d	listance: 3 i	in.; chute loc	ation: 1	-1/2 upstr	cam	
111	1	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
		Nozzle exit pla	ne to throat dis	tance: 2-1	/4 in.; chute	location	: 2 in. up	stream	-

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	1						- 1	······	1		1	+	I	1					
-	Pressure	2.0, 2.2, 2.1, 3.0		2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0		2.0, 2.7, 2.7, 3.0	1	2.0, 2.2, 2.7, 3.0	-	2.0, 2.1, 2.7, 3.0		2.0, 2.2, 2.7, 3 0	-	2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	
Elo 200	Total temperature (°F)	2,540	cant	2,540	nstream	2,540	stream	2,540	nstream	2,540	nstream	2,540	ıstream	2,540	-	7,540		2,540	
-	Blockage (%)	22.4	2 in. upstr	22.4	2 in. dow	22.4	2 in. down	22.4	: 2 in. dow	22.4	: 2 in. dow	22.4	2 in. down	22.4	-	22.4	-	22.4	
	Angle of attack (deg)	13	cation:	24	ocation	24	cation:	24	location	24	ocation	24	ocation:	19		19		18	
w elements	Penetration (%)	40	in.; chute lo	40	anar; chute l	40	ir.; chute lo	40	2 in.; chute	40	4 in.; chute l	40	in.; chute lo	40	hard-lined	40	hard-lined	40	hard-lined
Ejector flo	Quantity	∞	distance: 3	∞	tance: copl	8	stance: 3/4	8	stance: 1-1/	∞	tance: 2-1/	8	distance: 3	· ∞	jector wall	∞	jector wall	8	ijector wall
	Chute identification number	14	plane to throat	14	ne to throat dis	14	ane to throat di	<u>1</u> 4	ine to throat dis	14	ne to throat dis	14	plane to throat	14		14	щ	15	ц
	Ejector identification number	م	Nozzle cxit	6	Nozzle exit pla	6	Nozzle exit pl	6	Nozzle exit pla	6	Nozzle exit pla	9	Nozzle exit	8		∞	:	5	
	Nozzle identification number	_		1		1		Ī				1	:	-	-	4		-	
	Configu- ration	112		113		114	-	115		116	-	117		118		119	~	1'20	

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	nditions	> Pressure ratio	2.0, 2.2, 2.7, 3.0		2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	2.0, 2.2, 2.7, 3.0		2.0, 2.2, 2.7, 3.0		2.0, 2.2, 2.7, 3.0	- - - -	2.0, 2.2, 2.7, 3.0		2.0, 2.2, 2.7, 3.0	-	2.0, 2.2, 2.7, 3.0	
	Flow co	Total temperature (P)	2,540	و معمد المحمد الله المحمد	2,540		2,540	2,540		2,540		2,540		2,540		2,540	-	2,540	
		Blockage (%)	22.4	on ejector	22.4		22.4	22.4		22.4		22.4	jector	22.4		11.2	o-lobes	16.8	
(ts Analo	n attack (deg)	19	xtension	19	-	18	19	cictor	19		19	ision on e	19		19	vith nozzle	26	
	ow clemen	Penetration (%)	40	cent-lined e	40	nard-lined	40	40	ension on e	40	hard-lined	40	rgent exter	40	hard-lincd	40	es in line w	60	
	ljector 110	Quantity	∞	ined, diverg	∞	jector wall l	8	8	nt-lined exte	∞	jector wall l	ø	-lined, diver	8	jector wall]	4	-lined, chute	4	
		Chute identification number	15	ctor wall hard-l	'I 5	ш	16	16	Diverge	16	ш	16	jector wall hard	16	ш	16	ector wall hard	16	
	_	Ejector identification number	ø	Eje	8		.	8		∞.		×	Щ.	8		8	1 1 1 1	ΩΩ	
		Nozzle identification number	-					I		l		_		4		6		6	
		Configu- ration	121.		122		123	124		125	_	126		127		128		129	

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Test Configuration Index (continued)

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	-			Ejector f	low element	S		ī	
	Nozzle	Riector	Chute			Angle	-	Flow col	nditions
Configu- ration	identification number	identification	identification	Quantity	Penetration (%)	attack (deg)	Blockage (%)	temperature (°F)	Pressure ratio
									-
130	7	В	17	8	30	14	26.1	2.540	2.2, 3.0
131	7	В	17	×	40	18	34.8	2,540	2.2, 3.0
132	7	U	18	69 69	20	V/N	24.8	2,540	2.2, 3.0
133	7	U	18	8	50	N/A	62.1	2,540	2.2, 3.0
134	1	0	19	8	40	26	24.8	2,540	2.2, 3.0
135	1	4	19	×	40.	25	24.8	2,540	2.0, 2.2, 2.7, 3.0
136		6	19	ŵ	40	26	24.8	2,540	2.0, 2.2, 2.7, 3.0
137	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
138	-	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
		-	Chute lo	cation: 1/2	2 in. downsti	ream		1	
139	1	ō	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute	location: 1	in. downstre	eam		-	-
140	1	0	20	8	40	30	22.4	2.540	2.7, 3.0, 3.3
-		×	Chute loc	ation: 1-1/	2 in. downst	tream	-	- - - - - - - - - - - - - - - - - - -	
141	Ļ	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute	location: 2	in. downstr	cam	- -		
142	1	0	20	× ×	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute loc	ation: 2-1/	2 in. downst	tream		4 - -	-
143	1	0	50	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute I	ocation: 3	in. downstr	eam			

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1		-					-		غبيه	<u> </u>		·		
	o. and it is an	collations	Pressure ratio	2.7, 3.0, 3.3		2.7, 3.0, 3.3	`	2.0, 2.2, 2.7, 3.0, 3.3	2.0, 2.2, 2.7, 3.0, 3.3	2.0. 2. 2. 2. 7. 3.0. 3.3	2.0, 2.2, 2.7, 3.0, 3.3	2.0, 2.2, 2.7, 3.0, 3.3	20:2.2.7 3.0.33	2.0, 2.2, 2.7, 3.0, 3.3
	Flow	MOLT	Total temperature (F)	4 2,540 2.		2,540		2.540	2,540	2,540	2.540	2,540	2.540	2,54
		-	Blockage (%)	<u>22.4</u>		22.4		22.5	22.5	22.5	22.5	22.5	22.5	22.5
	S	Anole	of attack (deg)	30	fream	30	cam	30	30	30	30	30	30	30
	low-element		Penetration (%)	40	2 in. downsi	40	in. downstr	40	50	60	70	80	40	40
	Ejector fl		Quantity	2 	cation: 3-1/	∞	location: 4	8	8	8	ø	8	8	∞
			Chute identification number	20	Chute lo	20	Chute	21	22	23	24	25	32	32
	 		Ejector identification number	0	-	Q	_	Ð	Ċ	U	ט	ი	Ⴑ	Н
			Nozzle identification number]	1	I		1	1	
			Configu- ration	144		145	-	146	147	148	149	150	151	152

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				Ē	ector flow	elements		Flow condi	tions
				Angle		-	_	-	-
; ;	Nozzle	Ejector	Chute	of	Chute	Chute		Total	-
Configu- ration	lidentification number	identification	identification number	attack (deg)	length (in.)	location (in.)	Ejector slots	t. Inperature	Pressure ratio
153	1	6	Special	11.7	4.5	1-1/2 upstream	Open	2,540	3.0
154	I	6	Special	11.7	4.5	1-1/2 upstream	Closed	2,540	3.0
155	I	6	Special	14.1	4.5	At throat	Closed	2,540	3.0
156	1	6	Special	14.1	4.5	At throat	Open	2,540	3.0
157	-	6	Special	16.5	4.5	1-1/2 downstream	Closed	2,540	3.0
158	1	6	Special	16.5	4.5	1-1/2 downstream	Open	2,540	3.0
159		Ŷ,	Special	18.7	4.0	1-1/2 downstream	Closed	2,540	3.0
160	<u>1</u>	6	Special	18.7	4.0	1-1/2 downstream	Open	2,540	3.0
191	1	6	Special	15.9	4.0	At throat	Closed	2,540	3.0
162		6	Special	15.9	4.0	At throat	Open	2,540	3.0
163	1	6	Special	13.2	4.0	1-1/2 upstream	Closed	2,540	3.0
164	1	Q	Special	13.2	4.0	1-1/2 upstream	Open	2,540	3:0
165	1	6	Special	15.1	3.5	1-1/2 upstream	Closed	2,540	3:0
166	I	6	Special	15.1	3.5	1-1/2 upstream	Open	2,540	3.0
167	1	6	Special	18.3	3.5	At throat	Closed	2,540	3.0
168	-ī	6	Special	18.3	3.5	At throat	Open	2,540	3.0
169	1	6	Special	21.5	3:5	1-1/2 downstream	Closed	2,540	3.0
170	-	6	Special	21.5	3.5	I-1/2 downstream	Open	2,540	3.0
171	1	6	Special	25.3	3.0	1-1/2 downstream	Closed	2,540	3.0
1.72	1	Ģ	Special	25.3	3.0	1-1/2 downstream	Open	2,540	3.0
173	÷	9	Special	21.5	3.0	At throat	Closed	2,540	3.0
1 /4	1	6	Special	21.5	3.0	At throat	Open	2,540	3.0
175	1	6	Special	17.1	3.0	1-1/2 upstream	Closed	2,540	3.0

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					Ejector flov	v elements		Elow cond	tiona
				Angle		9			(TOTIS
Configu- ration	Nozzle identification number	Ejector identification number	Chute identification number	attack (deg)	Chute length (in.)	Chute location (in.)	Ejector slots	Total temperature (F)	Pressure ratio
176	1	و	Special	17.7	3.0	1-1/2 upstream	Open	2,540	3.0
. 177	i	9	Special	21.4	2.5	1-1/2 upstream	Closed	2,540	3.0
178		9	Special	21.4	2.5	1-1/2 upstream	Open	2,540	3.0
179	1	6	Special	26.0	2.5	At throat	Closed	2,540	3.0
180	I	9	Special	26.0	2.5	At throat	Open	2,540	3.0
181	I	9	Special	30.1	2.5	1-1/2 downstream	Closed	2,540	3.0
182	I	6	Special	30.1	2.5	I-1/2 downstream	Open	2,540	3.0
183	1	9	Special	39.8	2.0	1-1/2 downstream	Closed	2,540	3.0
184	ľ	9	Special	39.8	2.0	1-1/2 downstream	Open	2,540	3.0
185	H	9	Special	33.3	2.0	At throat	Closed	2,540	3.0
186	-1	6	Special	33.3	2.0	At throat	Open	2,540	3.0
187	-	6	Special	27.1	2.0	1-1/2 upstream	Closed	2,540	3.0
188	1	6	Special	27.1	2.0	1-1/2 upstream	Open	2,540	3.0
189	1	6	Special	37.4	1.5	1-1/2 upstream	Closed	2,540	3.0
190	1	6	Special	37.4	1.5	1-1/2 upstream	Open	2 540	3.0
191	1	6	Special	47.0	1.5	At throat	Closed	2,540	3.0
192	1	6	Special	47.0	1.5	At throat	Open	2,540	3.0
193	1	Q	Special	58.5	1.5	1-1/2 downstream	Closed	2,540	3.0
194	1	6	Special	58.5	1.5	1-1/2 downstream	Closed	2,540	3.0

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	-	Fiector flow e	lements			-
c	-		Anole	-	How condition	Ions
or ation er	Quantity	Penetration (%)	of attack (deg)	Blockage (%)	Total temperature (F)	Pressure ratio
4-2	Q	50	24	25	1,140,1,640,2,040 1,670,2,090 2;340	2.0 3.0 2.7, 3.0, 3.2
4-2	∞	50 Flat chute:	24 s with sides	33	2,340	2.7, 3.0, 3.2
N-2	9	50	24	25	1,140 2.090	3.0 3.5
		Triangula	ar chutes			-
N-2	8	50	24	33	2,340	2.7, 3.0, 3.2
		Triangula	ir chutes			

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Configuration	Nozzle identification number	Ejector identification number	Total temperature (°F)	Pressure ratio
199		Ι	2,540	2:3, 2.5, 2.7
200	1	0	2,540	2.0, 2.3, 2.7, 3.0
201	1	4	2,540	2.0, 2.3, 2.7, 3.0, 3.3
202	1	6	2,540	2.0, 2.2, 2.7, 3.0
203	-	8 Ejector wall hard-lined	2,540	2.0, 2.2, 2.7, 3.0
204	-	8 Divergent-lined extension on ejector	2,540	2.0, 2.2, 2.7, 3.0
205	I Ejector w	8 vall hard-lined; divergent-lined extension c	2,540 on ejector	2.0, 2.2, 2.7, 3.0
206	-	6 Ejector wall hard-lined; blow-in doors	2,540	2.0, 2.2, 2.7, 3.0
207	1	Э	2,540	2.7, 3.0, 3.3
208	1	Ċ	2,540	2.0, 2.2, 2.7, 3.0, 3.3
209	3	6	2,540	2.0, 2.7, 3.0
210	4 Ejector wall hard-lined	5	2,540	2.0, 2.7, 3.0
211	4	6	2,540	2.0, 2.2, 2.7, 3.0
212	4 Ejector wall hard-lined		2,540	2.0, 2.2, 2.7, 3.0
213	6 Ejector wall hard-lined	8	2,540	2.0, 2.2, 2.7, 3.0
214	1	8	2,340	2.0, 2.2, 2.7, 3.0

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A.3 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1966

Facility: North end of Boeing Field, Seattle YJ75-P-3 afterburning turbojet engine

Acoustic Data Reference: (

- (1) Coordination sheet 733-EDAS-60, "Status Report-J75 Suppressor Test Program," P B. Tate, September 9, 1966
- (2) Coordination sheet 733-EDAS-65, "Acoustic Data Analysis-J75 Suppressor Tests," R. B. Tate and J. Zurcher, November 21, 1966
- W. Klang, Engine Noise Suppression Program-SST, T6A-10341-3, The Boeing Company, October 1966

Performance Data Reference: (1) Ibid-

(2) Boeing document D6A-11065-1, "Exhaust System Performance Incorporating the Chuted Ejector Noise Suppressor for the 2707 (SST) Prototype Airplane," September, 1967

Performance Data Reference: Ibid

A.3.1 Test Hardware

A.3.1.1 Nozzles

Designation	Description
RC	Round convergent nozzle with conical center plug; $A_T = 527$ in. ²
16-pt star	16-point star-shaped convergent nozzle, 12% penetration of the primary flow; $A_T = 538 \text{ in.}^2$ Lab dwg SK11-029347
4 lobes	Conical section fitted with four lobes with parallel sides and rounded ex remities. Lobes positioned 90° apart. The ratio of the outer diam- eter of the lobes to the diameter of the conical section = 2:1, providing 50% lobe penetration of the flow; $A_T = 538$ in. ² Lab dwg SK11-036760
RC (AB)	Round convergent nozzle; $D_T = 32.4$ in., $A_T = 823$ in. ² Reference nozzle used for afterburning engine conditions. Lab dwg SK11-036762
4 lobes (AB)	Similar to four-lobe nozzle described above except $A_T = 823 \text{ in.}^2$ Used for afterburning engine conditions. Lab dwg SK11-036765

A.3.1.2 Ejectors

Sec. 1

Designation	Description
	Note: Ejector configurations tested had chutes 2.6 and 3.6 in. wide or scoops 2.6 in. wide. Jet penetration by the chutes or scoops varied between 30% and 50%.
1	Bellmouth entrance followed by a divergent conical section. The ratio of the ejector throat diameter to the exit diameter of the primary nozzle, RC. was 1.2:1, and the ratio of the ejector exit diameter to that of the throat was 1.1:1. Ejector positioned axially so its throat was 5 in. aft of primary nozzle exit plane. This ejector was used for non after- burning engine settings. Lab dwg SK11-036761.
2	A scaled-up version of ejector 1. It was used with the larger area nozzles for afterburning engine conditions. Lab dwg SK11-036764.

A.3.2 Test Configuration Index

			Chute	es	Scoo	ps	
Configuration	Nozzle	Ejector	Quantity	Width (in.)	Quant_ty	Width (in.)	Flow penetration (%)
1	RC	No					
2	4 lobes	No				-	
3	16-pt star	No					
4	16-pt star	Yes					
5	16-pt star	Yes			. 8	2.6	30 .
6	16-pt star	Yes			8	2.6	50
7	Тб-pt star	Yes			4	2.6	50
8	16-pt star	Yes	8	2.6			50
9	!6-pt star	Yes	8	2.6			30
10	16-pt star	Yes	4	2.6			50
11	RC	Yes					
12	RC	Yes					
13	RC	Yes			8	- 2.6	30 [.]
14A	4 lobes (AB)	No		_			

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_		-	Quantity		Scoops		
Configuration	Nozzle	Ejector	Quantity	Width (in.)	Chutes	Width (in.)	Flow penetration (%)
15A	RC (AB)	No ⁻				-	•
16A	RC (AB)-	Yes	-	-	-		-
17A	RC (AB)	Yes	8	3.6			30
18A	RC (AB)	Yes	8	3.6	-		44
19A	RC (AB)	Yes	-	_	- 8	2.6	37

A.3.3 Primary Flow Test Conditions

A.3.3.1 Configurations 1 Through 13

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Pressure	Total	Jet
ratio	temperature	velocity
(P _{T7} /P _{TAMB})	(T _{T7})	(ideal)
2.5	1,020° F	2,050 fps

A.3.3.2 Configurations 14A Through 19A

Pressure	Total	Jet
ratio	temperature	velocity
(P _{T10} /P _{TAMB})	(T _{T10})	(ideal)
2.2*	2,880°F*	2,900 fps

*Values calculated from measured engine parameters.

A.4 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1967 (PHASE 1)

Facility: Boardman, Oregon (Pad B-1)

YJ75-P-3 afterburning turbojet engine

Acoustic Data Reference: Boeing Test Report T6A10493-2, "Acoustic and Performance Evaluation of a B-2707 Jet Noise Suppressor (SST)," R. D. Cuthbertson and J. V. O'Keefe, August 1967

Performance Data Reference: (1) Ibid-

 (2) Boeing Test Report T6A10493-1, "Test Report for J-75 Turbojet Engine Noise Suppression Program, EWA 321599," W. Klang, June 1967

A.4.1 Test Hardware

A.4.1.1 Nozzles

2. O. S. M. W.

Designation	Description
RC (AB)	Round convergent nozzle; $D_T = 32.4$ in., $A_T = 823$ in. ²
4 lobes (AB)	Conical section fitted with four lobes with parallel sides and rounded tops. Lobes positioned 90° apart. The ratio of the outer diameter of the lobes to the diameter of the conical section was 2:1, providing 50% lobe penetration of the flow; $A_T = 823$ in. ²

A.4.1.2 Ejectors

Designation	Description				
	Note: Ejector configurations tested had chutes 2.6, 3.6, and 4.1 in. wide or scoops 2.6 in. wide to intercept the jet. Flow penetra- tions tested were 30%, 40%, and 50%.				
1	Round ejector; $D_I = 51.7$ in., $D_T = 39.2$ in., $D_E = 43.1$ in., overall length = 61.2 in. (see fig. A-1)				



DT = Ejector throat diameter

- DE = Ejector exit diameter
- D = Ejector inlet diameter
- = Unblocked jet flow diameter D_{C} PEN, $= 100\% \times (D_P - D_C)/D_P$
- RC(AB) = Round convergent-afterburner

- = Overall ejector length LE
- Lp = Distance, nozzle to exit
- ۰LC = Chute length
- Wc = Chute width: 2.6, 3.6, 4.1 in.
- = Scoop length LS
- Ws = Scoop width: 2.6 in.

FIGURE A-1.-RC(AB) NOZZLE-EJECTOR WITH CHUTES OR SCOOPS (CONFIGURATION FOR YJ75 FULL-SCALE TEST)

		-	Chutes		Scoo	ps		
Configuration	Primary nozzle	Ejec≁∋r	Quantity	Width (in.)	Quantity	Width (in.)	Flow penetration (%)	
_1	RC (AB)	No		-				
2	RC (AB)	Yes	-		-	-	-	
3	RC (AB)	Yes	8 -	2.6			30	
4	RC (AB)	Yes	· 8 ·	2:6			40	
5	RC (AB)	Yes	8.	2.6-			<u>5</u> 0	
6	RC (AB)	Yes	. 8	3.6	-		30	
7	RC (A)	Yes	8 -	3.6		-	40	
8	RC (AB)	Yes	8	3.6			50	
9	RC (AB)	Yes	8	4.1			30	
16	RC (AB)	Yes	8	4.1			40	
11	RC (AB)	Yes	8	4.1			50	
12	RC (AB)	Yes			8	2.6	30	
13	RC (AB)	Yes			8	2.6	40	
14	RC (AB)	Yes			8	2.6	50	
15	RC (AB)	Yes	4	2.6			50	
16	RC (AB)	Yes	4	2.6			40	
17	4 lobes (AB)	No						
	1			l I	1	1		

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A.4.2 Test Configuration Index

A.4.3 Primary Flow Test Conditions (Each Configuration)

Pressure ratio	Total temperature (°F)	Ideal jet velocity (fps)
1.9	2,910	2,640
2.0	3,080	2,800
2.2	3,190	3,020

A.5 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1967 (PHASE 2)

Facility: Boardman, Oregon (Pad B-1)

J-75 afterburning turbojet engine

Acoustic Data Reference: Boeing Test Report T6A11034-1, "Large Scale Jet Noise Suppression Tests-Acoustic and Performance Evaluation (Series No. 1)," G. W. Bielak, et al., March 1968

Performance Data Reference: Ibid

A.5.1 Test Hardware

A.5.1.1 Nozzles

Designation	Description
RC (AB)	Round convergent nozzle; $D_T = 32.4$ in., $A_T = 823$ in. ² (see fig. A-2)
16-pt star (AB)	16-point star-shaped convergent nozzle, 12% penetration of the primary flow; $A_T = 823$ in. ² (see fig. A-2)
4 lobes (AB)	Conical section fitted with four lobes with parallel sides and rounded extremities. Lobes positioned 90° apart. The ratio of the outer diameter of the lobes to the diameter of the conical section was 2:1, providing 50% lobe penetration of the primary flow; $A_T = 823$ in. ² (see fig. A-2)

A.5.1.2 Ejectors

Designation	Description
1	Note: Ejector configurations tested had flat chutes with sides, conical chutes, box chutes, and wing chutes. Chute lengths were 17.3 and 17.8 in. Chute flow penetration was 40%. (See figs. A-3 and A-4.)
2	Round (cylindrical) ejector; $D_{I} = 66.1$ in., $D_{T} = D_{E} = 40.2$ in., overall length = 69.3 in. (see fig. A-5)
3	Same as ejector 2 except $D_T = 48.6$ in.

Round convergent nozzle: (ref. dwg SK11-036762)

*



Dp = 32.4 (ref) $D_{P1}/D_{P} = 1.07$

 $D_{A}/D_{P} = 1.12$

 $L/D_{P} = 0.530$

16-pt star nozzle-12% PEN. (ref. dwg SK11-040192):





Four-lobe nozzle (ref. dwg SK11-036765):



FIGURE A-2.—PRIMARY NOZZLES FOR YJ75 WITH AFTERBURNER (BOARDMAN TESTS)



Blow-in door simulator (ref. dwg SK11-040206):

DP	T ₁ /D _P	T ₂ /D _P	Ť ₃ /υ _Ρ	ι ₁ /D _P	L ₂ /D _P	W ₁ /D _P	D ₁ /D _P	D ₂ /D _P
32.4	0.499	0.431	0.356	0.556	0.444	0.273	1.16	2.16

Divergent ejector extension (ref. dwg SK 11-040205):

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FIGURE A-3.—ATTACHMENTS FOR 1.50 D_E/D_P CYLINDRICAL EJECTOR (BOARDMAN TESTS)

Chute (typ eight places) RC(AB) s_c nozzle ₽Ę D_P ĉ -ଜୁ DC Ţ -D D - Ejector Secondary airflow (typ around)



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Dp	D _T /D _P	D _E /D _T	D _I /D _P	D _C /D _P	L _T /D _P	L _E /D _P	L _P /D _P	L _C /D _P	∙w _C /D _P	S _C /D _P
32.4	1.21	1.10	1.60	0.506 0.600 0.700	1.26	. 1.89	1.70	0.543	0.111 0.127	0.0810

ΰ _Ρ	Ξ	Diameter of RC(AB) nozzle
DT	= [Ejector throat diameter
DE	=	Ejector exit diameter
DI	=	Ejector inlet diameter
D _C	=	Unblocked jet flow diameter
LT	=	Distance, throat to exit
LE	=	Overall ejector length
RC(AB)	Ħ	Round convergent, afterburner
Lp	Ξ	Distance, nozzle to exit

- L_C = Chute length
- $W_C = Chute width$
- S_C = Chute-inlet step
- $\mathbf{\alpha} = \text{Chute angle of attack}$ = 19.0°, 24.8°, 30.5°
- PEN. = $100\% (D_P D_C)/D_P$ = 30%, 40%, 50%

FIGURE A-4.—RC(AB) NOZZLE—EJECTOR WITH CHUTES (CONFIGURATION FOR YJ75 FULL SCALE TEST, DIVERGENT EJECTOR STUDY)



	S _C ∕D _P	™ _C /D _P	₩ _C /D _P	L _C /D _P	L _P /D _P	L _E /D _P	L _T /D _P	D _I /D _P	D _E /D _T	D _T /D _P	DP
\square	0.0398	0.0555	0.111		_1.96	2.14	1.58	2.04	1.00	1.24	32.4
2	0.199	0.0555	0.111		1.96	2.14	1.58	2.04	1.00	1.50	32.4

- D_p = Diameter of RC(AB) nozzle
- D_T = Ejector throat diameter
- D_E = Ejector exit diameter
- D_I = Ejector inlet diameter
- D_C = Unblocked jet flow diameter
- PEN. = $100\% (D_P \cdot D_C)/D_P \approx 40.0\%$
- L_{T} = Distance, throat to exit

E

RC(AB) = Round convergent, afterburner

- L_E = Overall ejector length
- L_P = Distance, nozzle to exit
- L_C = Chute length
- W_{C} = Chute width
- T_{C} = Chute thickness
- S_C = Chute inlet step
- α = Chute angle of attack
 - = 25.5°, 15.6°

FIGURE A-5.—RC(AB) NOZZLE—EJECTOR WITH CHUTES (CONFIGURATION FOR YF75 FULL-SCALE TEST, CYLINDRICAL EJECTOR STUDY)

		Eiector		Chutes ^a				
	Primary	identification			Length	'n h		
Configuration	nozzle	number	Туре	Quantity	(in.)	Remarks		
1 -	RC (AB)	2	FWS	-8	17.3			
2	RC (AB)	2	Cone	8	17.3			
3	RC (AB)-	2	Wing	8	27 . 8			
4	RC (AB)	2	Box	8	27.8	-		
5	RC (AB)	2	FWS	8	27,8			
6	RC (AB)	3	Wing	-8	27.8			
7	RC (AB)	3-	Box ·	-8	27.8			
8	RC (AB)	3	FWS	8	27.8			
9	RC (AB)	2	FWS	8	17.3	$\alpha = 25.5^{\circ}$		
10	RC (AB)	2	FWS	8	27.8	$\alpha = 15.6^{\circ}$		
11	RC (AB)	3	FWS	8	17.3	$\alpha = 25.5^{\circ}$		
12	RC (AB)	3	FWS	8	27.8	$\alpha = 15.6^{\circ}$		
13	RC (AB)	3	FWS	5	17.3			
14	RC (AB)	3	FWS	7	17.3			
15	RC ⁻ (AB)	3	FWS	8	17.3			
16	RC (AB)	1	Cone	8	17.3			
17	RC (AB)	1	FWS	8	27.8			
18	RC (AB)	3	None			2-D _P extension		
19	16-pt star (AB)	3	None			2-D _P extension		
20	RC (AB)	3	None			-		
21	16-pt star	3	FWS	8	17.3	2-D _P extension		
22	RC (AB)	3	None			BID added		
23	RC (AB)	3	FWS	8	17.3	BID added		
24	RC (ÅB)	3	FWS	8	27.8	BID added		
25	RC (AB)	3	FWS	8	27.8	Water injection		
26	16-pt star	3	FWS	8	17.3	2-D _P extension		
27	RC (AB)	3	FWS	8	17.3	Lined ejector		
28	RC (AB)	3	FWS	8	17.3	Lined, 2-D _P ext.		
29	4 lobes (AB)	-				_		
30	4 lobes (AB)	3	None					
31	4 lobes (AB)	3	FWS	4	17.3			
32	4 lobes (AB)	3	FWS	4	17.3	60% penetration		
33	16-pt_star (AB)							
1) All chutes were 3.6 in wide $b = \alpha$ = chute angle of attack								

A.5.2 Test Configuration Index

^a 1) All chutes were 3.6 in. wide.
2) Chute penetration of the jet was 40% unless otherwise noted.

 α = chute angle of attack FWS = flat chute with sides 2-Dp extension = overall ejector length equal to 134 in. BID = blow-in-door simulation added to ejector

Pressure ratio (P _{T10} /P _{TAMB})	Total temperature (°F) (T _{T10})	Ideal jet velocity (fps)
1.84	2,900	2,570
2.02	3,100	2,800
2.20	3,200	3,020

A.5.3 Primary Flow Test Conditions (Each Configuration)

A.6 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1967 (PHASE 3)

- Facility: Boardman, Oregon (Pad B-1) YJ-75 afterburning turbojet engine
- Acoustic Data Reference: Boeing Test Report T6A11034-2, "Large Scale Jet Noise Suppression Tests—Acoustic and Performance Evaluation (Series No. 2)," G. W. Bielak, et al., May 1968

Performance Data Reference: Ibid

A.6.1 Test Hardware

A.6.1.1 Nozzles

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Designation	Description
RC (AB)	Round convergent nozzle; $D_T = 32.4$ in., $A_T = 823$ in. ²

A.6.1.2 Ejectors

Designation	Description
	Note: Ejector configurations tested had 3.6-in. wide flat chutes with sides (FWS) or water-injection-type chutes (WIT). Chute lengths were 13.0, 17.3, 20.25, 21.0, and 27.8 in. Blow-in-door hard-ware simulation was added to both ejectors for some tests.
E1	Contoured ejector with the diameter of the throat equal to the diameter of the exit. Ejector entrance diameter $(D_I) = 66.1$ in., throat diameter $(D_T) = 40.2$.n., exit diameter $(D_E) = 40.2$ in. (see fig. A-6)
E2	Contoured ejector with the diameter of the exit 1.15 times larger than the throat ($D_E = 1.15 D_T$); $D_I = 66.1 \text{ in.}$, $D_T = 40.2 \text{ in.}$, $D_E = 46.7 \text{ in.}$ (see fig. A-7)



L _T /D _P	L _M /D _P	L _E /D _P	L _H /D _P	L _C /D _P	T _C /D _P	W _C /D _P	S _C /D _P	x
0.47	0.75	1.89	2.07	$\bigwedge^{}$	0.0555	0.111	0.0772	

FIGURE A-6.—RC(A B) NOZZLE—E1 EJECTOR CONFIGURATION FOR YJ75 FULL-SCALE TEST, CHUTE AT THROAT

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Configuration	Primary nozzle	Ejector	Туре	Quantity	Length (in.)	Penetra- tion (%)	Remarks ^a
1	RC (AB)	E1	FWS	8	13	20	<i>α</i> = 22°
2	RC (AB)	E1	FWS	8	13	38	α = 36°
3	RC (AB)	E1	FWS	8	13	38	BID_added
4	RC (AB)	E1	FŴS	8	17.3	- 35	α = 24°
5 -	RC (AB)	Ë1-	FWS	8	17.3	35	BID added
·6·	RC (AB)	E2	FWS	8	17.3	35 [±]	BID added
7	RC (AB)	E1 ⁻	FWS	8	21.0	35	-α = 20°
8	RC (AB)	E1	WIT	8	27.8	37	$\alpha = 16^{\circ}$
9.	RC (AB)	E2	WIT	8	27.8	37	BID added
10	RC (AB)	E1	FWS	8	27.8	37	α=16°
JIp	RC (AB)	E2	FWS	8	20.2	41	$\alpha = 30^{\circ}$ and BID
12b	RC (AB)	E2	FWS	8	20.2	38	$\alpha = 38^{\circ}$ and BID
13p	RC (AB)	E2	FWS	8	20.2	30	$\alpha = 29^{\circ}$ and BID
14 ^{b.}	RC (AB)	E2	FWS	8	20.2	40	$\alpha = 35^{\circ}$ and BID
15 ^b	RC (AB)	E2	FWS	6	20.2	40	$\alpha = 35^{\circ}$ and BID
16	RC (AB)						Reference

A.6.2 Test Configuration Index

а α = chute angle of attack FWS = flat chute with sides

BID = blow-in-door simulation hardware WIT = water-injection-type chutes

^b Chutes installed forward of ejector throat. All other runs with chutes at ejector throat.

A.6.3 Primary Flow Test Conditions*

Pressure ratio (P _{T10} /P _{TAMB})	Total temperature (°F) (T _{T10})	Ideal jet velocity (fps)
1.93	3,010	2,700
2.11	3,165	2,900
2.28	3,220	3,100

*Each configuration tested at the three sets of conditions.

APPENDIX B SST 12-20 PNdB SUPPRESSION PROGRAM

This appendix lists most noise suppression hardware tested during the SST high-noisesuppression (12-20 PNdB) program. The test configurations and upstream flow conditions are included as well as available test references.

B.1 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1967

Facility: Boeing Annex D, Seattle

Acoustic Data Reference: Boeing Test Report T6A11488-1, "SST High Jet Noise Suppression Program Acoustic Results, Boeing Annex D, Scale Model Nozzle Facility (1967)," June 1969

- Performance Data Reference: (1) Boeing Test Report T6A10814-1, "Thrust Performance of a Pure Annulus and Multi-Tube Annular Sound Suppression Concept"
 - (2) Boeing Document D6A-12118-1 (Informal), "Multi-Spoke Suppressor Nozzle Characteristics-Volume I-Parametric Thrust Performance"

B.1.1 Test Hardware

B.1.1.1 Nozzles

Designation	Description
C-6	Round convergent nozzle with short conical plug equivalent to 1:8 scale JT3C-6 turbojet engine nozzle; $D_T = 3.10$ in., $A_T = 7.07$ in. ²
PW P1-S1	Round convergent nozzle; $D_T = 3.8$ in., $A_T = 11.34$ in. ²
PW-S1	Round convergent secondary flow nozzle; $D_T = 6.08$ in., $A_T = 29.2$ in. ²
HM-J75	Round convergent nozzle; $D_T = 4.1$ in., $A_T = 13.2$ in. ²
HM-P-0	Convergent annular nozzle; AR = 1.6 $A_T = 6.472$ in. ²
HM-P-1	Plain annular nozzle with -45° exit cant angle (inward); AR = 3.5, $A_T = 7.07$ in. ²
НМ-Р-2	Plain annular nozzle with -30° exit cant angle (inward); AR = 3.5, $A_T = 7.07$ in. ²
НМ-Р-З	Plain annular nozzle with -15° exit cant angle (inward); AR = 3.5, $A_{T} = 7.07$ in. ²
HM-P-4	Plain annular nozzle with 0° exit cant angle (coplanar); AR = 3.5, $A_T = 7.07 \text{ in.}^2$

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Designation	Description
HM-P-5	Plain annular nozzle with 15° exit cant angle (outward); AR = 3.5, $A_T = 7.07 \text{ in.}^2$
НМ-Р-б	225-tube annular array with 15° exit cant angle (inward); AR = 7.4, $A_T = 7.07$ in. ² , 0-in. tube length
HM-P-7	225-tube annular array with -15 ⁶ exit cant angle (inward); AR = 7.4, A _T = 7.07 in. ² , 0.75-in. tube length
НМ-Р-8	225-tube annular array with -15° exit cant angle (inward); AR = 7.4, A _T = 7.07 in. ² , 1.5-in. tube length
HM-P-9	225-tube annular array with -15° exit cant angle
HM-AP-6	Six radial arms with 20 parallel slots per arm; AR = 8.28, $A_T = 13.2$ in. ² , 0 exit cant angle
HM-AP-9	24 spokes with 95% flow penetration; AR = 1.9, $A_T = 13.2$ in. ² , 17.5 exit cant angle (outward)
HM-AP-12	Plain annular nozzle with 0° exit cant angle; AR = 4.0, $A_T = 13.2 \text{ in.}^2$
HM-AP-15	Six spokes with 50% flow penetration; $AR = 1.6$, $A_T = 13.2$ in. ²
HM-AP-16	37 equally spaced RC tubes, hexagonal array; AR = 3.33, $A_T = 13.2$ in. ² . 4.6-in. tube length
HM-AP-18	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 4.65, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-18a	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 8.0, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-22	12 spokes with 70% flow penetration; AR = 1.4, $A_T = 13.2$ in. ² , 17.5 exit cant angle (outward)
HM-AP-23	Seven tubes for tertiary air surrounded by round primary flow nozzle $AR = 1.8$, $A_T = 13.2$ in. ²
HM-AP-24	Five parallel slots, with 19.5 slot aspect ratio; $AR = 3.0$, $A_T = 13.2$ in. ² , 10.8-in, element length
HM-AP-28	24 spokes with 92.5% flow penetration; AR = 6.0, $A_T = 13.2$ in. ²
HM-AP-32	24 spokes with 90% flow penetration; AR = 4.0, $A_T = 13.2$ in. ²

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Designation	Description
НМ-АР-33	36 spokes with 90% flow penetration; AR = 4.0, $A_T = 13.2$ in. ²
HM-AP-37	$\overline{37}$ equally spaced RC tubes, hexagonal array; AR = 4.65, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-38	37 equally spaced RC tubes, hexagonal array; AR = 8.0, $A_{\bar{T}} = 13.2$ in. ² , 7-in. tube length
HM-AP-39	37 equality spaced RC tubes, hexagonal array; AR = 4.0, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-40	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 3.33, $A_{T} = 13.2$ in. ² , 7-in. tube length
HM-AP-41	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 4.0, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-42	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 5.2, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-43	37 equally spaced RC tubes, hexagonal array; AR = 3.33, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-44	37 equally spaced RC tubes, hexagonal array; $AR = 5.2$, $A_T = 13.2$ in. ² , 7-in. tube length
MPP 152	21 RC tubes (three sizes); AR = 2.4, $A_T = 6.48 \text{ in.}^2$
MPP 452	21-tube nozzle (10 tubes with six spoke ends); AR = 2.6. $A_T = 6.5$ in. ²
MPP 130-20	16 spokes with 70% flow penetration; AR = 2.25, $A_T = 5.8 \text{ in.}^2$, 20° exit cant angle (outward)
MAE 4A	12 spokes with conical center plug; AR = 2.9, $A_T = 6.7$ in. ²
MAE 53-18	24 spokes and conical center plug; $AR = 2.1$, $A_T = 5.9$ in. ² , 18° exit cant angle (outward)
MAE 203-3	20 spokes with 80% flow penetration; AR = 2.2, $A_T = 3.03 \text{ in.}^2$

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B.1.1.2 Ejectors

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Designation	Description
HM-AP-22	Round cross section with inlet diameter $(D_I) = 7.5$ in., throat diameter $(D_T) = 4.73$ in., exit diameter $(D_E) = 6.50$ in.; inlet-to-throat distance = 2.04 in., total length = 7.55 in.; 12 tapered box chutes 2.5 in. long were installed to intercept the jet within the ejector.
J75 E-9	Round cross section; $D_I = 7.3$ in., $D_{\overline{T}} = 6.35$ in., $D_{\overline{E}} = 6.35$ in., distance from inlet to throat = 2.98 in., total length = 9.1 in. Uses flat chutes with sides, 3.5 in. long and 0.5 in. wide
HM-AP-12-1	Cylindrical with bellmouth inlet; $D_T = 10.5$ in., total length = 7.05 in. Uses flat chutes with sides
HM-AP-12-2	Same as HM-AP-12-1 except D_T = 10.78 in.
HM-AP-12-3	Same as HM-AP-12-1 except $D_T = 11.39$ in.
HM-AP-12-4	Same as HM-AP-12-3 except total length = 14.1 in.
HM-AP-32	Cylindrical; $D_T = 8.96$ in., total length = 6.4 in. Lined with 1-in. fiber- glass blanket

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	Noise report reference					-
	Pressure ratio	2.07, 3.11 2.2, 2.6, 3.0 1.8, 3.2, 3.5 2.485, 1.8, 2.2 2.6, 3.0, 3.4 1.8, 2.2, 2.6 3.0, 3.4	2.7 2.7 2.4 2.4 2.4 2.4	nfiguration No. 1	1.8, 2.2, 2.6, 3.0, 3.2 1.8, 2.2, 2.6, 3.0, 3.2 1.8, 2.2, 2.6, 3.0, 3.2 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2 1.117, 1.275, 1.524, 1.892, 2.483, 3.19 1.117, 1.275, 1.524, 1.892, 2.483, 3.19 1.117, 1.275, 1.524, 1.892, 2.483, 3.19 1.117, 1.275, 1.524, 1.892, 2.483, 3.19 1.117, 1.275, 1.524, 1.892, 2.483, 3.19 1.117, 1.275, 1.524, 1.892, 2.483, 3.19 1.117, 1.275, 1.524, 1.892, 2.483, 3.19 1.117, 1.275, 1.524, 1.892, 2.483, 3.19	1 (1, () () () (] (]
	Total temperature (°F)	60 1,100 1,100 1,000 1,000 1,500	500 500 1,488 1,920 2,200	Same as Co	2,000 1,000 1,000 1,500 2,500 2,500 800 2,600 2,600 2,600 60 60	>
	Ejector					
uguration index	Nozzle	9-0-	IS-IA MA	PW S1	HM-J75	
0.1.2 1.est COII	Configuration	-	0	ŝ) 4	-

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Noise report reference	-					-	BI	Bl	B 1	B1	Bl	Bl	BI	B 1	BI	Bľ	B2	-			B2, B3				
Pressure ratio	$\begin{array}{c} 1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2\\ 1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2 \end{array}$	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	2.07, 3.11, 2.2, 3.4	2.2, 3.4	2.2, 3.4	2.2, 3.4	2.2, 3.4	2.2, 3.4	2.07, 3.11	2.07, 3.11	2.07, 3.11	2.07, 3.11	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2
Total temperature (oF)	500 800	1,000	1,400	700	2,300	2,600	60	60	60	60	60	60	60	60	60	60	60	1,000	1,500	2,000	60	800	1,000	1,500	2,000
Ejector									-		•										-				
Nozzle	HM-J75						0-d-MH	HM-P-1	HM-P-2	HM-P-3	HM-P-4	HM-P-S	HM-P-6	HM-P-7	HM-P-8	6-a-MH	HM-AP-6				HM-AP-9				
Configuration	4 (cont.)						5	6	7	∞	6	10	11	12	13	14	15				16				

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Test Configuration Index (continued)

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Neise report eference	B4, B5, B6	B4, B6	B4, B6	B4, B6	B4, B6	B4, B6	B4, B6	B4, B6	B4, B6	B7						
	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 7.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2 ⁻	1.117, 1.275, 1.524, 1.892, 2.483,	3.19, 4.25 1.117, 1.275, 1.524, 1.892, 2.483, 2.10, 4.25	1.117, 1.275, 1.524, 1.892, 2.483, 2.10, 4.55	2.12, 4.25 1.117, 1.275, 1.524, 1.892, 2,483, 2.10, 4.55	1.117, 1.275, 1.524, 1.892, 2.483,	2.12, 4.23 1.117, 1.275, 1.524, 1.892, 2.483, 2.10, 4.55	2.19, 4.25 3.19, 4.25 3.19, 4.25
Total temperature (oF)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	60	500	800	1,000	1,400	1,700	2,000
 Ejector		HM-AP-12-3	HM-AP-12-3 with 8 chutes		HM-AP-12-3 with 8 chutes	HM-AP-12-4 with 8 chutes	HM-AP-12-3	HM-AP-12-1 with 8 chutes	HM-AP-12-2 with 8 chutes							
Nozzie	HM-AP-12	HM-AP-12	HM-AP-12	HM-AP-12 with centerbody	HM-AP-12 with centerbody	HM-AP-12 with centerbody	HM-AP-12 , with centerbody	HM-AP-12 with centerbody	HM-AP-12 with centerbody	HM-AP-15						
Configuration	17	18	19	20	21	22	23	24	25	26			,			-

	Noise report reference	B7			B8, B3		bo, by, biu			B9		B11	B11	B14		B12	B13, B14, B15	B16		B17		-
continueu	Pressure ratio	1.117, 1.275, 1.524, 1.892, 2.483,	2.12, 4.23 1.117, 1.275, 1.524, 1.892, 2.483,	3.19, 4.25 1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	1.8, 2.2, 2.6, 3.0, 3.2 1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	1.275, 1.524, 1.892, 2.483, 3.19 1.275, 1.524, 1.802, 2.483, 3.19	1.8. 2.2. 2.6, 3.0. 3.2	1.8, 2.2, 2.6, 3.0	1.8, 2.2, 2.6, 3.0, 3.2	1.8, 2.2, 2.6, 3.0, 3.2	3.0	3.0	1.8, 2.6, 3.0, 3.4 1.8, 2.6, 3.0, 3.4	1.8, 2.6, 3.0	1.8. 2.2. 2.6. 3.0	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	2.0, 3.0, 3.4
A VODIT TION A	Total temperature (eF)	2,300	2,600	2,900	900 1,000	1,500	006	1,500	500	1.000	1,500	1,500	1,500	1,000	1,500	1,500 2,000	1,500	1.000	1,500	1,000	1,500	4,000
SUTION TOTA	Ejector												HM-AP-22 with 8 chutes	J75-E9	with 8 chutes			_				
	Nozzle	HM-AP-15			HM-AP-16		HM-AP-18			HM-AP-18a		HM-AP-22	HM-AP-22	HM-AP-22		HM-AP-23	HM-AP-24	HM-AP-28		HM-AP-32		
-	Configuration	26 (cont.)			27	(28			29		30	31	32		33	34	35)	36		

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Test Configuration Index (continued)

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Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
37	HM-AP-32	HM-AP-32	1,000 1,500	1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	B17
38	HM-AP-33		1,500	1.8, 2.2, 2.6, 3.0	None
39	HM-AP-37		1,500	1.8, 2.6, 3.0	B3, B18
40	HM-AP-38		1,500	1.8, 2.6, 3.0	B3
41	HM-AP-39		1,500	1.8, 2.6, 3.0	B3
42	HM-AP-40		1,500	1.8, 2.6, 3.0	B9
43	HM-AP-41		1,000	1.8, 2.2, 2.6, 3.0	B9, B19
P	HM_A P_47		1 500	7 6 3 0	ערמ טמ
75			1,000		07 CO
(HM-AF-43		_		b 3
46	HM-AP-44		1,500	1.8, 2.6, 3.0	B3
47	MPP 152		1,100	2.2, 2.6, 3.0	B21, B22
48	MPP 452		1,100	1.8, 2.2, 2.6, 3.0, 3.2; 3.5	B21, B22
49	MPP 130-20		1,100	2.2, 2.6, 3.0	B21
50	MAE 4A		1,100	2.2, 2.6, 3.0	B21
51	MAE 53-18		1,100	2.2, 2.6, 3.0	B21
	(no plug)				
52	MAE 53-18		1,100	2.2, 2.6, 3.0	B21
53	MAE 203-3		1,100	2.2, 2.6, 3.0	B 21

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B.2 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1968

Facility: Boeing AnnexD, Seattle

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Acoustic Data Reference: No formal documentation

- Performance Data Reference: (1) Boeing Document D6A12118-1 (Informal), "Multi-Spoke Suppressor Nozzle Characteristics-Volume I-Parametric Thrust Performance"
 - (2) Boeing Document D6A11815-1, "Ninety-Six-Tube Jet Noise Suppressor Acoustic Performance Test Data Analysis, Model NSC-82"
 - (3) Boeing Document T6A1178-1, Test Data-Report-Base Pressure Investigation of the NSC-82 Jet Noise Suppressor Nozzle with External Flow," February 1970
 - (4) Boeing Document D6A11822-1 and -2, "Multi-Tube Suppressor Noise Performance-Vols I and 2," July 1970

B.2.1 Test Hardware

B.2.1.1 Nozzles

Designation	Description
HM-J75	Round convergent nozzle, 1:8 scale of J-75 nozzle; $D_T = 4.1$ in., $A_T = 13.2$ in. ²
C-6	Round convergent nozzle with short conical plug equivalent to 1:8 scale JT3C-6 turbojet engine nozzle; $D_T = 3.10$ in., $A_T = 7.07$ in. ²
2.86-in. diameter (standard)	Round convergent nozzle; $D_T = 2.86$ in., $A_T = 6.42$ in. ²
4.75-in. diameter (standard)	Round convergent nozzle; $D_T = 4.75$ in., $A_T = 17.72$ in. ²
HM-AP-9	24 spokes with 95% flow penetration; AR = 1.9, $A_T = 13.2 \text{ in.}^2$, 17.5 exit cant angle (outward)
HM-AP-20	Annulus slot and center plug shaped for coanda effect (flow attachment); AR = 6.5, $A_T = 11.4$ in. ² , 60° exit cant angle (outward)
HM-AP-23	Seven tubes for tertiary air surrounded by round primary flow nozzle; AR = 1.8, $A_T = 13.2$ in. ²
HM-AP-32	24 spokes with 90% flow penetration; AR = 4.0, $A_T = 13.2$ in. ²

Designation	Description
HM-AP-33	36 spokes with 90% flow penetration; AR = 4.0, $A_T = 13.2$ in. ²
HM-AP-36	60 radial slots, annular arrangement, with 0° exit cant angle; $AR = 5.0$, $A_T = 13.2$ in. ² , some configurations had a center plug
HM-AP-37	37 equally spaced RC tubes, hexagonal array; AR = 4.65, $A_T = 13.2 \text{ in.}^2$, 7-in. tube length
HM-AP-41	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 4.0, $A_T = 13.2$ in. ² , 7-in. tube length
НМ-АР-43	37 equally spaced RC tubes, hexagonal array; $AR = 3.33$, $A_T = 13.2$ in. ² , 7-in. tube length
HM-AP-46	49 RC tubes arranged in seven tube clusters; AR = 5.2 (cluster AR = 3.0), $A_T = 17.5 \text{ in.}^2$, 7-in. tube length
HM-AP-47	49 tubes with 12 spoke ends each, arranged in seven tube clusters; $AR = 5.2$ (cluster $AR = 3.0$), $A_T = 17.5$ in. ² , 7-in. tube length
HM-AP-48	49 RC tubes arranged in seven tube clusters; AR = 6.5 (cluster AR = 3.0), $A_T = 17.5 \text{ in.}^2$, 7-in. tube length
HM-AP-49	49 tubes with 12 spoke ends each, arranged in seven tube clusters; AR = 6.5 (cluster AR = 3.0), $A_T = 17.5$ in. ² , 7-in. tube length
HM-AP-50	49 RC tubes arranged in seven tube clusters; AR = 6.5 (cluster AR = 4.0), $A_T = 17.5 \text{ in.}^2$, 7-in. tube length
HM-AP-51	49 tubes with 12 spoke ends each, arranged in seven tube clusters; AR = 6.5 (cluster AR = 4.0), $A_T = 17.5$ in. ² , 7-in. tube length
HM-AP-52	49 RC tubes arranged in seven tube clusters; AR = 7.8 (cluster AR = 3.0), $A_T = 17.5$ in. ² , 7-in. tube length
HM-AP-53	49 tubes with 12 spoke ends each, arranged in seven tube clusters; AR = 7.8 (cluster AR = 3.0), $A_T = 17.5$ in. ² , 7-in. tube length
HM-AP-56	37 tubes with hexagonal end for tertiary air surrounded by hexagonal- shaped primary flow nozzle; AR = 4.0, $A_T = 13.2$ in. ²
HM-AP-57	12 spokes with 75% flow penetration; AR = 1.86, $A_T = 13.2$ in. ²
HM-AP-79	49 equally spaced RC tubes; AR = 4.0, $A_T = 17.5 \text{ in.}^2$, 7-in. tube length
HM-AP-80	49 equally spaced tubes with 12 spoke ends each; $AR = 4.0$, $A_T = 17.5$ in. ² , 7-in. tube length

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Designation	Description
HM-AP-81-1	36 RC tubes, rectangular array (6 x 6); AR = 3.45, $A_T = 12.8$ in. ² , 7-in. tube length
HM-AP-81-2	36 RC tubes, rectangular array (6 x 6); AR = 5.4, $A_T = 12.8 \text{ in.}^2$, 7-in. tube length
HM-AP-82-1	36 RC tubes, rectangular array (4 x 9); AR = 3.4, $A_T = 12.8 \text{ in.}^2$, 7-in. tube length
HM-AP-82-2	36 RC tubes, rectangular array (4 x 9); AR = 5.4, $A_T = 12.8$ -in. ² , 7-in. tube length
MPP 152	21 RC tubes (three sizes); AR = 2.4, $A_T = 6.48 \text{ in.}^2$
MPP 452	21-tube nozzle (10 outer tubes with six spoke ends); AR = 2.6, $A_T = 6.5 \text{ in.}^2$
253 tubes	253 round convergent-divergent tubes; $AR = 4.0$, $A_T = 6.43$ in. ² , 6-in. tube length

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B.2.1.2 Ejectors

Designation	Description
HM-AP-43	Tight-fitting ejector, hexagonal cross section, 6 in. long
HM-AP-23	No information available
HM-AP-56	No information available
HM-AP-20	No information available
El	Cylindrical ejector with 10-in. inside diameter, lined with 1-in. TWF fiber- glass; 16.67 in. long
E2	Cylindrical ejector with 10-in. inside diameter (unlined); 16.67 in. long
E3	Cylindrical ejector with 11.67-in. inside diameter (unlined); 33.33 in. long
E4	Cylindrical ejector with 11.67-in. inside diameter, lined with 1-in. TWF fiberglass; 33.33 in. long
E5	Cylindrical, corrugated ejector with 10-in. inside diameter (unlined); 16.67 in. long
E6	Round ejector, divergent from 10-in. inside diameter to 11-in. inside diameter

B.2.2 Test Configuration Index

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Noise report reference					_	B2	B23	B23	B23	B12	-	B17
Pressure ratio	$\begin{array}{c} 1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 \\ 1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.2, 3.4 \\ 1.8 \\ 2.2 \end{array}$	$\begin{array}{c} 1.8, 2.0, 2.2, 2.5, 3.0, 3.4 \\ 1.8, 2.6, 3.0, 3.4 \end{array}$	1.8, 2.0, 2.2, 2.48, 3.0, 3.4	1.4, 1.8, 2.2	1.8 1.8, 2.6, 3.0 1.8, 2.6, 3.0	1.8 1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.6, 3.0, 3.4 1.8, 2.6, 3.0, 3.4	1.8, 2.6, 3.0, 3.4	1.8, 2.6, 3.0, 3.4	1.8 1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.4 1.4, 1.6	1.8 1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.4 18 2 2 2 6 2 0 2 4	1.0, 2.2, 2.0, 3.0, 3.7 1.8 1.8, 2.2, 2.6, 3.0, 3.2
Total temperature (°F)	1,000 1,500 540 1.200	1,000	1,000	1,000	1,140 1,500 1,640	1,000	1,000 1,500	1,500	1,500	540 1,000 1,500	540 1,000	1,000
Ejector								HM-AP-20 (unlined)	HM-AP-20 (lined)		HM-AP-23	
Nozzie	S7L-MH	C-6	2.86-in. diameter (standard)	4.75-in. diameter	(stanuaru)	6-4A-MH	HM-AP-20	HM-AP-20	HM-AP-20	HM-AP-23	HM-AP-23	HM-AP-32
Configuration	T	7	m	4		Ś	Q	L	∞	6	10	11

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Test Configuration Index (continued)

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Noise report reference B24, B25 B3, B18 B9, B19 **B**26 B26 B26 B19 B19 B19 B19 B26 Pressure ratio 1.8 1.8 1.8, 2.2, 2.6, 3.0, 3.2 1.8 1.8, 2.2, 2.6, 3.0 1.8 1.8, 2.2, 2.6, 3.0 1.8 1.8, 2.2, 2.6, 3.0 1.8 1.8 1.8, 2.2, 2.6, 3.0 1.8, 2.2, 2.6, 3.0 1.8 1.8, 2.2, 2.6, 3.0 1.8, 3.0 1.8, 2.2, 2.6, 3.0 1.8 1.8, 2.6, 3.0 1.8 1.8 3.0 $1.8 \\ 3.0 \\ 3.0$ Total temperature 1 (oF) 540 1,000 1,500 1,500 ,500 1,000 1,200 1,200 1,200 1,200 1,200 1,200 1,200 1,200 1,200 1,500 1,500 1,500 1,500 1,500 1,500 1,000 1,500 1,500 ,500 Ejector E2 E3 E4 El HM-AP-36 (Mod A) HM-AP-36 (Mod D) HM-AP-36 (Mod E) HM-AP-36 (Mod F) HM-AP-36 HM-AP-33 HM-AP-37 HM-AP-41 HM-AP-41 HM-AP-41 HM-AP-41 HM-AP-41 Nozzle Configuration 12 13 14 15 16 17 18 19 20 22 21 23

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 Test Configuration Index (continued)

			Total temperature		Noise report reference
guration	Nozzle	Ejector	(oF)	Pressure ratio	-
24	HM-AP-41	E5	1,000	1.8 1.8, 2.2, 2.6, 3.0	B19
25	HM-A.P-41	E6	1,000	1.8 1.8, 2.2, 2.6, 3.0	B19
26	HM-AP-43		540 1,000 1,500	1.8 1.8 1.8, 2.2, 2.6, 3.0	B3, B27
27	HM-AP-43	HM-AP-43	540 1,000 1,500	1.8 1.8 1.8, 2.2, 2.6, 3.0	B27 None
28	HM-AP-46		1,000 1,500	1.8 1.8, 2.6, 3.0	
29	HM-AP-47		1,000 1,500	1.4, 1.8, 2.2 1.8, 2.2, 2.6, 3.0	
30	HM-AP-48		1,000	1.8 1.8, 2.6, 3.0	
31	HM-AP-49		1,000 1,500	1.8 1.3, 2.6, 3.0	
32	HM-AP-50		1,000 1,500	1.8 1.8, 2.6, 3.0	
33	HM-AP-51		1,000 1,500	1.8 1.8, 2.5, 3.0	
34	HM-AP-52		1,000 1,500	1.8 1.8, 2.6. 3.0	
35	HM-AP-53		1,000 1,500	1.4, 1.8, 2.2 1.8, 2.6, 3.0	
36	HM-AP-56		540 1,000 1,500	1.8 1.8 1.8, 2.6, 3.0, 3.4	

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Test Configuration Index (continued)

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Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
37	HM-AP-56	HM-AP-56	1,000 1,500	1.8 1.8.2.6.3.0.3.4	
38	HM-AP-57		1,000	1.8, 2.2, 2.6, 3.0, 3.2, 3.4 1.8, 2.2, 2.6, 3.0, 3.2, 3.4	B28 Ivone
3ġ	HM-AP-79		1,000	1.8 1.8, 2.2, 2.6, 3.0	
40	HM-AP-80		1,000 1,500	1.8 1.8, 2.2, 2.6, 3.0	
41	HM-AP-81-1		1,000 1,500	1.8, 2.2 1.8, 2.2, 2.6, 3.0, 3.2	-
42	HM-AP-81-2		1,000 1,500	1.8, 2.2 1.8, 2.2, 2.6, 3.0, 3.2	
43	HM-AP-82-1		1,000 1,500	1.8, 2.2, 1.6, 3.0, 3.2	
44	НМ-АР-82-2		1,000	1.8, 2.2 1.8, 2.2, 2.6, 3.0, 3.2	
45	MPP 152		1,000	1.8, 2.0, 2.2, 2.5, 3.0, 3.4	B22
46	MPP 452		1,000	1.8, 2.0, 2.2, 2.48, 3.0, 3.4	B22
47	253 tubes		1,000	1.8, 2.0, 2.2, 2.48, 3.0, 3.4	B29

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B.3 MODEL-SCALE (1/8TH) NOZZLE NOISE AND PERFORMANCE TESTS IN 1968-69

Facility: Hot Nozzle Test Facility, North End Boeing Field, Seattle

Acoustic Data Reference: No formal documentation

Performance Data Reference: (1) Boeing Document D6A-12118-1 (Informal), "Multi-Spoke Suppressor Nozzle Characteristics-Volume I-Parametric Thrust Performance"

(2) Boeing Document D6A11822-1 and -2, "Multi-Tube Suppressor Noise Performance-Vols 1 and 2, July 1970-

B.3.1 Test Hardware

B.3.1.1 Nozzles

Designation	Description
6.0-in. diameter (standard)	Round convergent nozzle, approximately 1:8 scale of GE 4 engine nozzle; $D_T = 6.0$ in., $A_T = 28.3$ in. ²
4.1-in. diameter (standard)	Round convergent nozzle; $D_T = 4.1$ in., $A_T = 13.2$ in. ²
HM-AP-35	270 RC tubes, hexagonal annulus configuration, exit cant angle = 15° (inward); AR = 7.0, A _T = 28.3 in 2.745-in. tube length
HM-AP-45	36 spokes with flow penetration varying from 60% to 90%; AR = 2.06, $A_T = 28.3 \text{ in.}^2$
HM-AP-55C	37 equally spaced RC tubes; hexagonal array;, AR = 3.33, $A_T = 13.2 \text{ in}$, 5.3-in, tube length. Material: Cr-Ti-Si coated columbium (water-cooled base plate)
HM-AP-58A	42-tube array (six clusters of seven tubes each), with 12 spoke ends on each tube; $AR = 9.7$, $A_T = 15$ in. ² , 7-in. tube length
HM-AP-59A	42-tube annular array with 12 spoke ends on each tube; $AR = 8.3$, $A_T = 15 n.^2$, 7-in. tube length
HM-AP-59B	42-tube annular array with 12 spoke ends on each tube, 21 tubes in the outer row; AR = 8.3, $A_T = 15$ in. ² , 7-in. tube length
HM-AP-60	24 spokes with 90% flow penetration; AR = 2.0, $A_T = 13.2$ in. ²
HM-AP-61A	42 tubes with 12 spoke ends each in six clusters of tubes surrounding a 24-spoke nozzle (HM-AP-60); AR = 5.2. $A_T = 28.2$ in. ²
HM-AP-64A	42 tubes with 12 spoke ends each in an annular configuration surrounding a 24-spoke nozzle (HM-AP-60); AR = 4.4, $A_T = 28.2$ in. ²

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Designation	Description
HM-AP-65A	42 tubes with 12 spoke ends each in an annular configuration surrounding a 4.1-indiameter RC nozzle; AR = 4.4, $A_T = 28.2$ in. ²
HM-AP-78	Combination array of 16 spokes and 16 clusters of tubes (208 tubes total); AR = 3.1, $A_T = 28 \text{ in.}^2$
HM-AP-85-1	126 equally spaced RC tubes, hexagonal array; AR = 3.33, $A_T = 28.1$ in. ² , 7-in. tube length
HM-AP-85-2	126 equally spaced RC tubes, hexagonal array; $AR = 5.2$, $A_T = 28.1$ in. ² , 7-in. tube length
HM-AP-85-4	126 equally spaced nonconvergent tubes, hexagonal array; $AR = 2.8$, $A_T = 28.1$ in. ² , 7-in. tube length
HM-AP-86-1	330 equally spaced RC tubes, hexagonal array; AR = 4.0, $A_T = 28.3 \text{ in.}^2$, 7-in. tube length
HM-AP-86-2	330 equally spaced RC tubes, hexagonal array; AR = 5.2, $A_T = 28.3 \text{ in.}^2$, 7-in. tube length
NSC 82	96 elliptical tubes, round array configuration; AR = 2.9, $A_T = 26.9$ in. ² , includes cylindrical ejector
C-D (M _J 1.92)	Convergent-divergent configuration with 6-indiameter throat, 7.67-in diameter exit; $A_9/A_8 = 1.63$, $A_T = 28.3$ in. ²

B.3.1.2 Ejectors

Designation	Descriptio,
ID-CYL-UL	Cylindrical ejector, 8.6-in. inside diameter, 14 in. long
ID-CYL-L	Cylindrical ejector; 8.6-in. inside diameter, lined with 1-in. fiberglass, 14 in. long
1.2D-CYL-UL	Cylindrical ejector; 10.35-in. inside diameter, 14 in. long
1.2D-CYL-L	Cylindrical ejector; 10.35-in. inside diameter, lined with 1-in. fiberglass, 14 in. long
11 in. x 12 in. D	Cylindrical ejector; 12-in. inside diameter, 11 in. long
16 in. x 12 in. D	Cylindrical ejector; 12-in. inside diameter, 16 in. long
11 in. x 13 in. D	Cylindrical ejector; 13-in. inside diameter, 11 in. long

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B.3.2 Test Configuration InJex

Noise report reference			B25	B25	B25	B25	B25	B30, <u>B</u> 31	B30, B31	B30, B31	B30, B31
Pressure ratio	1.6, 1.8, 2.2, 2.6, 3.0, 3.4 1.5 1.8, 2.2, 2.6, 3.0, 3.4 2.0 2.5 1.8, 2.2, 2.6, 3.0, 3.4 2.6, 3.0, 3.4	5.0, 5.4 1.6, 1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4
Total temperature (°F)	500 820 1,000 1,120 1,500 2,500	2,800 2,100 2,600	500 1,000 1,500	1,500	1,500	1,500	1,500	1,000	1,500	1,500	JL 1,500
Ejector									ID-CYL-UL	1D-CYL-L	1.2D-CYL-L
Nozzle	6.0-in. diameter (standard)	4.1-in. diameter (standard)	HM-AP-35	HM-AP-35 at 100% conical plug	HM-AP-35 at 60% conical plug	HM-AP-35 at 40% conical plug	HM-AP-35 (240 tubes)	HM-AP-45	HM-AP-45	HM-AP-45	HM-AP-45
Configuration		61	ŝ	4	S	ę	2	8	6	10	11

Test Configuration Index (continued)

12.1

Noise report reference	B30, B31	* B 32	B33.		B34	R34	B34	B34	B34	B34	B34	B35			B36, B37	B38, B39	B40	B39, B40	-		B40	•		B40	-	
Pressure ratio	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6 3.0, 3.4	1.8, 2.2, 2.0, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.6, 2.2, 2.6, 3.0, 3.4	1.6, 2.2, 2.6, 3.0, 3.4	1.6, 2.2, 2.6, 3.0, 3.4	1.6, 2.2, 2.6, 3.0, 3.4	1.6, 2.2, 2.6, 3.0, 3.4	1.6, 2.2, 2.6, 3.0, 3.4	1.6, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4
Total temperature (°F)	1,500	1,600	2,100	2,600	1,500	1,500	1,5:30	1,500	1,500	1,500	1,500	500	1,000	1,500	500	1,000	1,500	500	1,000	1,500	500	1,000	1,500	500	1,000	1,500
Ejector	1.2D-CYL-L																	11 in. x 12 in. D			16 in. x 12 in. D			11 in. x 13 in. D		
Nozzle	HM-AP-45	HM-AP-55C			HM-AP-58A	HM-AP-59A	HM-AP-59B	HM-AP-60	HM-AP-61A	HM-AP-64A	HM-AP-65A	HM-AP-78		_	HM-AP-85-1			HM-AP-85-1			HM-AP-85-1			HM-AP-85-1		
Configuration	12	13			14	15	16	17	18	19	20	21			22			23			24			25		

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Test Configuration Index (continued)

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Noise report reference	B38	B41, B42, B38, B43	B4.1	B43	B39	B45	B45	None None
Pressure ratio	1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	$\begin{array}{c} 1.8, 2.2, 2.6, 3.0, 3.4 \\ 1.8, 2.2, 2.6, 3.0, 3.4 \\ 1.8, 2.2, 2.6, 3.0, 3.4 \\ 1.8, 2.2, 2.6, 3.0, 3.4 \end{array}$	$\begin{array}{c} 1.8, 2.2, 2.6, 3.0, 3.4\\ 1.8, 2.2, 2.6, 3.0, 3.4\\ 1.8, 2.2, 2.6, 3.0, 3.4\\ 1.8, 2.2, 2.6, 3.0, 3.4\end{array}$	1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	1.6 2.2, 3.0, 3.4	1.6 2.2, 3.0, 3.4	$\begin{array}{c} 1.8, 2.2, 2.6, 3.0, 3.4 \\ 1.8, 2.2, 2.6, 3.0, 3.4 \\ 2.6, 3.0, 3.4 \\ 2.6, 3.0 \\ \end{array}$
Total temperature (°F)	500 1,000 1,500	500 1,000 1,500	500 1,000 1,500	500 1,000 1,500	500 1,000 1.500	1,000 1,500	1,000 1,500	1,500 1,500 2,400 2,900
Ejector					11 in. x 12 in. D			NSC 82
Nozzle	HM-AP-85-2	HM-AP-85-4	HM-AP-85-4 (126-hole plate)	HM-AP-85-4 (elliptical tubes)	HM-AP-85-4	HM-AP-86-1	HM-AP-86	NSC 82 NSC 82
Configuration	26	27	28	29	30	31	32	33 34

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Noise report reference	B46				None	-			
Pressure ratio	1.8, 2.2, 2.6, 3.0, 3.4 1 5	1.8, 2.2, 2.6, 3.0, 3.4	2.5	1.8, 2.2, 2.6, 3.0, 3.4	2.2, 2.6, 3.0, 3.4	1.6, 1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	1.8, 2.2, 2.6, 3.0, 3.4	-
Total temperature (°F)	500 820	1,000	1,260	1,500	65	500	1,000	1,500	-
Ejector									
Nozzle	97-hole plate (NSC 82-hole	pattern)			C-D (M _J 1.92)				
Configuration	35				36				

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Test Configuration Index (continued)

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B.4 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1968

Facility: Boardman, Oregon Test Site (Pad B-2) YJ-93 engine

Acoustic Data Reference: Boeing Document D6A11501-1, "Thirty-Six Spoke Jet Noise Suppressor Acoustic and Performance Test Analysis," G. C. Teeter and J. R. Alberti, March 1969

Performance Data Reference: Ibid

B.4.1 Test Hardware

B.4.1.1 Nozzles

Designation	Description
RC	Round convergent nozzle; 603-in. ² area at exit plane
HL-AP-9	36-spoke nozzle; $AR = 2.2$, $A_T = 578$ in. ² (The HM-AP-45 model scale (1:4.7) nozzle was similar to the HL-AP-9 nozzle.)

B.4.1.2 Ejectors

Designation	Description
HL-AP-9	Cylindrical ejector with bellmouth inlet; 49-in. inside diameter, 61 in. long. The inside wall was optionally lined with fiberglass and perforated plates or solid plates.

B.4.2 Test Configuration Index

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio
1	RC		860	1.4
		-	1,060	1.8
-		-	1,360	2.3
	-		1,510	2.6
2	HL-AP-9	-	760 -	- 1.3
			960	1.7
-		-	1,270	2.2
			1,480	2.6
3	HL-AP-9	HL-AP-9	810	1.4
			1,020	1.7
			1,350	2.3
			1,620	2.8
4	HL-AP-9	HL-AP-9	830	1.4
		(fiberglass lined)	1,080	1.8
			1,420	2.4
		-	1,610	2.8

B.5 REFERENCES

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- B3 Coordination Sheet SST-ANPD-52, "Preliminary Acoustics Report on Model Scale Tests of 37 Plain Ended Tube Nozzles," J. R. Alberti, March 18, 1968.
- B4 Coordination Sheet SST-ANPD-58, "Noise Characteristics of the Pure Annulus Nozzle (Area Ratio = 4)," C. W. Miller, March 25, 1968.
- B5 Coordination Sheet SST-ANPD-64, "Comparison of Pure Annulus and 60-Lobe Annulus Noise Characteristics," C. W. Miller, May 7, 1968.
- B6 Coordination Sheet SST-ANPD-129, "Thrust Performance and Noise Suppression Characteristics of the Pure Annular Nozzle Series-HM-AP-12," R. A. Lipka and C. W. Miller, November 1, 1968.
- B7 Coordination Sheet SST-ANPD-22, "Effect of Power Setting on the Jet Noise Suppression Characteristics of a 6 Lobe Greatrex Nozzle (HM-AP-15)," R. B. Tate, September 11, 1967.
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- B10 Coordination Sheet SST-ANPD-94, "Additional Acoustic Data Analysis of the 37-Tube Jet Nozzles with 12-Lobe Greatrex-Type Terminations," C. P. Wright, August 7, 1968.
- B11 Coordination Sheet SST-ANPD-17, "Model Tests of the HM-AP-22, 12 Spoke Jet Noise Suppressor Series," J. R. Alberti, August 21, 1967.
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- B13 Coordination Sheet SST-ANPD-31, "High Noise Suppression Program-Five Slot Nozzle Tests HM-AP-24," C. W. Miller, November 10, 1967.
- B14 Coordination Sheet SST-ANPD-37, "High Noise Suppression Program-Five Slot Nozzle Tests HM-AP-25," C. W. Miller, December 5, 1967.

- B15 Coordination Sheet SST-ANPD-46, "Noise Characteristics of a Five Slot (Area Ratio = 3.0) HM-AP-24 Nozzle," C. W. Miller, January 19, 1968.
- B16 Coordination Sheet SST-ANPD-51, "Preliminary Analysis of the 24 Spoke (Area Ratio = 6.0) Nozzle Noise Suppression Characteristics," R. B. Tate, February 21, 1968.
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- B19 Coordination Sheet SST-ANPD-85, "Suppression Characteristics of a 37-Tube Greatrex Model Jet Nozzle With Various Types of Ejector Shrouds," A. Elston, July 25, 1968.
- B20 Coordination Sheet SST-ANPD-94, "Additional Acoustic Data Analysis of the 37-Tube Jet Nozzles with 12-Lobe Greatrex-Type Terminations," C. P. Wright, August 7, 1968.
- B21 Coordination Sheet SST-ANPD-14, "Preliminary Results of Recent Noise Suppression Measurements on Model Jet Nozzles, Type MAE4A, MAE152, MPP130-20, MAE53-18, MAE203-3 and MPP452," C. P. Wright, August 1967.
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- B24 Coordination Sheet SST-ANPD-64, "Comparison of Pure Annulus and 60-Lobe Annulus Noise Characteristics," C. W. Miller, May 7, 1968.
- B25 Coordination Sheet SST-ANPD-82, "Noise Characteristics of the 60-Lobe Annulus With Concentric Rings," C. E. Burton and C. W. Miller, July 29, 1968.
- B26 Coordination Sheet SST-ANPD-186, "Noise Suppression Capability of 60 Lobe Annulus (10° Canted Flow) With and Without Conical Centerbody Plugs," R. B. Tate and C. W. Miller, July 29, 1969.
- B27 Coordination Sheet SST-ANPD-90, "Model Scale Test of a 3.33 Area Ratio, 37-Plain Ended Tube Nozzle (HM-AP-43) With a Close-Fitting Ejector," D. H. Underwood, August 7, 1968.
- B28 Coordination Sheet SST-ANPD-53, "A Preliminary Acoustic Analysis of a 12 Lobe Greatrex Jet Nozzle Acoustic Noise Characteristics (HM-AP-57)," C. P. Wright, March 26, 1968.

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- B29 Coordination Sheet SST-ANPD-65, "A Preliminary Acoustic Analysis of a 253 Tube (Area Ratio 4) Jet Nozzle's Accustic Characteristics," C. P. Wright, June 6, 1968.
- B30 Coordination Sheet SST-ANPD-109, "A Preliminary Acoustic Analysis of a 36-Spoke Area Ratio 2.06 Jet Nozzle's Noise Characteristics (HM-AP-15)," C. P. Wright, September 26, 1968.
- B31 Coordination Sheet SST-ANPD-131, "Thrust Performance and Acoustic Characteristics of a Small Scale 36 Spoke Suppressor Nozzle (J-93 Replica)(AR 2.06)," C. P. Wright and F. G. Strout, November 20, 1968.
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- B33 Coordination Sheet SST-ANPD-198, "General Electric JENOTS Facility 37 Tube (3000° F) Suppressor Nozzle Test Results," C. P. Wright, September 12, 1969.
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- B35 Coordination Sheet SST-ANPD-159, "Preliminary Acoustic Report on Model Scale Tests of an Area Ratio 3.1, 16 Tubed Spoke Suppressor, HM-AP-78," D. H. Underwood, February 28, 1969.
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APPENDIX C PNL SUPPRESSION VALUES FOR EIGHTH-SCALE SUPPRESSOR NOZZLES TESTED

Appendix C shows the PNL suppression (PNdB) as a function of thrust loss for the various model-scale suppressor nozzles tested during the SST high noise suppression program. Figures C-1 through C-15 show the noise suppression and thrust loss relationship of the suppressor nozzles at primary gas conditions of PR = 1.8, 2.2, 2.6, 3.0, and 3.4 and $T_T = 500^\circ$ F, 1,000° F, and 1,500° F.

More detailed nozzle descriptions can be found in appendix D. The values plotted in figures C-1 through C-15 should not be interpreted as being absolute. For instance, noise suppression values are usually consistent for a given jet configuration, but thrust loss is variable, depending on nozzle design parameters affecting secondary flow and base drag.























FIGURE C-11.-PR = 1.8, $T_T = 1500^{\circ}F$, V_J (IDEAL) = 1923 FPS

C12



FIGURE C-12.-PR = 2.2, $T_T = 1500^\circ F$, V_J (IDEAL) = 2200 FPS



FIGURE C-13.-PR = 2.6, $T_T = 1500^{\circ}F$, V_I (IDEAL) = 2402 FPS



FIGURE C-14.-PR = 3.0, $T_T = 1500^{\circ}F$, V_J (IDEAL) = 2555 FPS



 $FIGURE C-15.-PR = 3.4, T_T = 1500^{\circ}F, V_J (IDEAL) = 2678 FPS$

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APPENDIX D SST 12-20 PNdB SUPPRESSION PROGRAM NOZZLES AND THEIR NOISE AND THRUST CHARACTERISTICS

D.1 NOZZLES TESTED (MODEL SCALE)

The list below contains the model-scale nozzles tested and their locations in the compendium. Some nozzles are not included because the acoustic data were in the process of analysis when the SST program was terminated and the results are incomplete.

Nozzle	Description	Page
HM-AP-6	6 lobes, multislot, $AR = 8.28$	D5
HM-AP-9	24 spokes, $AR = 1.9$	D15
HM-AP-12	Annulus, $AR = 4.0$	D25
HM-AP-15	6 spokes, AR = 1.6	D32
HM-AP-16	37-tube hexagonal array, AR = 3.33	D48
HM-AP-18	37-tube (12 spoke ends) hexagonal array, AR = 4.65	D56
HM-AP-18a	37-tube (12 spoke ends) hexagonal array, AR = 8.0	D64
HM-AP-20	Annular slot with coanda-type plug, $AR = 6.5$	D~2
HM-AP-22	12 spokes, $AR = 1.4$	D80
HM-AP-23	7 tubes, internally ventilated, $AR = 1.8$	D87
HM-AP-24	5 parallel slots, $AR = 3.0$	D95
HM-AP-28	24 spokes, AR = 6.0	D105
HM-AP-29	24 spokes, $AR = 6.0$	D112
HM-AP-32	24 spokes, $AR = 4.0$	D113
HM-AP-33	36 spokes, AR = 4.0	D121 2
HM-AP-35	270-tube annulus, $AR = 7.0$	D122
HM-AP-36	Annulus array of 60 slots, $AR = 5.0^{-1}$	D130
HM-AP-37	37-tube hexagonal array, AR = 4.65	D137
HM-AP-38	37-tube hexagonal array, AR = 8.0	D144
HM-AP-39	37-tube hexagonal array, AR = 4.0	D151
HM-AP-40	37-tube (12 spoke ends) hexagonal array, AR = 3.33	D158
HM-AP-41	37-tube (12 spoke ends) hexagonal array, AR = 4.0	D165
HM-AP-42	37-tube (12 spoke ends) hexagonal array, AR = 5.2	D172
HM-AP-43	37-tube hexagonal array, AR = 3.33	D179
HM-AP-44	37-tube hexagonal array, AR = 5.2	D186
HM-AP-45	36 spokes, AR = 2.06	D193
HM-AP-46	49 RC tubes arranged in 7-tube (AR = 3.0) clusters, AR = 5.2	2
НМ-АР-47	49 tubes (12 spoke ends) arranged in 7-tube (AR = 3.0) clusters, AR = 5.2	F

Nozzle	Description	Page
HM-AP-48	49 RC tubes arranged in 7-tube (AR = 3.0) clusters, AR = 6.5	2
HM-AP-49	49 tubes (12 spoke ends) arranged in 7-tube (AR = 3.0) clusters, AR = 6.5	
HM-AP-50	49 RC tubes arranged in 7-tube (AR = 4.0) clusters, AR = 6.5	
HM-AP-51	49 tubes (12 spoke ends) arranged in 7-tube (AR = 4.0) clusters, AR = 6.5	
HM-AP-52	49 RC tubes arranged in 7-tube (AR = 3.0) clusters, $AR = 7.8$	2
HM-AP-53	49 tubes (12 spoke ends) arranged in 7-tube (AR = 3.0) clusters, AR = 7.8	2
HM-AP-54	24 spokes (air-cooled, 3,000°F), AR = 2.0	3
НМ-АР-55А	37-tube hexagonal array (3,000° F), AR = 4.0	3
HM-AP-55B	37-tube hexagonal array $(3,000^{\circ}F)$, AR = 5.2	3
HM-AP-55C	37-tube hexagonal array (3,000°F), AR = 3.3°	D203
HM-AP-56	37 tubes, internally ventilated, AR = 4.0	D213 2
HM-AP-57	12 spokes, AR = 1.86	D214
HM-AP-58A	42 tubes, 6 clusters of 7 tubes each, $AR = 9.7$	D225
HM-#P-59A	41-tube (12 spoke ends) annular array, AR = 83	D232
HM-AP-59B	42-tube (12 spoke and RC ends) annular array, AR = 8.3	D239
HM-A. ⁹ -60	24 spokes, $AR = 2.0$	D?46
HM-AP-61A	42 tubes, 6 clusters of 7 tubes each, and 24-spoke nozzle in the center, $AR = 5.2$	D254
НМ-АР-64А	42-tube (12 spoke ends) annular array and 24-spoke nozzle in the center, AR = 4.4	D261
КМ-АР-65А	42-tube (12 spoke ends) annular array and 4.1-in. RC nozzle in the center, $AR = 4.4$	D268
HM-AP-06	42-tube annular array and 3.0-in. RC central nozzle	3
HM-AP-78	16 spokes and 16 clusters of tubes, $AR = 3.1$	D275
HM-AP-79	49-tube array, $AR = 4.0$	2
НМ-АР-80	49-tube (12 spoke ends) array, $AR = 4.0$	2
HM-AP-81-1	36-tube rectangular (6 x 6) array, AR = 3.45	2
HM-AP-81-2	36-tube rectangular (6 x 6) array, AR = 5.4	2
Нм-АР-81-3	36-tube rectangular (6 x 6).array, AR = 8.2	3
HM-AP-82-1	36-tube rectangular (4 x 9) array, AR = 3.4	$\frac{1}{2}$
НМ-АР-82-2	36-tube rectangular (4 x 9) array, AR = 5.4	$\frac{1}{2}$
HM-AP-82-3	36-tube rectangular (4 x 9) array, AR = 8.2	3
HM-AP- 3-1	36-tube rectangular (2 x 18) array, AR = 3.4	3
HM-AP-02	36-tube rectangular (2 x 18) array, AR = 5.4	3
HM-AP-83-5	36-tube rectangular (2 x 18) array, ÅR = 8.2	$\overline{3}$
HM-AP-85-1	126-tube hexagonal array, AR = 3.33	D278 3

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Nozzle	Description	Page
HM-AP-85-2	126-tube hexagonal array, AR = 5.2	D287 4
HM-AP-85-4	126-tube hexagonal array, AR = 2.8	D289 4
HM-AP-86-1	330-tube hexagonal array, AR = 4.0	D292
HM-AP-86-2	330-tube hexagonal array, AR = 5.2	D297
MAE 4A	12 spokes with plug, $AR = 2.9$	D301
MAE 203-3	20 spokes, AR = 2.2	D308
MPP 130-20	16 spokes, $AR = 2.25$	D315
MAE 53-18	24 spokes with plug, $AR = 2.1$	D322
MPP 152	21 tubes, $AR = 2.4$	D329
MPP 452	21 tubes (6 spoke ends on outer tubes), $AR = 2.6$	D337
253 tubes	253 tubes, $AR = 4.0$	D344
29xx8400	RC primary nozzle with ejector and 8 chutes	D352
97-hole plate	97 holes, $AR = 2.8$	D358 4
C/D nozzle	Round convergent-divergent nozzle ($A_E/A^* = 1.63$)	
NSC 82	97 tubes, $AR = 2.8$ at ejector	D359 2
NSC-119B	61 tubes, $AR = 2.9$ at ejector	

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> Destroyed during testing

> Acoustic data partially analyzed

3 Needs testing

>- Measured data lost

D.2 COMPENDIUM

Descriptions of most nozzles used during the 12-20 PNdB jet noise suppression program follow. Many of these suppressor nozzles have been tested with ejectors, but the appropriate reference must be used to obtain specific information on particular configurations. The material presented here deals in particular with the noise characteristics of the primary suppressor nozzle; this represents the first stage in supersonic jet suppression.

A separate section is devoted to each nozzle. Each section provides a summary of jet noise and thrust performance characteristics from test data. The first page contains a physical description and photograph of the nozzle. Also, extrapolated perceived noise level suppression values (PNdB) as a function of jet velocity (ideal) are included. The ratic of perceived noise level suppression to the percentage of thrust loss as a function of pressure ratio is another relationship included on the first page of each section. In the SST jet noise suppression program, any ratio of Δ PNdB to Δ thrust greater than unity was considered worthy of consideration, with a ratio of two considered acceptable to program goals.

The second page of a nozzle section contains further subjective acoustic data relationships: maximum perceived noise level as a function of jet velocity and perceived noise level beam patterns at the 1,500-ft. sideline. Perceived noise levels on the first and second-pages
included the effect of ground-to-ground sound propagation losses. PNL suppression values vary only slightly when extra ground attenuation propagation loss is excluded from the extrapolation procedure. PNL suppression values at the 2,128-ft sideline tend to be about 1 PNdB higher than at the 1,500-ft sideline because of suppressor nozzle acoustic spectrum high-frequency emphasis and relatively higher absorption of high-frequency energy by the atmosphere.

The third page contains objective acoustic relationships in terms of measured noise levels (dB) on a 200-ft polar arc (full-scale equivalent). Suppressor nozzle radiated jet noise beam patterns (OASPL versus angle) at various pressure ratios and constant total temperature are shown. Typical octave-band spectra are also shown for three pressure ratios, nominally PR = 1.8, 2.2, and 3.0. The reference, round convergent, nozzle noise tends to peak near 50° relative to the jet axis, so these data are included in the spectral plots. Multielement suppressor nozzles tend to 1... maximum PNL values near 70° if jet mixing noise dominates or at 50° if jet coalescence noise dominates. These spectra were plotted to provide an indication of the relative magnitude of low-frequency jet coalescence noise and the higherfrequency jet mixing noise.

The fourth page includes some remarks about the suppressor nozzle test results, such as other configurations tested. References pertaining to test results are listed on this page.

The fifth page contains run log information for basic suppressor nozzle acoustic data. This information is to be used with measured acoustic data provided on the sixth page. Measured acoustic data are listed according to run number and angle relative to the nozzle exit and jet axis. The overall SPL, which is the integration of the eight octave bands, is given. The acoustic data are expressed in terms of actual frequencies and distances so that this information can be scaled as the user desires.

The seventh page is devoted to suppressor nozzle performance relationships. Gross thrust coefficients, discharge coefficients and base pressure ratio are shown for various pressures ratios and vertilation parameters to the extended by available test data. When ejectors were tested, the nozzle-ejector data are presented.



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HM-AP-6 NOZZLE

(16 LOBE, MULTI - SLOT, AR 8.28)

The HM-AP-6 nozzle has 6 radial arms or lobes with 20 parallel slots per arm. Area ratio was defined as the ratio of circular area enclosed by the extreme flow boundary to the normal flow area. Slot bleed and nozzle base bleed parts of primary flow are incorporated in the nozzle design.

Number of Elemen⁺s: 6 radial arms, 20 slots/arm

Flow Area: 13.2 square inches

Base Width Between Slots: 0.15 in.





D6

Martin Lance



HM-AP-6

(6 Lobe, Multi-slot, AR 8.28)

Remarks

The HM-AP-6 nozzle was tested with the slot bleed ports open and closed with little or no effect on noise suppression values, see Reference Dl. Tests at a total temperature of 2000° F indicated a loss of suppression of about 1 PNdB compared to values attained at 1500° F.

Thrust losses were excessive.

-HM-AP--6

Facility: Annex D (Cell #1) Nozzle and microphone heights are 20 inches

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<u>Run No</u> .	$P_{T/P\infty}$	$\frac{T_T}{T}$	V_{J} (Ideal)	Nozzle
н 425	1.8	1000°F	1659 fps	HM-AP-6
п 420 и 1.07	2.2	11	1900	11
н 421	2.0	11	2013	11
н 420	3.2	11	2200	11
н 430	1.8	1.500°F	1923	ų
н 431	2.2		2202	u
н 432	2.6	u	2402	11
н 433	3.0	11	2555	11
н 434	3.2	11	2620	и
Н 502	1.8	1000°F	1659 fps	4.1 Inch Round Convergent Nozzle
H 503	2.2	11	1900	u
н 504	2.6	11	2073	11
н 505	3.0	11	2205	11
н 506	3.2	11	2250	11
н 497	1.8	1500°F	1923	11
н 498	2.2	11	2202	11
н 499	2.6	11	2402	11
н 500	3.0	11	2555	11
H 501	3.2	11	2620	11

Measured acoustic data is recorded in Reference D2.

HM-AP-6

OCTAVE BAND LEVEL - dB RE: 0.0002 DYNES / CM2// 25 FT

RUN NO.	OASPL	500	١K	2K	-4K	8K	16K	32K	64K
H425L30	110.0	107.8	102,4	97.6	95.2	93.8	94.8	98.2	63.5
H425L40	111.2	108.3	105.7	97.1	97.3	95.5	95.6	99.0	94 6
H425L50	112.8	109.1	107.3	99.1	100.2	96.6	99.8	102.4	95.5
H425L60	112.5	108.6	106.8	100.1	101.5	98.1	99.4	101.1	96.2
H425L70	112.3	106.7	104.2	100.0	103.4	100.4	104.0	103 6	26.3
H425L80	110.9	104.8	100.8	97.7	101 3	99.9	103.0	104 5	36.0
H425L90	108.7	101.9	101.1	98.0	99 4	98.8	00 Q	100 3	05.1
H426L30	112.3	109.3	105.0	101 3	100 5	98 7	GR 1	100.5	04.1
H426L40	113.1	109 4	107 3	100 4	1.01 0	99-6	-00 1	101 2	90.0
8426150	115 2	110 8	109 9	102.6	10/ 8	0.00 TOO	102 6	101.2	97.0
84261.60	114 3	100.0	108 2	102.0	105 1	101.7	102.0	102 6	90.0
H4261.70	114 1	107.8	105 8	102.0	1.06 1	102.7	102.1	105 2	97.1
H4261.80	112 8	105 7	102 0	00 8	100.1	102.1	105 /	102.2	90.5
H426L90	110 6	102.8	102.0	100 1	101 0-	101.6	102.4	102 /	96.1
H4271.30	112.8	110 3	106 3	104.2	101.9	100.9	1047	102.4	90.4 06.4
8427559	114 8	110 6	100.5	103.6	105 5	100.0	100.1	102.0	90.0
H427150	116 3	111 8	110 7	104.2	102.0	102.0	101.0	102.0	97.5
8427160	116 1	111 3	100.0	104.2	100.1	102.5	104.3	102.0	90.0
1427200	115 5	100 3	107.6	104.0	100 0	104.7	104.4	102.9	98.5
u/271.90	117.3	107.0	107.4	104.1	100.0	105.1	100.9	105.9	99.4
1427200	110 0	10/.0	103.0	101.7	100.0	104.9	100.0	107.3	99.0
1427590	114.4	100.0	100.1	101.0	103.8	103.5	102.0	103.9	97.4
1420130	116.0	112.7	110.1	100.0	107.9	104.2	102.7	102.4	97.5
1420240	170.0	112.2	110.1	100.3	T03:"0	1028	104.0	103.1	90.4
11420630	110 V	110.7	111 0	107.0	109.5	105.0	105.9	100.1	99.4
1420100	117.0	112.7	TTT 2	107.0	110.8	T07.0	106.4	104.7	99.4
H420L/U	115 5	TTO"2	T08.8	100.1	110.3	107.4	T08.3	100.4	99.0
H420L0U	112.2	105.0	104.8	103.4	108.2	106.9	10/./	107.0	99.5
H420L90	130 1	112.4	104.2	103.4	105.9	102.2	105.8	104.5	98.1
1429630	110.1	112.9	110.1	100./	110.5	T07.0	104.7	104.0	100.5
1429140	110.9	11/ 0	112.0	100.4	1-1-1-O	108.1	107.1	102.0	101.0
H4296JU	110 0	112 1	112 1	100.0	17-1 0	108.1	107.9	107.2	102.5
H429L00	117 0	111 1	112.1	100.1	111.0	108.0	107.42	100.2	99.0
1429170	115 0	100 5	105.7	100.9	100.7	108.3	108.9	102.2	99.9
8429600	122.9	105.0	105.7	104.3	106.7	107.3	10/.8	10/./	99.7
1429690	110 0	100.0	102 5	104.1	106.8	102.8	106.2	104./	98.7
H430L30	110.8	109.0	103.5	98.7	957	94.5	96.7	97.9	93.4
H430L40	112.2	109.3	100.1	90.0	989	95.5	98.4	100.4	95.0
H430L50	114.1	110.0	108.9	100.5	10T°3	97.0	100.1	102.0	95.7
H430L00	112 0	100.5	100.0	102.5	104.8	TOD (101.5	101.7	96.5
H430L70	112 5	100.0	100.0	102.7	102.9	101.4	104.2	103.8	96 4
14 30 500	170 5	100.0	102.0	100.4-	101.0	101.4	103.7	105.2	90.5
8430730	1.10.5	104.0	102.9	100.2	101.3	100.1	101.8	101.0	94.7
1431L30	113.1	110 2	107.2	102.0	102.2	98.4 TOO 5	100.0	99.2	94.0
1431140	115 7	111 0	197.5 A orf	102.1	10.3.2	100.5	100.8	101.0	95.5
1431630	176 0	111.9	110.4	103.2	104.8	TOF'T	102.1	103.4	90.0
1431L00	115 4	110.2	100.3	105.0	100 0	103.4	103.4	102.4	97.4
H4312/0	TT2.0	100.2	100.3	102.0	100.0	104-L	105.3	104.7	97.7
H431L00	114.2	100.1	104.1	102.4	105.1	104.0	102.2	100.2	97.2
11431L90 11/391 90	116 7	112 3	104.0	102.0	104-12	103.2	102.2	103.1	92.¥
n434630	116 2	112.4	170 1	105 0	102 5	104.2	T07'3	103.0	100 L
1432L40 112331 50	112.2	217	110.1	102.18	107.2	104.8	104.3	98.4	100.1
1432139 11/337/0 1	110.4	11411	112.7	100.3	100 0 T0A'T	155.4	105.1	105.0	100.7
1432601	11/.9	113 5	111.0	107.2	103.9	T00.3	TO2 (1	105.5	23.4 19.4
1432177	227.2	120 1	מ,∉טי י ימנ	104 /	LLU./	100.5	107.	102.0	95,0 95,0
1432L65 11/22165	112.8	1.19.1	100.1	104-4-	100.1	105 1	105 0	10/.0	98.0 07 (
D432699	5.011 - 5.011	TOO'T	T04.2	104.0	T00.0	T'COT	103.8	104-17	37,4
NO ⁻	IE: THIS [JATA IN	CLUDES	GROUND	REFLEC	l fion in	TERFER	FNCF	

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HM-AP-6

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES 'CM2/25 FT

RUN NO.	OASPL	500	١K	2K	-4K	8K	16K	32K	64K
H433L30	118.1	114.2	110.0	108.7	110_2	106.4	104.1	103.2	99.8
H433L40	118.9	114.1	111.8	108.8	111.3	108.1	106.6	105.1	100.2
H433L50	120.3	115.6	114.3	109.5	112.3	108.3	107.6	105.8	100.7
H433L60	120.8	115.7	114.3	110.2	113.6	110.0	108.2	106.1	101.5
H433L70	123.2	114.0	112.2	109.8	114.1	110.0	110.1	107.2	101,2
H433L80	117.8	111.4	107.9	106.3	111.1	169.1	108.8	108.2	101.5
H433L90	116.0	108.4	106.9	106.3	108.4	107.7	107.9	105.5	99.6

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-6

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES / CM2/ / 25 FT

RUN NO	DASPI	500	Я IK	2К	4K	8K	16K	32K	64K
(Contribution)		000	* ***	-1 <u>2</u>	413		ļ	•===	
H4-341.30	T19 8	115 0	11.1 3	110.1	113 9-	108 7	105 7	103 0	100.0
H434L40	103	114-2	112.6	109.6	112.8	109.5	107.7	105.6	100.0
H434L50	121.3	115.3	115.0	110.9	113.9	109.9	109.1	107.5	101.4
H434LED	121.5	116.1	115.0	111.1	114.6	111.0	109.0	106.3	102.4
H434L7 0	120.8	114-4	TT2.6	110.5	115.0	111.0	110.9	107.3	101.4
H434L91	118.5	111.8	108.5	107.3	112.0	110.1	109.3	108.3	101.5
H434L95	116.E	108.9	نسر 107	107-1	109.2	108.5	108.5	105.7	99.7
H502L30	1=.7	122.3	123.6	115.0	115.1	105.5	100.1	94.7	0.0
H502L4C	18	122.5	122.7	113.5	115.5	107.3	101.5	94.7	0.0
H302L50	127	122.9	120.8	111.9	114.7	107.8	103.0	97.8	0.0
H502L60	120.5	115.9	115.9	109.5	112.5	106.8	102.3	97.2	0.0
H502L70	117	II2.)	111.4	107.4	111.1	106.2	102.5	95.1	0.0
H502L30	112. 6	126.4	105.9	104.3	106.3	102.6	98.5	94.0	0.0
H502L90	111.0	103.3	105.6	103.6	104.4	100.9	97.1	91.3	0.0
H203L30	130.6	125.5	126.6	120.2	122.9	113.8	109.8	106.7	0.0
H503L40	131.2	125.7	127.5	120.0	123.3	115.9	111.6	105.9	0.0
H503L50	129.2	124.4	125.5	117.4	120.4	113.7	110.0	105.6	0.0
H503L50	124.7	119.3	120.5	113.6	17.3	111.2	107.6	102.4	0.0
503L70	120.8	114.Ē	114.9	110.4	115.0	110.3	107.7	101.4	0.0
H503L80	116.2	109.2	109.5	107.3	110.3	106.9	104.3	100.4	0.0
H503L90	114.6	106.2	108.4	106.6	168.6	105.8	102.1	96.6	0.0
H504L30	132.3	127.4	128.1	122.2	124.4	116.6	113.3	110.1	0.0
H504L40	133.6	127.6	129.5	123-3	126.6	119.6	115.4	110.6	0.0
H504L50	132.0	126.6	127.9	121,5	124.5	118.5	114.5	110.7	. 0,0
H504L60	127.5	121.9	122.1	110.3	110.8	112.0	112.4	107.8	101.7
HOU+L/U	124.3	111.1	117.4	111.0	116.9	112.0	100 7	105.4	100.9
N204200	170.1	100 2	110 6	110.2	112.7	112.1	109.7	102.0	99.1 06.6
EJ04120	119.1	100.4	110.0	723 6	774 1	117.0	112.3	1102.2	50.0 C C
H565140	135.0	120 0	130 9	125 0	128 0	121 4	117 2	112.0	109 3
#5051 SO	134.7	128.6	129 5	174 2	120.0	121 2	117 5	113.3	108:8
H505160	123.6	123.6	124 E	119.6	122.6	118.4	114.7	111.1	0.0
85051.70	126.6	118.8	119.2	117.2	120.7	118.7	116.1	110.7	0.0
85051.80	122.9	112.2	112.9	114.3	117.5	116.8	112.6	109.1	102.5
H505L90	12.7	109.5	112.1	114.0	119.1	115.3	112.3	106.1	190.7
おろうじょうご	133.3	129.3	129.5	124.7	124.0	117.1	113.1	110.3	0.0
H506L40	135.6	129.7	131.8	125.4	128.0	121.4	117.2	112.2	108.2
H506L50	134.9	129.3	130,0	125.0	128.3	122.2	118.8	114.5	110.1
H506L60	130.2	24.3	125.2	119_9	123.1	119.0	115.0	112.2	0.0
H506L70	127.6	119.2	120.0	118.4	121.7	119,9	117.4	112.1	107.8
H206L80	124.2	112.8	113.5	115.6	119.0	118.1	11?.9	110.5	104.2
H206190	124,2	110.1	ļ12.6	116.0	120.5	116.8	113.8	107.9	102.2
H497L30	127.5	122.1	1.24 . /	118. 0	115.1	107.9	102.7	98.0	0.0
H4971 40	128,8	123.2	126.1	118.1	117.6	110.2	104.6	98.9	0.0
H497L50	126.1	121.5	122,7	114,1	116.0	163.7	103.8	97.5	0.0
H497L60	123.9	118.4	119.9	113.1	116.4	110.0	104.6	99.9	0.0
H497L70	118.5	112.8	112.8	108.3	112.8	107.0	103.3	96.4	0.0
H497LE0	114.2	107,5	1081	102.0	108.8 110 (103.4	99 <u>,4</u>	93.9	87.7 D. 0
H498L30	129.5	124.9	123.1	121.0	102 2	114 0	111 C	106 6 TO2'A	0.0
1490L40 117081 20	131./	143.1	128.4 198 H	144.0 110 s	122.2	11/ 0	110 0	102 0 T00'0	9.0 3.0
11490LDU 11490LDU	174 S	110 7	ままみ(月 1つつ つ	116 7	120 3	112 B TTÅ12	100 8	105 3	0.0
114 20LUU 114 02LUU	1.9.2	11/ 7	115.1	110./	117 0	א ווד	109.0	102.1	0.0
1420LED 1420LED	117.8	100 5	110 8	109 1	113.2	108.2	104.9	100.4	0.0

NOTE: THIS DATA INGLUDES GROUND REFLECTION INTERFERENCE

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NOZZLE TEST DATA HM-AP-6

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OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2//25 FT

RUN NO.	OASPL	500	١K	2K	4K	8K	.16K	32K	64K
H499L30	130.9	126.7	126.4	121.8	120.8	115.3	111.7	107 4	0.0
H499L40	134.7	128.1	131.0	126.3	126.4	121.2	116 3	111 8	107 7
H499L50	132.7	126.2	128.0	. 123.5	126.4	119.6	116 3	111 6	107.7
H499L60	130.4	122.5	125.3	120.9	125.1	119.2	114.8	111 4	0.0
H499L70	124.9	116.3	118.2	115.5	120.1	115.6	113.6	107 8	0.0
H499L80	120.1	113.5	110.8	110.4	115.0	111.7	108.5	107.0	98 5
H500L30	132.1	128.5	127.3	122.6	121.3	115.8	111.7	107 5	0.0
H500L40	135.0	128.8	131.4	125.6	126.5	120.7	116.5	111 8	107 7
H500L50	134.6	127,8	129.7	125.5	128.7	122.1	119.2	114 1	110.5
H500L60	131.6	123.7	126.1	125.3	126.6	120.4	116.5	112 8	107.8
H500L70	127.4	118.3	119.8	118.4	122.3	119.1	116.8	111 6	107.3
H500L80	124.7	116.1	114.4	115.4	119.9	117.8	113.8	109 4	103 4
H501L30	133.3	130.0	128.1	123.9	122.5	116.8	113.2	108.6	100.4
H5011.40	136.0	130.0	132.4	126.6	127.4	121.5	117 0	112 7	108 /
H501L50	135.5	128.9	130.5	126.7	129.4	122.8	119 7	114 7	111 0
H501L60	133.4	125.5	127.9	124.4	128.3	122.1	118.2	114.7	100 2
H501L70	128.6	119.6	121.6	119.9	123.0	119.9	117 7	112 1	107.8
H501L80	125.6	114.4	116.0	116.7	121.2	118.6	114.7	111.4	107.1

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE



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HM-AP-9

(24 Spokes, AR 1.9)

Remarks

An addition of a short ejector with a diameter equal to the flow diameter resulted in reduced PNL suppression values, see Reference D1. PNL suppression values attained at $T_T = 2000^{\circ}F$ were approximately the same as those at $T_T = 1500^{\circ}F$.

HM-AP-9

Facility: Annex D (Cell #1) Nozzle and microphone heights are 20 inches

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Run No.	$\frac{P_{T}/P}{P_{T}}$	$\frac{T_{T}}{T}$	VJ (Ideal)	Nozzle
н 452	1.8	1000°F	1659 fps	нм-ар-9
H 453	2.2	11	1900	11
H 454	2.6	tī	2073	18
н 455	3.0	11	2205	11
н 456	3.2	11	2250	17
н 457	1.8	1500°F	1923	11
н 458	2.2	11	2202	-11
н 459	2.6	11	2402	11
н 460	3.0	11	2555	11
н 461	3.2	117	2620	11
H 502	1.8	1000°F	1659 fps	4.1 Inch Round Convergent Nozzle
H 503	2.2	11	1900	11
н 504	2.6	11	2073	11
Н 505	3.0	11	2205	11
н 506	3.2	11	2250	11
н 497	1.8	1500°F	1923	11
н 498	2.2	tt	2202	17
н 499	2.6	11	2402	11
н 500	3.0	11	2555	11
H 501	3.2	11	2620	. "

Measured acoustic data is recorded in Reference D2.

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES / CM2// 25 FT

HM-AP-9

RUN NO.	OASPL	500	١K	2K	4K	8K	16K	32K	64K
H452L30	113.7	111.9	106.2	99-6	99.4	99.2	-98.0	94.9	0.0
84521.40	114.6	111.9	109.2	99.6	101.8	100.8	99.8	95.4	0.0
H4521.50	114.8	111.7	109.9	100.1	102.4	100.2	100.8	95.4	0.0
H4521.60	114.8	110.7	109.1	101.9	106.5	102.4	102.0	97.6	89.8
H4521.70	113.3	108.4	106.6	100.5	105.6	103.4	102.7	96.8	90.4
H4521 SO	117 1	106 1	104.2	89.2	103.5	100.7	1.01.1	96.2	89.9
¥4521 90	109-8-	103.7	102.8	99.5	101.8	100.4	100.9	96.2	87.1
H452130	116 6	114.8	108.0	103.1	103.8	104.4	100.6	96.9	0.0
H453140	117 0	174.1	110.7	103.1	106.5	105.1	102.7	97.7	0.0
84531:50	776.9	113.5	111.3	102.8	106.6	104.6	103.9	99.9	0.0
H453L60	117 0	117 2	110.8	104.9	109.8	106.3	104.7	101.4	0.0
H453170	115 4	109.5	108.1	103.5	108.4	106.8	106.7	100.3	0.0
#4531.80	173 1	107.2	105.8	101.5	106.1	103.9	103.8	99.8	0.0
#4531.90	111 7	104 5	104.1	102.1	104.4	103.1	103.0	99.9	0.0
H4541 30	122 8	118 9	118.8	111.3	107.4	108.4	109.6	104.8	0.0
1454140	120.1	116 8	114.2	106.1	110.2	109.5	106.5	100.2	0.0
1454150	139 5	116.0	114.0	105.6	109.4	107.4	106.1	101.6	0.0
4656160	119 7	114 5	113.0	107.3	117.7	108.6	107.3	103.3	96.4
1454170	117 6	111 6	110:0	106.2	111.0	108.8	108.1	102.2	0.0
14541 20	115 7	109 2	108.1	165.5	109.3	106.8	105.8	192.2	0.0
1454100	113.8	105 8	105.8	104.9	106.5	105.8	105.1	102.2	95.3
H4557 30	124 4	122 8	115.3	110.0	112.8	117.5	106.1	103.1	C.O
#4551 40	124.4	119 2	117.6	109.7	113.7	111.8	1.09.6	104.1	0.0
#455150	127 2	118.7	116.5	108.8	112.8	109.7	108.6	103.5	0.0
1455160	121 3	116.8	114.9	109.6	114.0	110.3	108.7	104.4	97.3
H455L70	119 0	112.8	111.9	108.0	112.6	109.6	108.8	103.3	98.2
#4551 80	116 1	110.1	108.7	105.7	109.8	106.6	105.9	102.4	0.0
46551.90	114 7	706.9	107.3	105.2	108.0	105.7	105.5	102.7	95.9
145561 30	1-26-7	125.3	116.3	112.0	115.9	113.1	107.3	104.4	0.0
#4561.40	124.8	121.1	119.1	111.6	115.7	113.4	110.9	105.0	0.0
14561 50	123.2	119.5	117.6	110.0	114.1	110.9	109.6	104.2	99.0
#4561.60	122.1	117.4	116.0	110.6	114.9	111.2	109.5	105.1	98.2
#4561.70	119.8	113.8	112.6	108.1	113.6	110.5	110.0	103.7	98.6
H456T 80	117.1	110.5	109.8	106.7	111.1	107.6	106.6	103.2	98.6
#4561.90	115 6	107.7	108.2	106.1	108.7	106.7	106.9	103.5	95.8
H4571.30	114.5	112.5	107.5	101.4	100.4	100.3	98.4	95.0	0.0
#457L40	115.3	112.5	109.9	101.6	102.9	101.3	100.2	95.9	0.0
#4571.50	115.9	112.7	111.1	101.8	103.8	101.7	102.6	97.2	0.0
H4571.60	115.1	110.6	109.9	103.3	106.7	102.7	102.2	98.6	0.0
H457L70	116.1	110.1	103.8	104.7	109.4	107.4	106.4	100.1	0.0
H457L80	113.0	107.2	105.7	102.8	106.1	103.5	103.3	98.8	0.0
H4571.90	111.3	104.2	104.3	102.6	104.1	102.2	102.1	98.0	0.0
H458L30	118.6	116.5	109.7	106.1	106.6	108.1	102.9	93.5	0.0
H458L40	118.5	114.9	112.7	105.6	108.8	108.1	104.8	98.7	0.0
H458L50	1-18.4	114.7	113.1	105.3	108.3	106.5	105.1	100.4	0.0
H458L60	117.4	112.3	111.6	105.7	110.0	106.8	105.3	101.3	0.0
H458L70	117.5	110.9	109.6	106.2	111.5	109.3	108.0	101.9	0.0
H458L80	116.6	108.8	107.8	106.0	110.9	108.4	107.7	103.8	98.0
H458L90	113.8	105.8	105.6	105.0	107.1	105.8	105.1	100.5	0.0
H459L30	123.6	122.0	113.5	110.2	112.4	112.0	106.3	102.0	0.0
H459L40	122.4	118.9	116.6	109.3	113.5	112.4	108.7	102.2	0.0
H459L50	121.2	117.2	115.7	107.8	112.3	110.1	107.8	102.9	0.0
H459L60 '	119.9	114.9	114.2	108.1	112.7	109.5	107.3	102.9	0.0
H459L70	119.8	112.9	112.0	108.6	114.2	111.1	109.9	103.7	28.6
H459L80	116.9	109.5	108.7	106.5	111.4	108.2	107.1	103.0	97.9
H459L90	115.3	106.8	107.2	106.4	109.2	107.5	106.0	102.0	0.0

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NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERENCE

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2/25 FT

HM=AP-9 RUNINO: OASPL 500 2K 4K .8K • 16K 32K 64K 1K 103.5 H460L30 128.6 127.5 117.9 114.9 115.9 113.8 107.8 0.0 H460L40 126.1 1:2.4 120.4 113.6 115.0 110.7 104.5 0.0 117.7 H460L50 124.3 120.4 119,1 <u>111.1</u> 115.5 112.6 110.6 104.8 0.0 H460L60 122.6 117.6 116.9 110.7 115.4 112.3 109.7 104.9 98.6 99.5 H460L70 121.8 115.1 114.2 116.2 113.2 104.6 111.3 111.1 111.8 120.1 112.6 110.7 109.5 105.3 100.1 H460L80 114.8 111.2 108.9 108.8 108.4 110.8 108.7 106.9 103.1 95.5 H460L90 116.9 H461L30 131.3 130.2 121.8 117.7 118.2 114-6 108.8 104.5 0.0 128.4 116.2 105.7 H461L40 125.1 122.5 115.0 120.3 111.0 0.0 Ó.0 H461L50 126.1 122.2 120.8 113.7 117.4 114.5 111.0 305.6 106.8 124.1 118.0 118.3 112.9 117.1 113.3 111.9 0.0 H461L60 122.9 116.4 115.6 112.0 117.5 113.4 111.6 105.4 100.3 H461L70 105.2 100.2 H461L80 120.2 11.3.2 112.5 110.5 114.7 110.8 109.1 103.5 95.9 117.7 109.7 109.8 109.7 111.6 109.1 107.2 H461L90

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NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERENCE

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/ CM2//25 FT

HM-AP-9

RUN=NO.	OASPL	500	ĬK	2K	4K	-8K	-16K	32K	64K
H502L30	126.7	122.3	123.6	115.0	115,1	105.5	100.1	94.7	´ ∩ ∩
H502L40	126.8	122.5	123.7	113.5	115.5	107.3	101.5	94 7	0.0
H502L50	124.7	120.9	120.8	111.9	114.7	107.8	103.0	97.8-	0.0
H502L60	120.5	115.9	115.9	109.5	112.5	106.8	102 3	97.0	0.2
H502L70	117.4	112.0	111.4	107.4	111.1	106.2	102.5	06 1	0.0
H5021-80	112.6	106.4	105.9	104.3	106 3	102 6	102.0	40.1 0/ 0	0.0
H502120	111.0	103.3	105.6	103 6	100.5	102.0	07 1	94.0	5.0
H503L30	136.6	125.5	126 6	120.2	122 0	1-12 9	100 0	91.3	0.0
H503L40	131 2	125.7	127 5	120.2	122.2	115.0	109.8	106./	0.0
H5031.50	129 2	124 4	125 5	117 /	120.5	112.7	110.0	105.9	0.0
H503L60	124 7	110 3	120 5	11.2 6	117 2	111 2	107 (102.6	0,0
85031.70	120.8	114 6	11/ 0	110 /	115 0	110.2	107.0	102.4	0.0
H5031-80	116.2	100-2	200 5	107 2	115.0	110.3	107.7	101.4	0,0
H5037 90	114 6	106 2	102.0	107.5	110.3	106.9	104.3	100.4	9,0
N506130	177 2	100.2	100.4	100.0	108.0	105.8	102.1	96.6	0.0
N504130	133 2	107 6	120.1	122.2	124.4	110.6	1-13.3	110.1	0,0
485047.50	132.0	126.6	107 0		120.0	119.6	115.4	110 6	0.0
N204220	127.5	121 0	100 7	121.2	124.5	118.5	114.5	110.7	0.0
NS04L00	124.3	141.9	112.1	110.0	120.8	115.6	112.4	107.8	101.7
US0/J 80	124.5	110.9	11/34	113.9	118.9	115.6	113.7	106.9	100,9
1504200	110.1	100 2	110.0	111.0	114.5	113.1	109.7	105.6	99.1
11-04630	173.7	100.2	100 2	110.2	114.1	112.3	108.7	102.2	96.6
N202770	125.0	120.0	120.3	123.0	124.1	117.0	112.8	110.0	0.0
N505150	137.0	129.0	T20.8	129:0	128.0	121.4	117.,2	112.0	109.3
N5051.50	120 4	120.0	129.5	124-2	127.4	121.2	117.5	113.3	105.8
1505500	125.0	110 0	124.0	113.0	122.0	118.4	114.7	111.1	0.0
1505270	122.0	110.0	119.2	11/.2	120.7	118.7	116.1	116.7	0.0
H5051 00	122.9	100 5	112.9	114.3	117-5	-116.8	112.6	109.1	102.5
11505150 115061 30	142.7	107.0	120 5	114.0	119 4	172.3	112.3	106.1	100.7
H506L50	133.9	120.7	129.0	124.7	124.0	11/.1	113.1	1.0.3	0.0
N5061 50	134.0	120 2	120.0	140.0	128.0	121.4	11/.2	112.2	109.2
¥506160	130.2	122.3	105 0	125.0	128.3	122.2	118.8	114.5	110.1
H506170	127 6	110 2	120.0	119.9	123.1	119.0	115.9	112.2	0:0
H506180	12/.0	112.4	112 5	110.4	141.7	1:19.9	11/.4	112.1	107.8
N5061 90	126.2	110 1	110 6	112.0	120 5	118.1	113.9	110.5	104.2
11/07130	127.5	100.1	122.0	110.0	120.5	116.8	113.8	107.9	102.2
1427120	178 5	102 2	124.7	118.0	115.1	107.8	102.7	98.9	0.0
2/67150	126.0	101 5	120.1	11/ 1 TTO'T	11/.0	110.2	104.6	98.9	0.0
R497160	120.1	110 /	110 0	114.L	110.0	108.7	103.8	97.5	0.0
H4971.70	118 5	112 8	112 0	100. J	110.4	110.0	104.6	99.5	0.0
H497180	114.2	107 5	10.9 1	105 0 T00'3	112.0	107.0	103.3	95.4	0.9
-H495130	129.2	126.0	1.04 1 1710'-T	102.0	100.0	103.4	99.4	\$3.9	87.1
NA087 40	123.5	124.7	100.1	121.0	118.4	113.8	108.8	103.9	0.0
P/0815C	120 6	122.1	126.4	110 5	123.2	117.0	111.5	106.6	0.0
1490150 1408160	125.0	110 7	122.5	119.0	142.0	114.9	110.8	105.9	0.0
NA981 70	122 0	116 7	115 0	1/10/1	117 0	113.8	103.8	105.3	0.0
H492120	117 9	106 2	110.0	100 1	112 2	100 0 TTT'9	T03.3	102.1	0.0
86991 . 0	130 0	126 7	196 /	107.1	170 0 TT2.7	100.2	104.9	100.4	0.0
44997-4n	1-26 7	128 1	131 0	126 2	102 7	101.0	111./	10/.4	107 7
84991 50	1.22 7	126.2	128 0	123 5	120.4	141.4	110.3	111.8	10/ · /
46991-50	-130 4	122.5	125 2	120.0	125.4	113°0 TTA'0	110.3	777.0	0.0
H4Q91-70	12:2 0	116 3-	118 2	1.15 =	142.1	116 4	114.8	111.4	0.0
H4991.50	726 1	114.5	110.2	110 %	115.0	TTD.0	100 F	107.8	0.0
4777490	34V+1	44060	110.0	170.4	TT3.0-	111.1	100.2-	T03.8	98.5

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

OCTAVE BAND LEVEL HB RE: 0.0002 DYNES/CM2/25 FT

			- 11W-	-APY					
RUNNO	OASPL	500	-ĪK	ŻΚ	4K	-8K	16K	32K	64K
H500L30	132.1	128.5	127.3	122.6	121.3	115.8	111.7	102.5	0.0
H500L4C	135.0	128.8	1.31.4	125.6	126.5	120.7	116.5	111.8	107.7
H500L50	134.6	127.8	129.7	125.5	128.7	122.1	119.2	114.1	110.5
H500L60	131.6	123.7 [.]	126.1	122.3	126.6	120.4	116.5	112.8	107.8
H500L70	127.4	118.3	119.8	118.4	122.3	119.1	116.8	111.5	107.3
H200180	124.7	116.1	114.4	115.4	119.9	117.8	113.8	109.4	103.4
H501L30	133.3	130.0	128.1	123.9	122.5	116.8	113.2	108.6	0.0
H501L40	136.0	130.0	132.4	126.6	1274	121.5	117.0	112.7	108.4
H501L50	135.5	128,9	130.5	126.7	129.4	122.8	119.7	114.7	111.0
P5011.60	133.4	125.5	127.9	124.4	128.3	122.1	118.2	114.4	109.2
H501L70	128.6	119.6	121.6	119.9	123.3	119.9	117.7	112.1	107.8
H501L80	125.6	114.4	116.0	116.7	121.2	118.6	114.7	111.4	107.1

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE





HM-AP-12 NOZZLE

(ANNULUS, AR 4.0)

Description

The HM-AP-12 is an annulus nozzle that provides ventilation to the center tase area through hollow struts. The hollow struts lead from the outside periphery of the nozzle to a hollow plug that projects into the primary flow.

Number of Elements: one annulus

Area Ratio: 4.0

Flow Area: 13.2 square inches

Annulus Width: 1.1 inches

Outside Diameter of Annulus: 8.2 inches

Exit Cant Angle: 0 degrees

Material: 321 CRES



D25

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HM-AP-12

(Annulus)

Remarks

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The HM-AP-12 nozzle was tested with various hardware edded downstream of the nozzle exit plane, see References D3, D4 & D5. The configurations tested were:

- (a) Pure Annulus with ventilation to the center region.
- (b) Pure Annulus with 11.4" diameter ejector.
- (c) Pure Annulas with 11.4" diameter ejector and 100% penetration of the jet with chutes.
- (d) Pure Annulus with cylindrical centerbody.
- (e) Pure Annulus with cylindrical centerbody and 11.4" diameter ejector with 100% penetration with chutes.
- (f) Pure Annulus with cylindrical centerbody and 11.4" diameter ejector.
- (g) Pure Annulus with cylindrical centerbody and 10.5" diameter ejector and 100% penetration with chutes.
- (h) Pure Annulus with cylindrical centerbody and 10.8" diameter ejector with 100% penetration with chutes.

HM-AP-12

Facility: Annex D (Cell #1) Nozzle and microphone heights are 20 inches.

Date:

Tamo:

R.H.:

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Run No-	PT/P	$\underline{\mathbf{T}}_{\underline{\mathbf{T}}}$	<u>V; (1deal</u>)	Nozzle
н 776	1.8	1500° रू	1923 fps	HM-AP-12
н 777	2.2	11	2202	11
н 778	2.6	11	2402	11
E 779	3.0	11 ₋	2555	11
н 841	1.8	1500°F	1923 fps	4.1 Inch Round Convergent Nozzle
н 842	2.2	11	2202	n
н 843	2.6	11	2402	11
н 844	3.0	11	2555	ţi .

Measured acoustic data is recorded in Reference D2.

OCTAVE BAND LEVEL- JB RE: 0.0002 DYNES/CM2//25 FT

HM-AP-12

RUN NO

NON-INO,	OASPL	500	IK	-2K	4K-	-8K	10K-	JZK	04K
H776L40	119.3	115.0	114.0	106.0 [.]	111.0	109.0	104.0	96.0	÷_0- 0
H776L50	117.9	113.0	113.0	106.0	110.0	107.0	104-0	97 Ó	94 N
H776L60-	116.7	111.0	111.0	105.0	110.0	107.0	104.0	-98-0	91.0
H776L70-	115.2	108.5	109.0	104.0	109.5	106.0	103.5	-96.0	90-5
H776L80	112.4	106.0	106.0	102.0.	106.0	104.0	106.5	93.0	88-0
H777L40	124.5	120.5	119.0	110.0	116.0	114.0	110.0	102 0	97.6
H777L50	122.2	117.0	117Ó-	110.0	115.0	112.0	109.0	102.0	98.0
H777L60	121.0	115.0	115.0	109.0	115.0	111.0	109.0	103-0	975
H777L70	119.2	112.0	112.0	107.0	116.0	-111.0	109.0	102 0	~0.1)
H777L80	116.4	109.5	109.0	106.0	111.0	108.5	105.0	99.0	92.5
H778L40	128.4	124.0	124.0	114.0	119.0	113.0	113.0	106.0	~0.0
H778L50	125.7	120.5	121.0	113.5	118.0	115.0	112.0	105.0	101.0
H778L60	123.9	117.0	118.0	112.5	118.0	115.Ō	112.0	107.0	100.G
H778L70	122.2	114.0	115.0	111.0	117.0	114.0	112.0	106.0	101.0
H778L80	119.4	112.0	112.0	109.0	113.0	112.0	110.0	103.0	98.0
H779L40	131.9	128.0	127.5	117.0	122.0	120.0	115.0	108.0	105.0
H779L50	128.9	124.0	124.0	117.0	121.0	118.0	115.0	108.0	-0.0
H779L60	126.5	120.0	120.0	116.0	120.5	117.5	114.5	109.0	103.0
H779L70	124.6	116.5	117.0	114.0	119.0	117.0	115.0	108.5	103.0
H779L80	122.1	114.0	114.0	112.0	116.0	115.0	113.0	106.0	100.0
HS41L40	127.9	123.0	125.0	117.0	115.0	111.0	106.0	98.0	-0.0
H841L50	125.6	120.0	122.5	113.0	117.0	111.0	107.0	99.0	96.0
H841L60	121.5	115.0	117.0	111.0	115.0	110.0	107 <i>;</i> 0	99.0	-0.0
H841L70	119.0	111.0	113.0	198.0	114.0	110.5	106.0	98.0	~0.0
H841L80	114.6	107.0	108.0	105.0	109.5	105.5	102.0	94.0	88.0
H842L40	131.5	126.0	128.0	122.0	121.5	118.0	113.0	106.0	106.0
H842L50	129.9	123.0	126.0	118.0	122.0	117.0	113.0	105.0	-0.0
H842L60	126.1	118.0	131.0	116.0	120.0	116.0	112.0	105.0	98.0
H842L70	122.9	114.0	116.0	112.5	118.0	115.0	112.0	105.0	99.0
H842L80	118.8	109.0	111.0	110.0	114.0	111.0	108.0	101.0	-0.0
H843L40	133.9	127.5	130.0	124.0	126.0-	122.0	118.0	112.0	110.0
H843L50	132.9	126.0	129.0	122.0	126.0	121.0	118.0	111.0	107.0
H8431.60	129.5	121.5	124.0	119.0	124.0	120.0	117.0	111.0	-0.0
H843L70	126.7	116.0	119.0	116.0	121.0	120.0	118.0-	111.0	105.0
H843L80	122.5	111.0	113.0	113.0	117.0	117.0	113.0	107.0	100.0
H844L40	135.6	129.0	132.0	126.0	126.5	124.0	120.0	114.0	111.0
H844L50	134.6	127.5	130.0	124.0	128.0	124.0	121.0	114.5	109.0
H844L60	131.1	123.0	125.0	121.0	125.5	122.0	119.5	114.0	108.0
H844L/U	128.9	118.0	120.0	118.0	123.0	123.0	121.0	114.0	109.0
£044L8U	172.0	TT3.0	114.0	110.0	120.0	121.0	116.0	110.0	103.5

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE





032





HM-AP-15

(6 Spokes, AR 1.6)

Remarks

The HM-AP-15 nozzle was tested at Tr equal to ambient, 500°F, 800°F, 1000°F, 1400°F, 1700°F, 2000°F, 2300°F, 2600°F, and 2900°F. Seven pressure ratios, ranging from 1.117 to 4.25 were tested at each temperature. Each condition was run at least twice and some conditions three or four times to check data consistency. It was noted that data repeatability was not very good, especially at the lower temperatures. The total temperature was based on a single point measurement in a region of the burner duct where an irregular and poorly shaped temperature profile was known to exist.

Maximum noise suppression attained by the HM-AP-15 nozzle was 4 to 5 PNdB. Suppression is likely to improve if spoke penetration had been deeper. Noise suppression trends were of interest. Maximum noise suppression tended to occur at a jet velocity of about 2200 fps. Negative suppression values occurred at a jet velocity below 1300 fps on the average. A deterioration in PNL suppression was noted at jet velocities above 2200 fps. These PNL suppression characteristics have been noted to occur with other multi-element nozzles tested over a wide range of gas conditions. The HM-AP-15 jet noise output was more sensitive to pressure ratio variations than temperature. See Reference D6. HM-AP-15:

(6 Spokes, AR 1.6)

Test Facility:

Annex D (Cell #1) Nozzle and Microphone heights are 20 inches. ÷ √

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Date:

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R.H.:

Run No.	PT/P	$\underline{\mathrm{T}}\underline{\mathrm{T}}$	V_J (Ideal)	Nozzle
н 185	1.117	500°F	610 fps	HM-AP-15
н 186	1.275	11	860 -	88
н 187	1.524	11-	1170	11
н 188	1.892	11	1400	11
н 189	2.483	11	1610	39
H 190	3.190	11	1800	11
H 191	4.250	11	1960	11-
H 213	1.117	1000°F	690	97
н 214	1.275	11	1070	11
H 215	1.52և	11	1420	11
н 216	1.892	11	1720	11
H 217	2.483	11	2010	11
Н 218	3.190	13	2230	11
н 219	4.250	11	2440	11
н 227	1.117	1400°F	780	11
н 228	1.275	11	1210	11
Н 229	1.524	13	1660	11
н 230	1.890	11	1940	11
H 231	2.483	п	2260	11
Н 232	3.190	11	2520	11
н 234	4.250	11	2760	21
Н 255	1.117	2000°F	910	.11
н 256	1.275	11	1400	11
н 257	1.524	11	1860	11
н 258	1.892	11	2210	ti
н 259	2.483	11	2610	11
н 260	3.190	11	2900	H
н 261	4.250	Ħ	3190	11
H 301	1.117	2600°F	1020	11
H 302	1.275	11	1550	11
н 303	1.524	11	2160	11
н 304	1.892	11	2480	11
H 305	2.483	11	2900	11
н 306	3.190	11	3250	11
H_307	4.250			

JJ36

		HŴ		
Run Nc.	P _T /P	TT	V _J (Ideal)	Nozzle
н 377	1.117	500°F	610 fps	4.1 Inch Round Convergent Nozzle
H 318	1.275		000	 H
H 379	1.524	**	1170	11
H 300	1.892	11	1400	11
H 20T	2.403	11	7-600 TOTO	11
H 302	3.190	-11	7000	11
n 303	4:250	10009	1900	11
n 39T	7.77(1000 - F.	090	. 11
н 392	T.5()	tt	T010	31
и 393	1.724	11	1420	11
n 594 u 207	1.092	11	1120 2010	11
n 391	2.403	ít.	2010	11
n 206 U 222	3.190	Ĥ	2230	11
n 290	4.20	110000	2440	11
и 200	1 275	1400 F	100	11
n 100	1.21)	U	160	71
н 400 : Ъот	1 800	11	1000	31
H 102	2.092	tt	2260	11
11 402 11 1.02	2.405	11	2200	11
H 405), 250	ň	2760	81
н 356	4.200 1 117	2000 ⁶ ±	2100	11
H 357	1 275	1	1100	12
H 358	1 524	n	1860	11
н 350 н 350	1 802	11	2000	11
н 360	2 L83	*2	2610	11
н 361	3,100	11	2900	n
H 362	4,250	**	3190	11
н 440	1.117	2600°*	1020	11
н 441	1.275	"	1550	(I
H 442	1.524	u	2160	U.
н 443	1.892	н	2480	11
н 444	2,483	n	2900	11
н 445	3,100	11	3250	11
н 446	4.250	17	3560	**

Measured acoustic data is recorded in Reference D2.

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• NOZZLE TEST DATÀ

OGTAVE BAND LEVEL-dB RE: 0:0002 DYNES/CM2//25 FT

HM-AP-15

* ŘUN NO.	OASPL	500	١K	2K	4K	8K	16K	32K	64K
H185 140	94.5	92.6	88.2	80.5	-81.4	76.5	70.2	65.0	63 9
H185 160	94.8	92.2	88.1	83.1	85.2	80.8	76.2	73.2	66 0
H185 L70	93.4	90.6	85.7	81.4	85.5	81.1	74.9-	68.4	63.8
H185 L80	91.3	88.0	84.1	80.6	83.0	79.5	75.0	.70.2	-65 7
H186 L40	102.6	100.1	97.0	89.2	91.5	86.9	81.0	75.8	7.3 9
H186 L60	102.4	98.7	96.0	91.1	94.1	91.1	87.2	81-5	77 6
H186 L70	101.6	97.1	94.0-	90.6	94.7	92.8	87.9	80.6	75 0
H186 L80	98.3	93.7	90.8	88.0	90.9	89.9	85.4	80.8	75.2
H187 L40	110.1	106.4	104.5	97.4	102.1	97.5	92.3	87 7	84 3
H187 I.60	109.5	103.5	102.1	98.5	103.6	100.6	97.4	92 8	86 9
H187 L70	106.3	99.4	97.5	95.4	101.1	99.2	94.6	89.1	81 5
H187 L80	103.7	96.3	94.7	94.0	97.4	96.5	94.5	89.8	80.16
H188 L40	116.2	111.8	110.6	104.0	108.8	105.8	100.8	95.6	88 5
H188 L60	114.5	107.6	106.3	104.0	109.3	106.0	103.2	99.1	91.5
H188 L70	112.3	104.0	103.2	101.3	107.1	105.7	102.4	96.9	90.6
H188 L80	109.6	100.8	99.8	99.5	103.6	103.0	100.9	97.2	89 0
1199 L40	123.0	117.7	116.9	110.8	116.4	113.6	108.9	104.7	98.6
H139 L60	121.1	113.1	112.3	110.9	115.7	113.8	-111.1	107.8	102.2
H139 L70	118.7	108.5	107.9	106.7	113.7	112.9	109.5	104.8	99.4
H189 L80	116.3	104.2	103.9	103.9	109.0	111.7	109.0	106.0	98.3
H190 L40	128.7	123.1	123.3	116.8	121.9	113.7	113.8	110.2	106.5
H190 1.60	124.9	115.6	115.8	114.7	119.7	117.5	114.3	111.5	105.8
H190 L70	122.9	111.8	111.7	111.9	117.6	117.5	113.8	108.8	103.3
H190 L80	121.9	108.1	108.2	110.2	115.9	117.2	114.5	110.4	102.8
H191 L40 4	134.5	129.2	130.6	124.6	125.8	121.1	116.0	112.3	107.9
H191 L60	130.8	123.2	122.6	121.7	125.1	123.3	119.1	115.8	101.1
H191 L70	128,9	117.3	117.6	120.5	124.2	123.0	117.7	112.9	208.0
H181 L80	136,6	113.4	113.5	119.2	121.8	120.5	116.3	113.1	105.5
H312 L40	97.0	94.9	91.5	83.8	82.3	78:4	71.3	69.7	73.0
H213 L60	99.8	96.9	94.1	88.2	90.3	85.0	79.3	71.9	74.8
H213 L70	94.3	91.5	87.5	82.2	85.9	81.4	75.6	68,9	63.8
H213 L80	92.8	89.7	85.5	91.4	84.6	81.0	75.5	70.9	65.2
H214 L40	108.1	105.2	103.4	94.5	96.8	91.0	84,2	81.2	83.2
H214 L60	110,1	106.1	104.1	99.4	102.6	97.5	92.1	84.5	85.4
H214 L70	104.7	100.2	97.1	93.0	99.3	942	88.2	82.0	75.4
H214 L80	101.9	97.7	94.2	91.8	94.7	92.5	87.9	03.4	76.1
H215 L40	115.1	111.3	110.4	102.4	106.3-	100.9	94.8	89.2	84.6
H215 L60	117.3	112.0	111.7	106.6	110.8	106.1	102.5	96.4-	90.3
H215 L70	111.2	105.6	104.2	100.1	105.1	102.4	98.0	91.9	85.9
H215 L80	108.7	102.9	101.2	97.5	102.3	100.6	96.9	92.9	-86.2
H216 L40	120.9	116.5	116.0	109.1	113.0	109.1	103.8	99.5	95.4
H216 L60	122.7	116.4	116.7	112.8	116.5	112.9	109.4	104.4	-100,1
H216 L70	116.3	109.0	108.5	104.9	111.3	108.6	104.0	99.0	93.0
H216 L80	113.0	105.6	104.5	102.3	107.0	105.6	102.9	99.5	91.7
H217 L40	126.1	121.3	120.8	114.0	118.7	115.4	111.0	106.5	100./
H217 L60	127.1	120.2	121.2	116.9	121.1	117.6	114.6	110.2	105.4
H217 1.70	121.2	112.6	113.0	110.2	116.5	113.8	110.1	105.4	100.4
H217 L80	117.4	108.2	108.0	105.7	111.5	111.0	108.4	105.4	98.1
H218 L40	131.9	126.7	127.4	120.5	123.6	121.5	115.1	111.7	10//
H218 L60	131.7	124.6	125.0	121.8	126.2	122.6	118.6	114.0	110.9
HZI8 L/0	124.8	112.4	110.2	111 3	176 2	110.U	112.2	TOR'C	102.5
H218 L80	122.2	111.0	114.3	136 0	176 0	100 (TTD')	115.4	109.7	102.8
H219 L40	135.0	105 1	120 5	120.0	120.0 120 r	125 5	1.10./	112./	1-1-2-0
R010 100	100.0	122.1	130 2	106 T	120.7	105 5	10. 0 121.0	TT/ ')	11,3.9
H210 170	132.0	177.7	101.0	140.L	120.5	123.3	121.8	117.5	113.9
1210 I 80	124.2	115 0	122.3	112 1 TTÄ*O	122 1	120 5	11/.4	132.6	108.2
ET13 FOO	170.0	172.0	TT0.2	TT1°T.	744.7	120.5	T10.0	112.4	105.6
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE									

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OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2//25 FT

HM=AP=15

RUN NO.	OASPL	-500	1K	-2K	4K	8K	-16K	32K	64K
H227 T.40	99.7	07 5	<u>0</u> 74 /	96 6	95 -0-	01 (71. 6	mā .	
H227 1.60	101 3	07.9	05 5	00.0	02.9	01.0	./4.6	71.1	74.2
H227 T70	07 7	01.0	00 /	907. 06 e	93.2	8/.5	82.1	74.4	75.5
H227 T.80	9/ 6	01-2	90.4 07 1	.00.0	90.0	86./	80.1	74.0	71.7
H228 140	110 6	107 /	105 7	03.0	85.4	81.4	/9.2	73.9	65.8
H228 L60	111.4	107.4	105.7	97.8	99.3	94.4	87.7	83.1	83.7
H228 T70	107 7	100.9	100.0	100.9	104.4	100.9	94.7	86.9	86.0
H228 180	107.7	402.0	T00.9	90.3	101-2	98,6	93.1	86.2	82.2
-H220 140	117 2	112 2	110 0	92.5	96.0	94-1	90.8	85.4	74.4
H229 140	118 7	112.0	112.0	105.6	107.6	104.0	98.5	92.5	85.9
H229 E00	113 2	107 2	· 104 3	108.2	112.4	107.3	104.1	978	89.6
H229 180	110 7	10/.3	100.3	102.3	1073	104.8	100.5	93.4	86.0
H230 T40	121 6	104.7	112.0	100.5	104.6	102,6	99.5	94.9	86.3
H230 170	124.0	116 0	117 O	109.5	114.2	110.9	106.3	101.7	96.5
H230 T70	1-1 8 7	110.0	110 0	114.8	118.2	114.6	111.4	105.9	100.5
H230 180	116.7	104 4	105 3	108.5	113.4	111.4	107.3	101.6	95.8
H231 1-40	127 1	100.0	103.3	104.4	108.3	107.4	104.8	100.6	91.2
H231 L60	128 0	107 0	121.0	114.7	120.3	116.9	112.7	108.5	102.5
H231 L70	123.4	11/ 3	116.0	112.2	123.2	119.6	116.0	111.5	106.0
H231 L80	120.0	110 6	110 5	100 0	118.7	110.5	112.1	107.3	101.0
H232 L40	132 5	176 0	120.0	109.2	. 114.5	113.5	111.2	107.3	99.4
H232 L60	133 0	120.5	120.0	122.0	127.0	1/1./	116.7	112.9	108.5
H232 I.70	126.1	116.8	118 2	115 5	127.0	122.9	119.9	115.0	111.3
H232 L80	123.3	113.2	113 5	112 5	1177 6	119.1	114.5	109.9	104.2
H234 L30	99.6	97.9	03 4	82.0	11/.0	71/.2	114.2	110.6	102.7
H234 L50	100.0	97.4	94.7	88.0	04.1 99 2	70.0	70.6	70.5	73.7
H234 L60	100.1	97.3	94.7	88 0	01 2	05./	//.4	13.4	74.6
H234 L70	98.9	95.4	92.1	87 3-	51.42 01 Å	02.4	00.2	/3.0	74.1
H234 L90	93.9	89.2	87.7	.83.4	87 0	94.2	70 5	72.1	74.0
H255 L40	100.7	98.6	95.1	87 0	87.0	04°.J 20 1	77.0	74+1	00.8
H255 L60	100.8	97.7	94.3	89.9	92 9	85 0	90 /	11.1	74.7
H253 L70	100.2	96.4	92.5	88.9	92.5	80.5	00.4 01 7	75.5	74.4
H255 L80	95.7	92.3	88.1	85.0	88.0	86 7	02.7 90 1	72.9	/3.3
H256 L40	112.1	108.8	107.5	100.9	100.8	97 g	00.1	74.0	00.9
H256 L60	112.0	107.5	106.5	101.5	104.6	100 3	0/ 0	07.5	04.0 95.0
H256 L70	110.8	105.2	103.6	99.7	105.0	102 7	94.9	80.0	0.00
H256 L80	105.9	101.1	98.3	95.5	99.1	97.3	07 6	87 7	70 7
H257 L40	119.2	114.7	114.6	108.5	109.9	107.2	101 0	07.7	70.J 05.0
H257 L60	119.6	113.4	113.6	109.8	113.9	109.3	104 5	07 0	05 /
H257 L70	118.1	110.5	110.1	107.3	113.5	110.7	104.6	07 0	90.4 80.6
H257 L80	112.8	106.5	104.6	103.2	106.3	105.3	101.5	97.9	07.0 88 7
H258 L40	124.2	119.0	118.5	113.0	117.3	114.0	109.0	10/2	08.6
H258 I.60	124.5	117.5]18.8	115.0	118.7	114.5	110.7	104.2	100.0
H258 L70	123.7	114.8	115.5	112.9	119.4	116.4	111.4	104 9	08 7
H258 L8C	117.3	109.8	109.0	106.5	111.6	110.3	106.6	102.5	02.2
H259 L40	129.9	124.0	124.2	118.0	123.8	120.6	115.1	111.2	107.8
H259 L60	1,29.9	122.5	123.5	120.2	124.9	120.2	115.7	110.9	107.8
H259 L70	127.9	118.0	119.4	117.3	124.0	120.8	115.2	109.9	103.8
H259 L80	122.2	113.4	113.2	111.9	117.1	115.4	112.1	108.0	100.5
H260 L40	132.9	127.2	128.4	122.2	125.3	121.8	116.6	112.4	108.5
H260 L60	133.6	125.8	127.1	123.7	128.9	123.8	119.3	114.9	110.7
H260 L70	121.2	121.6	123.1	121.7	126.5	174.4	118.9	113.8	108.9
H260 L80	125.3	115.3	115.4	115.8	119.8	119.4	114.8	111.4	103.5

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2/25 FT

HM-AP-15

RUN-NO.
H261L40
H2611.60

RUN-NO.	OASPL	500	١ĸ	2K	4K	8K	16K	32K	-64K
H261L40	136.5	132.1	132.3	126.5	126.6	122.5	117.7	113.7	109.3
H261L60	136.4	129.5	131.3	126.8	130.2	126.0	122.0	118.1	113 8
H261L70	133.6	124.4	126.3	124.5	128.6	126.1	121.2	116.2	111.3
H261L80	129.2	118.6	119.6	119.7	123.7	123.4	118.7	114 9	109 2
H301L30	104.0	102.2	98.3	89.8	87.1	81.7	74.6	71 0	73-1
H301L50	103.7	101.3	98.6	90.8	91.1	85.4	79.3	74.7	7/ 3
H301L60	104.0	100.6	98.1	92.9	96.0	89.1	83 4	77.8	74.5
H301L70	102.9	99.5	95.8	91.7	95.6	90.8	85 3	77.8	73.0
H302L30	114.1	111.8	108.5	101.6	101.5	94.9	88 7	83.2	83.2
H302L50	114.6	111.1	110.2	102.2	104.4	99.2	93 6	87 5	84 8
H302L60	114.8	110.2	109.4	104.6	107.3	102.4	97 3	91 1	25.3
H302L70	113.1	108.3	106.2	102.1	107.1	103.2	98.4	90.9	85 3
H302L90	106.8	100.9	99.9	97.2	100.1	98.3	94 3	88.6	80.7
H303L30	120.4	117.6	114.2	108.4	111.1	105.5	100.4	94.9	00.7
H303L50	122.1	117.6	117.7	110.3	113.5	109.2	104 6	98.9	05.5
H303L60	122.9	116.7	117.1	113.3	117.1	111.8	107.2	101 8	96.1
H303L70	121.1	114.4	113.9	110.3	116.3	112.0	107.4	100.4	95.5
H303L90	112.9	106.1	105.5	103.8	106.2	105.4	101 8	Q6 7	8G 1
H304L30	125.7	123.2	117.3	112.8	117.3	113.7	109 0	104 0	97.6
H304L50	127.0	121.4	122.2	115.4	120.2	115.8	111 8	106 6	101 3
H304L60	127.5	120.3	122.0	118.6	122.1	116.1	111 2	105 4	101.5
H304L70	126.2	117.6	118.3	116.2	122.1	17.7	113 4	107 5	102 2
H304L90	116.8	108.4	108.7	108.1	110.5	109.9	106 5	102 5	94 0
, H305L30	1.30.9	128.0	123.9	119.1	122.5	110.0	113 1	102.0	105 3
' H305L50	133.1	127.3	127.9	121.7	126.5	122.7	118 6	114 0	100.0
H305L60	133.2	125.5	127.4	124.2	127.2	122.9	119 0	114.0	110 0
-H305L70	130.9	122.1	123.7	121.1	126.4	122.2	118 0	112 7	108 /
H305L90	121.7	112.3	113.1	112.5	115.7	114.9	112.6	108 1	101 4
H306L30	134.6	132.3	128.0	122.9	124.3	118.4	113.7	109.4	105.6
H306L50	136.5	130.5	131.6	126.2	129.3	126.0	121.9	117.1	112 5
H306L60	136.7	128.3	129.9	127.8	131.9	127.1	123.3	119 3	114 4
H306L70	132.4	122.6	124.6	123.6	127.8	124.5	119.9	114 7	110 2
H306L90	125.1	114.1	114.5	116.4	118.4	119.9	116.3	111.7	104 8
H307L3C	138.2	136.3	131.5	126.0	125.4	120.1	115.5	111.2	106.6
H307L50	141.0	135.0	136.7	131.1	133.2	129.1	124.7	120.9	118 0
H307L60	140.9	133.0	134.8	132.4	135.6	130.4	126.7	123.2	119.4
H307L70	136.2	126.7	129.0	127.4	131.8	127.5	123.5	118.6	114.2
H307L90	129.4	117.2	118.2	120.9	124.6	123.2	119.5	115.3	109.5
H377L30	96.1	94.9	89.1	79.6	72.0	75.6	0.0	0.0	0.0
H377L40	97.2	95.5	91.3	82.2 ⁻	79.8	78.9	0.0	0.0	0.0
H377L50	94.9	93.0	89.0	81.1	80.3	76.0	68.8	0:0	0.0
H377L60	95.0	92.8	89.2	81.6	82.2	77.8	71.6	67.2	0.0
H377L70	92.7	90.7	86.8	78.8	79.9	75.1	69.7	62.6	0.0
H377L80	90.9	88.9	84.5	77.7	78.3	74.6	68.6	63.5	0.0
H377L90	89.6	86.9	83.7	78.9	78.4	74.8	69.2	64.6	0.0
H378L30	105.1	103.7	98.8	89.1	85.9	82.3	76.5	0.0	0.0
H378L40	105.9	103.6	100.5	92.0	93.4	87.4	82.5	0.0	0.0
H378L50	103.2	100.6	97.6	90.6	92.1	86.2	82.3	78.2	0.0
H378L60	102.4	99.2	96.9	91.1	93.0	87.7	94.3	79.2	0.0
H378L70	99.2	95.9	93.6	87.6	90.2	84.6	82.1	75.0	0.0
H378L80	96.7	93.0	91.1	85.6	87.9	83.8	80.2	74.5	0.0
H378L90	95.3	90.8	89.8	85.9	-87.0	83.4	80.4	73.8	0.0

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2//25 FT

HM-AP-15

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RUN NO	OASPL	500	١K	2K	4K	8K	16K	32K	64K
H379L30	114.2	112.3	109.1	98.6	95.6	91.0	85.9	-0.0	-0.0
H379L40	113.9	111.3	100.1	100.1	102.1	95.7	91.5	86.6	-0.0
H379L50	110.3	107.0	104.6	98.7	101.4	95.4	92.2	88.2	-0.0
H379L60	108.4	104.0	102.6	98.1	101.0	96.2	93.4	87.3	-0.0
H379L70	104.8	99.7	98.8	94.3	98.2	93.4	91.8	83.5	-0.0
H379L80	102.4	96.7	96.0	93.0	95.9	92.1	89.0-	83.7	-0.0 -0
H379L90	101.6	94.7	95.2	93.2	95.4	91.9	89.4	83.0	-0.0
H380L30	122.1	118.9	118.3	110.0	106.0	100.8	95.7	-0.0	-0.0
H380L40	121.6	117.8	117.8	108.8	110.7	104.3	100.4	96.0	-0.0
H380L50	118.3	114-0	113.4	107.1	110.3	104.8	101.9	97.0	-0.0
H380L60	114.9	109.3	108.7	105.0	108.9	104.2	101.4	95.9	-0.0
H380L70	110.5	103.9	103.8	100.7	104.9	100.9	99.0	92.2	-0.0
H380L80	109.1	101.4	101.8	101.0	103.3	100.6	97.4	92.3	-0.0
H380L90	106.6	98.6	99.9	98.8	100.4	97.8	95.7	89.3	-0.0
H381L30	129.0	124.2	125.0	119.9	119.4	113.4	109.6	107.1	-0.0
H381L40	128.6	123.1	124.6	118.9	120.4	112.11	110.8	105.2	-0.0
H381L50	125.6	119.8	120.5	115.9	118.5	113.7	111.5	107.1	-0.0
H381L50	122.2	114.3	114.6	114.0	116.6	11.3.4	111.2	105.7	-0.0
H381L70	118.1	108.4	109.1	110.4	112.4	110.7	108.7	102.2	-0.0
H381L80	116.3	104.9	105.4	108.5	110.6	110.5	106.3	101.9	92.7
H381L90	116.6	103.9	105.1	109.1	111.7	110.3	107.2	101.3	93.2
H382L30	132.8	127.9	128.4	125.2	121.7	117.8	113.9	111.1	-0.0
H382L40	134.2	127.8	129.6	125.7	127.3	121.4	118.0	113.8	-0.0
H382L50	129.6	123.1	123.4	123.0	122.4	118.0	115.5	112.5	-0.0
H328L60	127.8	118.2	119.3	120.7	121.6	120.5	117.7	113.0	107.0
H382L70	125.0	111.6	115.3	120.5	118.6	116.8	116.5	107.8	1.1.6
H382L80	123.5	108.7	111.1	116.6	119.6	116.0	112.6	108.9	101.6
H382L90	124.1	108.1	110.0	116.6	121.1	115.6	113.0	107.7	101.3
W383L30	135.8	131.9	131.7	120.7	122.5	119.0	115.4	112.3	-0.0
H383L40	138.2	131.3	134.1	128.9	131.0	125.6	122.2	117.9	113.8
H383L50	132.8	126.3	127.1	123.6	126.0	122.5	120.2	117.4	112.2
H383L60	131.2	121.6	123.0	122.1	125.6	124.3	120.8	116.9	113.4
H383L70	128.0	114.8	118.5	119.0	124.0	120.4	118.3	112.5	-6.0
H383L80	128.1	111.6	115.8	120.5	125.0	120.0	116.6	113.4	-0.0
B383L90	128.9	112.2	118.7	123.3	124.8	119.9	115.9	112.5	-0.0
H391L30	100.6	99.4	93.8	84.0	77.5	75.6	69.2	-0.0	-0.0
H391L40	99.9	98.1	94.5	84.4	82.3	77.6	71.6	-C.O	-0.0
H391L50	98.3	96.0	93.3	84.6	83.6	77.5	72.4	-0.0	-0.0
H391L60	97.0	94.3	92.1	84.7	85.1	78.3	73.7	68.7	-0.0
H391L70	94.4	92.6	89.5	82.0	82.7	76.1	71.6	64.6	-2.0
H391L80	93.3	89.5	87.3	80.7	80.7	75.4	70.7	65.8	-0.0
H391L90	81.3	87.7	&ó.2	81.8	81.4	76.4	71.6	66.4	-0.0
H392L30	113.6	112.2	107.3	97.4	92.4	88.1	82.4	-0.0	-0.0
H392L40	112.6	110.7	107.2	97.5	96.9	90.6	85.0	-0.0	-0.0
H392L50	110.0	107.8	104.5	97.1	97.5	90.8	86.2	-0.0	-0.0
H392L60	108.1	105.0	102.7	96.7	98.5	91.7	87.3	81.1	-0.0
H392L70	104.5	101.0	98.9	93.7	96.0	90.0	86.1	78.4	-0.0
H392L80	101.6	97.8	95.9	91.9	93.3	88.3	83.6	78.9	-0.0
H392L90	100.6	95.3	95.2	92.3	93.3	88.6	84.5	78.5	-0.0
H393L30	121.6	119.3	117.2	107.5	103.4	97.9	92.3	-0.0	-0.0
H393L40	122.2	119.2	118.3	107.6	108.7	102.1	96.6	-0.0	-0.0
H393L50 ·	119.4	116.4	115.0	106.6	107.8	101.5	97.2	-0.0	-0.0
H393L60	116.3	112.5	111.0	105.4	107.8	102.1	97.7	92.0	-0.0
H393L70	111.6	107.0	105.8	101.4	104.4	99.4	96.3	88.8	-0.0
H393L80	108.2	103.4	101.9	99.3	101.0	96.8	92.3	88.3	-0.0
113931.90	107.4	100.9	101.6	99.5	100.6	97.1	93.5	88.1	-0.0
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OCTAVE BAND LEVEL - dB RE: 0.0002 DYNES / CM2//25 FT

HM-AP-15

RUN NO	OASPL	500	1K	2K	4K	-8K	16K	- 32K	64K
H394L30	127.5	122.3	124.5	117.7	114.3	108.6	102.8	98.5	-0.0
H394L40	128.4	123.9	125.1	116.6	118.0	110.9	105.9	100.1	-0.0
K394L50	125.3	121.1	121.4	1:3.1	115.7	108.1	105.4	100.8	-0.0
H394L60	122.7	118.2	117.9	111.9	114.9	109.3	105.8	100.5	-0.0
H394L70	116.8	111.0	111.4	106.5	110.6	105.1	102.7	94.6	-0.0
E394L80	112.8	106.9	106.4	103.4	106.8	102.7	99.6	94.2	-0.0
H394L90	111.9	104.5	105.7	103.6	105.8	102.2	99.4	93.5	-0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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	UCTAVE BAND LEVEL AB KE. 0.00002 DINLOV CM V 2011
4	HM-AP-15
	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
	H398L30103.3102.495.686.379.777.670.3 -0.0 -0.0 H398L50100.697.486.584.679.572.8 -0.0 -0.0 H398L50100.797.995.988.688.381.876.6 -0.0 -0.0 H398L7097.294.292.385.486.178.472.8 68.0 -0.0 H398L7097.294.292.385.486.178.472.8 68.0 -0.0 H398L8094.591.589.383.184.078.472.8 68.0 -0.0 H398L9093.489.283.5 63.6 84.176.573.9 65.2 -0.0 H399L30114.9113.1110.499.899.792.286.6 -0.0 -0.0 H399L50112.7113.1100.499.490.3 -0.0 -0.0 H399L70106.4102.6100.995.998.491.888.380.4 -0.0 H399L70106.4102.6100.995.990.486.480.1 -0.0 H399L70106.4102.6100.995.990.486.480.1 -0.0 H399L70106.4102.6100.995.390.486.480.1 -0.0 H400L30122.5119.6118.6110.0104.799.092.9 -0.0 -0.0 H400L40123.6120.1 <t< td=""></t<>
<u> </u>	H402L70 122.9 114.9 117.1 113.4 117.5 112.9 111.4 104.2 -0.0 H402L80 119.4 110.5 111.4 110.4 114.0 112.0 109.0 104.0 -6.0 H402L90 118.9 108.8 110.9 110.1 113.6 111.8 108.7 102.3 -0.0 H403L30 134.7 131.3 129.3 126.2 122.8 118.7 115.1 111.9 -0.0 NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE 100.0

North Start

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OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2//25 FT

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FIAA

HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	- 8K	16K	32K	64K
H403L40	136.3	130.3	132.3	127.3	128.4	122.6	119.1	114.7	-0.0
H403L50	135.2	128.6	130.7	126.2	128.2	122.7	120.2	117.1	111.9
H403L60	132.7	126.0	127.7	123.3	126.1	121.3	118.7	114.5	-0.0
H403L70	127.0	118.1	120.0	117.8	121.6	118.4	116.7	110.2	103.3
H403L80	125.0	113.1	114.3	116.3	120.1	119.1	115.1	110.6	103.2
H403L90	124.3	111.3	113.1	115.7	120.4	116.8	114.9	109.4	102.6

-OCTAVE-BAND-LEVEL-dB -RE: -0.0002 D' NES/CM2//25.FT

HM-AP-15

RUN NO.	OASPI	500	1K	2K	4K	8K	16K	32K	64K
H404L30	136.3	134.1	29.8	126.2	1221	· 118 7	115 3	11.1 5	0.0
H404L40	138.4	133.0	35.0	128.8	1-28 0	123.6	1-20 /	115 0	0.0
H404L50	137.9	131.6	133.6	1.28.9	130 4	125.0	120.4	110.4	0.0
H404L60	135.2	128.6	130.1	126 0	127 8	122.1	122.0	117.0	114.2
H404L70	130.5	121.2	123.3	121 5	125 1	129.0	122.0	-1/2/ .9	113.9
L404L80	128.6	116.1	118 3	120 6	12/ 0	122.2	120.1	1145	109.7
H404L90	1.29 1	- 1:14 8	117.2	121 1	125.0	121.0	118.2	114.0	109.2
H356L30	105.8	104.8	08 5	80-1-	12J ./	120.9	118.3	113.8	108.7
E356L40	105.9	- 104.2	100.5	80 8	00 0	11.5	/0.1	Ų.Ų	0.0
H356L50	104.1	101.7	99.2	01.0	00.0	00.3	75.0	.0	0.0
H356L60	103.1	100.1	08.3	01 6	01 0	01.3	75.9	0.0	0.0
H356L70	100.2	96.7	05 7	80.0	00.3	02.0	11-+5	10.0	0.0
H356L80	97.3	93 7	62 4	86.8	20.0	04./	77.5	/0./	0.0
H356L90	97.5	92 7	93 1	98.2	00.0	01.0	/0.i	/2.1	0.0
H357L30	118 0	115 7	112 7	102 1	60./	03.0	//./	/3.6	0.0
H357L40	118 2	115 0	11% 0	103.1	30.4 102 C	91.0	84.7	0.0	0.0
H357L50	115 7	112.8	111 2	103.5	102.0	94.0	88.0	0.0	0.0
HH357L60	113 6	110 1	708 2	103.4	105.0	92.1	39.8	0.0	0.0
H357L70	109.6	105 2	104 0	00 2	102.1	97.5	91./	86.9	0.0
H357L80	106.1	101 0	100 5	96.7	002.7	90.0	91.3	83.4	0.0
H357L90	105.1	99 0	90 0	06.0	00 0	93.1	00.1	82.5	0.0
H358L30	126.1	122.0	122 8	116.1	30.2	102 0	05.9	82.0	0.0
H358L40	126.6	122.3	123 5	116.1	11/. 6	102.0	95.9	0.0	0.0
H358L50	124.7	120.4	121.2	113 1	116 5	106.0	99./	95.0	0.0
H358L60	122.3	117.9	117.7	111 6	114.1	100.5	101.2	90.5	- 0.0
H358L70	117.0	111.7	111.4	106.9	110.8	10/ 0	100 1	91.2	0.0
H358L80	112.8	106.9	106 6	103 6	106.0	102.2	100.1	97.1	0.0
H358L90	112.0	104.6	105.9	104.3	105 9	102.1	97.0	· 01 0	0.0
B359L30	130.9	126.0	125.9	123.5	120.3	114 2	104 2	91.0 105 6	0.0
H359L40	132.2	126.8	128.3	122.8	124.1	116 4	173 5	107.8	0.0
H359L50	131.2	126.0	127.4	121.0	122.7	115 3	171 5	107.8	0.0
H359L60	128.2	122.8	124.0	117.9	120.8	114.8	110 5	107.0	0.0
H359L70	122.9	117.1	117.3	112.7	117.0	111 8	107 7	101 0	0.0
H359L80	118.0	111.4	110.8	108.9	112.6	108.6	104 1	09.2	90.6
H359L90	115.9	1078	109.5	107.1	110.1	106.7	103.5	97 4	80.0
H360L30	132.8	1.28.3	127.8	125.1	121.0	117.9	113.5	110.8	0.0
H360L40	135.1	128.7	130.9	126.8	127.2	122.0	117.9	113.8	0.0
H360L50	135.1	128.0	130.7	126.9	127.6	123.0	120.1	116.6	111.7
H360L60	133.1	126.1	128.4	124.2	126.7	121.5	117.6	113.7	0.0
H360L70	127.2	119.2	121.6	117.6	121.7	117.5	114.5	108.4	102.1
H360L80	122.4	113.4	114.2	113.1	117.4	114.7	111.6	107.3	100.2
H360L90	121.4	111.3	113.1	113.0	116.2	114.3	110.9	105.5	99.1
H361L30	135.1	131.8	129.8	126.1	123.2	118.3	115.8	112.7	108.9
H361L40	137.2	131.3	133.1	128.1	129.3	123.3	119.8	116.1	111.9
H361L50	137.5	1.30.0	132.8	128.5	131.2	125.0	123,1	119.7	114.6
H361L60	135.9	127.5	130.2	126.9	130.6	125.6	122.4	118.6	114.4
H36LL70	130.4	121.1	123.7	121.0	125.6	121.5	118.6	113.5	108.6
H361L80	126.8	115.0	116.6	117.2	122.1	120.6	117.0	112.9	106.0
H361L90	125.5	113.5	114.9	116.4	121.1	118.9	115.4	111.0	105.2
H362L30	137.9	135.4	132.0	128.2	124.7	120.9	3.17.5	114.2	110.1
H362L40	139.4	134.2	135.7	129.8	129.6	124.8	121.6	117.6	113.2
H362L50	140.5	134.0	136.0	131.6	133.1	127.7	125.2	122.3	119.1
H362L60	137.8	131.0	132.4	128.4	131.7	127.2	123.9	120.3	115.9
H362L70	133.1	124.1	126.2	124.1	128.1	124.3	121.0	115.8	17.1.3
	NOTE:	I HIS DAT	TA-INCLU	JDES-GR(DUND R	EFI ECT	ION INTE	RFEREN	CE

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OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2//25 FT

KM-AP-15

RUN NO.	OASPL	-500	١K	2K [′]	4K	8K	-16K	32K	64K
H362L80	129.9	13.8.4	119.8	121.3	125.3	123.2	119.2	115.5	110.0
H362L90	130.4	116.9	118.6	121.8	127.2	122.4	119.3	114.7	109.9
H440L30	108.1	107.4	99.5	89.3	84.1	78,9	71.6	-0.0	0.0
H440L40	107.3	105.4	102.4	89.8	87.3	79.7	-0.0-	0.0	0.0
H440L50	105.8	103.9	100.6	<u>,</u> 89 . 7	88.8	80.2	74.2	0.0	0.0
H440L60	104.1	101.6	98.9	91.5	92.1	82.8-	76.9-	71.2	0.0
H440L70	101.3	98.1	96.1	90.9	91.7	84.3	78.7	70.9	0.0
H440L80	\$9.L	95.4	94.3	88.8	90.1	82.4	76.5	70.9	0.0
H440L90	97.9	92.9	93.6	89.8	89.0	82.2	77.2	7.1.3	0.0
H441L30	119.2	117.0	114.4	205.8	99-2	93.4	84.4	0.0	0.0
H441L40	119.7	115.8	1.16.9	104.6	103.2	94.7	86. <u>9</u> :	0.O	0,0
H441L50	117.4	114.3	113.7	103.5	103.7	95.2	89.0	0.0	0.0
H441L60	114.7	111.2	110.1	103.4	105.0	97.1	91.0	0.0	0.0
H441L70	110.7	106.5	105.2	100.5	103.7	*96.2	90.9	83.0	0.0
H441L80	107.9	102.7	102.3-	98.9	101.8	94.2	89.8	83.0	0.0
H441L90	106.3	99.6	101.3	99 . 3	99-,3-	93.6	88.0	82.5	0.0

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OCTAVE BAND LEVEL OF RE: 0.0002 DYNES / CM2// 25 FT

RUN≣NO.	OASPL	:500-	∃ΪK	2K	<u>4</u> K	8K	16K	32K	64K
H442L30	126.5	121.9	123.3	117.2	112.7	104.8	9 6.8	-0.0	-0.0
H442L40	127.0	121.8	124.6	115.3	114.2	106.2	99.4	-0.0	-0.0
H442L50	125.3	120.8	122.3	112.8	113.4	106.4	101.1	-0.0	-0.0
H442L60	122.5	117.9	118.4	111.5	114.3	107.1	101.4	95.7	-0.0
H442L70	118.1	113.1	112.3	108.2	111.9	105.5	101.5 -	93.5	-0.0
K442L80	114.3	108.3	108.5	105.4	108.5	102.4	98.5	92.2	-0.0
H442L90	112.4	104.8	106.9	105.2	106.1	101.1	973	91.3	-0.0
H443L30	129.8	125.8	124.9	121.1	120.2	113.5	107.5	103.9	-0.Ō
H443L40	131.3	124.8	128.0	121.8	123.4	:15.9	111.2	105.4	-0.0
H443L50	130.9	125.2	127.2	120.1	123.2	115.7	111.6	106.5	-0.0
H443L60	128.6	122.6	124.2	118.3	122.1	115.5	111.6	106.5	-0.Ū
H443L70	123.6	117.4	117.9	114.0	ī17.7	112.5	109.6	102.5	-0.0
H443L80	119.4	112.3	112.5	110.4	114.5	109.2	105.1	99.8	-0.0
H443L90	116.7	107.8	110.1	109.9	110.9	107.4	103.3	97.7	-0.0
H444L30	132.3	129.4	126.7	123.0	120.0	116.7	110.9	106.7	-0.0
H444L40	133.8	127.6	130.4	124.6	125.1	1Ì9.0	114.1	109.2	-0.0
H444L50	134.7	128.2	130.3	124.7	128.6	121.3	118.1	113.3	-0.0
H444L60	133.8	126.2	128.5	124.4	128.6	122.1	117.9	114.2	108.5
H444L70	128.5	121.0	122.1	119.8	123.1	118.7	115.6	109.7	-0.0
H444L80	124.1	115.1	115.9	115.3	119.6	115.4	112.4	107.3	100.9
H444L90	121.8	110.8	112.9	114.9	116.4	114.7	110.8	105.0	95.7
H445L30	135.0	132.8	128.9	123.0	122.2	117.4	112.1	109.3	-0.0
H445L40	136.0	130.8	132.7	125.3	126.6	120.4	116.1	111.5	-0.0
H445L50	136.8	130.4	132.7	127.2	129.6	122.9	120.4	115.9	-0.0
H445L60	137.1	128.5	131.1	128.4	132.3	126.1	122.2	119.7	116.0
H445L70	131.6	122.9	125.2	123.0	126.5	122.1	119.3	113.1	109.0
H445L80	127.5	117.0	118.5	118.8	123.6	.119.6	116.6	112.3	-0.0
H445L90	125.9	113.5	115.3	117.4	121.3	119.7	115.6	110.4	-0.0
H446L30	137.8	136.2	130.7	125.5	123.5	119.3	114.3	110.9	-0.0
H446L40	138.4	134.1	134.8	127.4	127.9	121.8	118.3	113.3	-0.0
H446L50	139.3	133.7	135.5	129.4	130.7	124.8	122.2	117.5	-0.0
H446L60	139.2	131.8	133.6	130.4	134.0	127.5	123.7	121.1	116.8
H446L70	134.4	126.7	127.8	125.7	129.1-	124.5	121,8	116.3	-0.0
H440L30	130.9	120.8	121.5	122.5	126.9	122.8	119.1	114.7	110.3
H4461.90	129.8	116.9	118.1	122 1	125 0	122 7	110 2	116 1	106 6

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

1) 17



HM-AP-16 NOZZLE (37-TUBE:HEXAGONAL ARRAY AR:3:33)

Description

The HM-AP-16 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were permanently installed in a 17-inch diameter water-cooled baseplate. Number of Elements: 37 tubes with round convergent ends Area Ratio: 3.33 Flow Area: 13.2 square inches Exit Cant Angle: 0 degrees Length of Tubes: 4.6 inches Tube Exit Diameter: 0.674 inches Material: 321 CRES





RE: 0.0002 DYNES/CM²// 200 FT POLAR ARC OCTAVE PASS BANDS IN HERTZ 130 140 RE: 0.0002 DYNES/CM²//200 FT POLAR ARC 06 01 07 021 06 001 071 POLAR ARC 125 OVERALL SPL~dB OCTAVE BAND LEVEL~dB 120 115 # 110 30⁰ 40⁰ 50⁰ 60⁰ 70⁰ 800 900 ANGLE TO: THE JET AXIS~DEGREES TOTAL TEMPERATURE (T 8) : 1500° F NOZZLE EXIT AREA (A 8): 5.9 FT2 70 Ś 1-100 2 5 5 1 1000 10000 FREQUENCY IN HERTZ HM-AP-16 NOZZLE PRESSURE RATIO: 1.8 (37 TUBE HEXAGONAL ARRAY) TOTAL TEMPERATURE: 1500° F AR 3.33 JET VELOCITY (IDEAL): 1930 FPS SCALE FACTOR: 8:1 NOZZLE EXIT AREA (A8): 5.9 FT2 OCTAVE PASS BANDS IN HERTZ OCTAVE PASS BANDS IN HERTZ 140 140 RE: 0.0002 DYNES/CM²//200 FT POLAR ARC 08 06 001 011 021 051 RE: 0.0002 DYNES/CM²//200 FT POLAR ARC 08 6 00 01 01 05 05 50 OCTAVE BAND LEVEL~dB OCTAVE BAND LEVEL~dB 70 70 Ś 5 1 1000 1 100 2 Ż Ś Š 1 1000 2 100 5 5 10000 10000 FREQUENCY IN HERTZ FREQUENCY-IN HERTZ PRESSURE RATIO: 2.2 PRESSURE RATIO: 3.0 TOTAL TEMPERATURE: 1500° F TOTAL TEMPERATURE: 1500° F JET VELOCITY (IDEAL): 2200 FPS JET VELOCITY (IDEAL): 2550 FPS NOZZLE EXIT AREA (A8): 5.9 FT2 NOZZLE EXIT AREA (A8): 5.9 FT2 DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-16

(37 Tube Hexagonal Array, AR 3.33)

Remarks

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The noise characteristics of the HM-AP-16 nozzle are given in Reference D7. This nozzle is similar to the HM-AP-43 nozzle, except tube length is about 2.5 inches less.

HM-AP-16

Test Facility: Annex D (Cell #1) Nozzle and microphone height is 20 inches.

Date: July 1967

Tamb:

R.H.:

<u>Run No</u> .	$\frac{P_{T}/P}{P}$	$\frac{\mathbf{T_T}}{\mathbf{T}}$	V_{J} (Ideal)	Nozzle
н 622	1.8	1000°F	1660 fps	HM-AP-16
н 623	2.2	11	1900	11
н 624	2.6	11	2070	11
н 625	3.0	11	2200	11
н 626	3.2	11	2250	11
н 627	1.8	1500°F	1930	11
н 628	2.2	11	2200	11
н 629	2.6	11	2:400	11
н 630	3.0	11	2550	11
н 631	3.2	11	2620	n
н 637	1.8	1000°F	1660 fps	4.1 Inch Round Convergent Nozzle
н 638	2.2	11	1900	11
н 639	2.6	U	2070	*1
н 640	3.0	11	2200	11
н 641	3.2	1:	2250	11
н 642	1.8	1500°F	1930	11
н 643	2.2	11	2200	11
н 644	2.6	11	2400	11
н 645	3.0	11	2550	11
н 646	3.2	11	2620	11

	oc	TAVE BA	ND LEVE		RE: 0.00 P-16	02-DYNE	s / GM²//	25 FT		,
	RUN NO.	OASPL	500	IK	2K	4K	8K	16K	32K	64K
ł	H622 L40	113.6	105.5	101.0	95.0	106.5	108.5	106.5	101.5	91.0
	H622 L50	114.8	105.0	103.0	97.0	108.0	110.0	108.0	103.0	93.0
	H622 L60	114.0	101.0	101.0	96.0	108.0	110.0	106.0	102.0	93.0
	H622 L70	112.1	100.0	99.0	95.0	106.0	106.0	106.0	103.0	94.0
	H622 L80	110.9	98.0	97.0	93.0	103.0	105.5	105.5	102.5	92.0
	H623 L40	11/.8	111.5	107.0	99.U	111 0	112 0	113.0	108.0	30.0
	H623 L30	116.9	10/ 0	106.0	102.0	110 0	113.0	100 0	105.0	96.0
	N025 100 N623 170	115 8	103.0	104.0	98.0	10.0	110.0	170.0	107.0	98.0
	H623 L80	114 8	102.0	100.0	96.0	106.5	109.5	109.5	106.5	96.0
	H624 L40	120.9	176.0	111.0	103.5	110.0	113.5	114.0	108.0	101.5
	H624 L50	120.8	114.0	111.0	105.5	111.0	114.5	114.5	109.5	102.5
	H624 L60	118.2	108.0	107.0	102.0	111.0	114.0	110.0	107.0	100.0
	H624 L70	1.18.3	106.0	105.0	101.0	112.0	113.0	112.0	103.0	160.0
	H624 L80	116.0	104.0	103.5	99.0	108.0	110.5	110.5	107.0	99.0
	H625 L40	123.6	120.0	115.0	105.0	113.0	115.5	114.0	110.0	102.5
	H625 L50	122.9	115.0	114.0	106.0	115.0	116.0	117.0	110.0	104.5
	H625 L60	119.9	110.0	109.0	104.0	113.0	115.0	112.0	109.0	101.0
	H625 L70	119.0	108.0	107.0	103.0	112.0	113.0	113.0	130.6	102.0
	H625 L80	11/./	100.0	100.0	101.5	112 5	112.0	112 5	109 5	101.5
	H626 L40	122.2	117 5	115 0	108.5	113 0	116.5	116.0	119.0	104.5
	H620 LJU H626 I 60	120.5	111 0	111.0	106.0	113.0	116.0	112.0	109.0	102.0
	H626 L00	119.8	109.0	109.0	106.0	11-3.0	114.0	113.0	109.0	103.0
	H626 L80	118.0	107.5	106.5	102.5	109.0	112.0	112.0	110.0	102.0
	H627 L40	115.3	108.0	102.0	97.0	107.5	116.5	108.0	103.5	96.0
	H627 L50	117.0	107.0	104.5	98.0	110.0	112.0	111.0	105.0	97.0
	H627 L60	116.3	103.0	102.0	97.0	111.0	112.0	108.0	105.0	95.0
	H627 L70	115.5	102.0	101.0	97.0	110.0	110.0	109.0	106.0	97.0
	H627 L80	114.1	100.5	99.0	95.0	106.5	109.5	108.0	105.5	95.0
	H628 L40	119.6	115.5	108.5	100.5	110.5	112.0	11/ 0	107.0	101 0
	H628 L50	120.0	107.0	106.0	102.5	120.0	114.0	110.0	107 0	101.0
	H628 L60	110.3 110.2	107.0	105 0	101.0	112 0	113 0	112 0	107.0	100.0
	1020 L/U 1628 I SO	116.5	103.5	103.0	93.0	108 5	111.5	111.0	107.0	98.0
	H620 L60	122 6	119.0	114.0	105.0	113.0	114.0	113.5	103.5	101.5
	H629 1.50	122.1	115.0	113.0	106.0	114.0	115.5	115.0	110.0	104.5
	H629 L60	119.9	110.0	109.0	104.0	113.0	115.7	112.0	109.0	102.0
	H629 L70	119.5	108.0	107.0	103.0	113.0	114.6	113.0	109.0	103.0
	H629 L80	118.5	106.5	105.5	102.0	110.5	113.5	112.5	109.5	101.5
	H630 L40	125.9	123.0	118.0	108.0	115.5	116.5	115.0	110.5	-0.0
Ì	H630 L50	124.6	118.0	117.0	109.0	116.0	118.0	117.0	111.0	105.0
	H630 L60	121.7	112.0	112.0	106.0	115.0	117.0	113.0	110.0	103.0
	H630 L70	121.4	110.0	111.0	106.0	112.0	110.0	112 5	110 2	102.0
	H630 L80	119.4	108.5	10/.5	111 5	117.0	112.2	11/ 0	110.0	-0.0
	HOJL L40	127.0	120 5	110.0	131 0	176 0	117.0	117.0	111.5	106.0
	H631 160	122.6	114.0	114.0	108.0	116.0	117.0	114.0	110.0	103.0
	H631 1.70	122.0	111.0	112.0	108.0	117.0	116.0	115.0	112.0	104.0
	H631 L80	120.0	109.0	108.0	105.5	112.5	114.5	113.5	111.0	103.5
-	H637 L40	126.1	120.5	124.0	112.5	113.0	104.0	97.5	92.0	-0.0
-	H637 L50	123.7	119.5	120.0	111.5	113.5	106.5	102.5	95.0	-0.0
	H537 L60	118.6	113.0	114.0	109.0	112.0	106.5	100.5	93.0	-0.0
-	H637 L70	115.2	109.0	109.0	105.0	110.0	104.0	101.0	94.0	-0.0
1	H637 L80	112.2	105.5	106.0	103.5	106.5	101.5	98.0	93.0	-0.0
1	H638 L40	129.3	124.0	126.0	118.5	120.5	111.0	106.0	103.0	-0.9
ľ	H638 L50	127.6	122.0	124.0	116.5	119.5	112.5	109.5	103.5	-0.0
	H638 L60	122.3	116.0	117.5	111.5	110.0	741.5	100.0	102.5	-0.9
	H538 L70	419.2	112.0	112.0	103.0	110 5	107 E	100.0 10/ c	08 ¢ T0:7+0	~0.0 ¢¢ n
	H538 L80	112.9	10/.5	108.2	10/.5	110.2		104.3	70.J	- 30.0

st.

D53 -

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES / CM2// 25 FT

HM-AP-16

* RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32К	64K
_H639L40	131.6	125.C	128.0	122.5	124.0	116.5	11-3-0	110.0	ΔÓ
H639L50	130.4	124.0	12,0	120.5	122.0	1-16.0	114.5	109-5	0.0
H639L60	125.4	118.0	120.0	115.5	120.0	115.0	111.5	106.5	0.0
H639L70	123.0	114.0	115.0	113.0	118.0-	115.0	113.0	107 0	100.0
H639L80	120.1	110.0	110.5	111.5	114.5	113.5	110.5	105 5	07 0
H640L40	133.6	127.0	130.0	124.0	126.0	119.5	115.0	113 0	107 5
H640L50	132.9	126.0	129.0	123.0	126.0	119.0	118.5	113.5	109 5
H640L60	127.8	120.5	122.0	117.0	122.0	118.5	115.5	110.0	101 5
H640L70	125.6	115.0	117.0	117.0	120.0	118.0	117.0	111.0	104 0
H640L80	123.0	111.5	112.5	114.5	118.0	116.5	113.5	109.5	101 5
H641L40	135.5	128.0	132.0	127.0	128.0	121.0	117.0	113.0	108.5
H641L50	134.2	127.0	130.0	124.0	128.0	121.5	119.0	114.5	110 5
H641L60	128,7	121.0	123.0	119.0	123.0	119.0	116.5	112.0	0.0
H641L70	126.6	116.0	118.0	117.0	122.0	119.0	117.0	112.0	195.0
H641L80	124.5	112.5	113.5	116.5	120.0	117.5	114.5	110.5	103.5
H642L40	127.0	121.0	124.0	117.0	118.0	107.0	103.0	97.Ō	0.0
H642L50	126.3	120.5	123.0	115.5	118.0	109.5	106.5	99.0	0.0
H642L60	121.5	115.5	117.0	111.0	115.0	109.0	103.5	97.0	0.0
H642L70	118.7	112.0	112.0	109.0	114.0	108.0	103.0	98.0	0.0
H642L80	114.7	106.5	108.0	106.5	109.5	105.5	101.5	95.0	0.0
H643L40	130.5	123.5	127.0	120.0	124.0	115.0	110.0	107.0	0.0
H643L50	130.0	123.0	126.0	120.5	123.5	115.0	113.5	108.0	0.0
H641L60	127.0	119.0	122.0	117.0	122.0	116.0	112.0	105.0	97.0
H643L70	122.2	114.0	115.0	113.0	118.0	112.0	109.0	103.0	97.0
H64_L80	118.8	109.5	111.0	111.5	113.5	110.5	197.5	102.5	0.0
H644L40	132.2	125.0	128.0	122.0	126.5	118.0	114.5	110.0	0.0
H644L50	132.2	126.0	129.0	123.0	127.0	120.0	118.9	112.5	108.5
H644L60	129.2	120.0	124.0	120.0	124.5	118.0	114.5	110.0	0.0
H644L70	125.4	116.0	118.0	116.0	121.0	116.0	114.0	109.0	192.0
H644L80	- 121.8	111.5	112.5	113.5	116.5	114.5	112.5	107.5	99.0
ABORTED	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H645L40	133.8	127.0	130.0	124.0	127.0	119.0	115.0	112.5	107.5
H645L50	135.3	128.0	131.0	125.0	129.0	122.0	121.5	116.0	112.5
11645160	130.2	122.0	125.0	120.0	125.0	120.0	116.5	112.5	0.0
H645L70	127.7	118.0	120.0	118.0	123.0	120.0	116.0	112.0	105.0
H645L80	124.6	113.5	114.5	115.5	119.5	118.5	114.5	111.5	104.0
H646L40	134.4	128.0	131.0	125.0	126.0	119.0	115.0	112.0	107.5
H646L50	135.9	128.0	132.0	126.0	129.0	123.0	123.0	117.5	112.5
H646L60	131.3	123.0	126.0	121.5	J.26.0	121.0	117.0	113.0	107.5
H646L70	128.1	119.0	121.0	119.0	123.0	119.0	117.0	113.0	108.0
H646L80	125.5	113.5	115.5	116.0	120.0	120.0	116.0	112.5	104.5

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE



HM-AP-18 NOZZLE (37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY, AR 4.65)

Description:

The HM-AP-18 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have 12 spoke nozzle terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with 12 spoke ends

Area Ratio: 4.65

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes:

7 inches
12 spoke terminations, AR = 1.86
Flow area = 0.357 square inches'
Exit cant angle = 0 degrees
Ventilation gutter angle = 77
 degrees
Spoke penetration = 75%
Material: 321 CRES



NO PICTURE AVAILABLE





D58

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HX=AP-18

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 4.65)

Remarks

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There were five different area ratios of the 37 tube hexagonal array (with 12 spoke terminations on each tube) tested:

HM-AP-18	AR	4.65
HM-AP-18a	AR	8.0
HM-AP-40	AR	3.33
HM-AP-41	AR	4.0
HM-AP-42	AR	5.2

The test results for the HM-AP-18 - izle are discussed in References D7, D8 and D9. The nozzles with area ratios of 3.33 and 4.0 atteined highest PNL suppression values over the range of pressure ratios $(1.8 \ge 3.0)$ and total temperatures $(500^{\circ}F \ge 1500^{\circ}F)$ tested. HM--AP--18

Test Facility: Annex D (Cell #1) Nozzle and microphone height are 20 inches.

Date: Tamb: R.H.:

Run No.	$\frac{P_{T}/P}{P}$	$\frac{T_{T}}{T}$	VJ (Ideal)	Nozzle
H720	1.89	500°F	1400 fps	HM-AP-18
H721	2.48	11	1610	11
H722	3.19	11	1.800	11
H729	ī.8	1000°F	1660	łt
H730	2.2	11	1900	II
H731	2.6	11	2070	11
H732	3.0	11	2200	11
H733	3.2	IJ	2250	13
H1128	1.8	1500°F	1930	11
H1129	2.6	11	2400	11
H1130	3.0	11	2550	11
н692	1.89	500°F	1400 fps	4.1 Inch Round Convergent Nozzle
H693	2.48	**	1610	11
нб94	3.19	11	1800	11
H701	1.8	1000°F	1660	11
H702	2.2	11	1900	11
Н703	2.6	11	2070	11
H704	3.0	11	2200	11
H705	3.2	11	2250	11
H1125	1.8	1500°F	1930	u
H1126	2.6	11	2400	'n

2550

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Measured acoustic data is recorded in Reference D2.

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3.0

H1127

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OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES / CM²// 25 FT

HM_AP_18

RUN-NO.	OASPL	500	١K	2K	4K	8K	.16K	32K	64K	
117201.40	105.0	101.0	96.0	88.0	96.0	96.0	96.0	93.0	84.0	
H720L50	106.0	100.0	97.0	90.0	97.0	98.0	99.0	96.0	87.0	
117201.60	106.1	98.0	94.0	87.0	26.0	99.0	101.0	98.0	89.0	
H720L70	105.4	97.0	.93.0	87.0	95,0	98.0	100.0	98.0	90.0	
117201,80	103.2	95.0	91.0	85.0	94.0	96.0	98.0	95.0	86.0	
H721L40	109.2	104.0	100.0	92.0	101.0	102.0	101.0	97.0	89.0	
117211,50	-110.1	103.0	101.0	94.0	102.0	103.0	103.0	100.0	92.0	
=H721L60	110.0	101.0	98.0	910	100.0	103.0	1)5.0	102.0	93.0	
H721L70	109.9	100.0	970	91.0	99.0	103.0	105.0	103.0	94.0	
H721L80	107.1	98.0	94.0	89.0	98.0	100.0	102.0	99.0	910	
H722L40	114.8	110.0	106.0	So.0	106.0	108.0	106.0	101.0	93.0	
H722L50	114.6	108.0	106.0	99.0	106.0	108.0	107.0	103.0	96.0	
H722L60	113.8	106.0	103.0	97.0	104.0	107.0	108.0	105.0	97.0	
H722L70	113.1	104.0	101.0	96.0	103.0	106.0	108.0	105.0	98.0	
H722L80	110.7	102.0	99.0	94.0	102.0	104.0	105.0	102.0	94.0	
H729L40	107.0	102.0	98.0	90.0	99.0	100.0	98.0	94.0	87.0	
H729L50	107.7	101.0	100.0	92.0	100.0	100.0	100.0	96.0	89.0	
H729L60	108.4	100.0	98.0	91.0	100.0	102.0	102.0	99.0	91.0	
H729L70	108.6	98.0	97.0	90.0	99.0	102.0	104.0	100.0	92.0	
H729L80	106.1	97.0	95.0	89.0	98.0	100.0	100.0	97.0	89.0	
H730L40	110.3	105.0	101.0	94.0	102.0	104.0	101.0	97.0	89.0	
H730L50	111.4	104.0	103.0	95.0	103.0	105.0	104.0	100.0	93.0	
H730L60	111.2	103.0	100.0	94.0	103.0	105.0	105.0	101.0	94.0	
H730L70	111.6	101.0	99.0	93.0	102.0	105.0	107.0	103.0	95.0	
H730L80	108.8	99.0	97.0	92.0	100.0	103.0	103.0	100.0	92.0	
H731L50	114.3	107.0	106.0	98.0	106.0	108.0	107.0	102.0	95.0	
H731L60	113.8	106.0	103.0	96.0	106.0	108.0	107.0	103.0	96.0	
117311,70	113.7	104.0	101.0	95.0	104,0	107.0	109.0	105.0	97.0	
H731L80	111.0	102.0	100.0	94.0	103.0	105.0	105.0	101.0	94.0	
H732L40	116.6	112.0	107.0	100.0	107.0	111.0	107.0	101.0	95.0	
H732L50	116.8	110.0	108.0	101.0	108.0	111.0	109.0	104.0	96.0	
H7321,60	115.9	108.0	106.0	100.0	108.0	110.0	109.0	105.0	970	
H732L70	116.4	106.0	104.0	99.0	107.0	110.0	112.0	107.0	99.0	
H732L80	113.0	104.0	.102.0	97.0	105.0	107.0	107.0	103.0	96.0	
H733L40	118.0	114.0	109.0	101.0	108.0	111.0	109.0	103.0	96.0	
H733L50	117.9	111.0	110.0	103.0	109.0	112.0	110.0	104.0	97.0	
H7331.60	116.9	109.0	107.0	101.0	109.0	111.0	110.0	106.0	98.0	
H733L70	117.2	107.0	105.0	100.0	107.0	111.0	113.0	107.0	99.0	
H733L80	114.0	105.0	103.0	98.0	106.0	108.0	108.0	104.0	96.0	
H1128L40	106.9	103.0	97.Q	89.0	99.0	97.0	97.0	95.0	92.0	
H1128L50	108.5	104.0	99.0	90.0	100.0	99.0	100.0	98.0	95.0	
H1128L60	108.6	101.0	97.0	91.0	100,0	101.0	103.0	99.0	94.0	
H1128L70	107.8	100.0	96.0	89.0	99.0	100.0	101.0	100.0	97.0	
H1128L80	105.2	97.0	94.0	88.0	96.0	97.0	99.0	98.0	93.0	
H1129L40	114.0	109.0	104.0	96.0	106.0	107.0	105.0	102.0	98.0	
H1129L50	115.0	109.0	105.0	96.0	107.0	108.0	107.0	104.0	101.0	
H1129L60	115.3	107.0	103.0	97.0	108.0	109.0	109.0	105.0	100.0	
H1129L70	114.6	106.0	103.0	95.0	106.0	108.0	108.0	106.0	103.0	
H1129L80	111.3	103.0	99.0	93.0	102.0	104.0	105.0	104.0	99.0	
H1130L40	116.5	111.0	107.0	98.0	108.0	110.0	108.0	104.0	100.0	
H1130L50	117.1	111.0	108.0	99.0	109.0	110.0	109.0	106.0	102.0	
H1130L60	116.6	109.0	106.0	99.0	109.0	110.0	110.0	106.0	100.0	
H1130L70	116.2	108.0	104.0	98.0	107.0	110.0	110.0	107.0	103.0	
H1130L80	112.2	104.0	101.0	95.0	103.0	105.0	106.0	104.0	99.0	
	NOTE: THIS DATA INCLUDES ODOLUD DEEL FOTION INTERFERENCE									

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2/25 FT

HM_AP-18

H692 L60 120.4 117.6 117.6 106.0 106.0 99.0 87.0 -0.0 H692 L63 L16.2 L12.0 L10.0 L04.0 L07.0 L02.0 99.0 91.0 -0.0 H692 L60 L10.1 107.6 L01.0 100.0 101.0 100.0 101.0 100.0 101.0 91.0 -0.0 H693 L40 L27.6 L17.0 L18.0 L10.0 L15.0 L10.0 L04.0 97.0 -0.0 H693 L60 L18.5 L10.0 L13.0 L12.0 L12.0 L12.0 L12.0 L10.0 L13.0 L10.0	RUN NO.	OASPL	500 [±]	IK	2K	4K	8K	16K	32K	64K
Heigz Lso 112.0 112.0 104.0 107.0 102.0 99.0 90.0 90.0 Heigz Lso 112.1 107.0 100.0 101.0 106.0 101.0 99.0 91.0 -0.0 Heigz Lso 101.4 104.0 103.0 105.0 101.0 99.0 91.0 -0.0 Heigz Lso 107.6 101.0 104.0 105.0 101.0 107.0 99.0 -0.0 Heigz Lso 127.2 121.0 124.0 123.0 115.0 110.0 107.0 99.0 -0.0 Heigs Lso 112.6 113.0 113.0 113.0 113.0 103.0 100.0 100.0 90.0 90.0 -0.0 Heigs Lso 122.7 122.0 123.0 113.0 113.0 113.0 103.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0	H692 L40	120.4	117.0	117.0	106.0	106.0	100.0	95.0	87.0	-0.0
Hesp Leo 112.1 107.0 107.0 101.0 106.0 101.0 98.0 91.0 -0.0 Hesp Lio 110.4 104.0 103.0 100.0 105.0 101.0 98.0 95.0 87.0 82.0 Hesp Lio 122.6 117.0 118.0 113.0 115.0 110.0 104.0 97.0 -0.0 Hesp Lio 118.5 110.0 113.0 110.0 108.0 108.0 08.0 95.0 97.0 -0.0 Hesp Lio 118.5 108.0 108.0 108.0 108.0 08.0 95.0 91.0 -0.0 Hesp Lio 118.5 108.0 108.0 113.0 112.0 114.0 109.0 105.0 98.0 93.0 -0.0 Hesp Lio 122.0 124.0 122.0 124.0 120.0 115.0 108.0 108.0 105.0 106.0 100.0 105.0 98.0 91.0 99.0 91.0 91.0 108.0 108.	H692 I 50	116.2	112.0	112.0	104.0	107.0	102.0	99.0	90.0	89.0
Heige 1.00 110.4 104.0 103.0 100.0 105.0 101.0 99.0 91.0 -0.0 Heige 1.80 107.6 101.0 101.0 98.0 102.0 98.0 91.0 87.0 82.0 Heige 1.80 112.0 124.0 120.0 115.0 110.0 104.0 97.0 -0.0 Heige 1.50 122.6 117.0 118.0 113.0 113.0 110.0 108.0 107.0 99.0 -0.0 Heige 1.50 116.2 105.0 106.0 113.0 113.0 113.0 113.0 113.0 113.0 113.0 113.0 113.0 115.0 116.0 107.0 99.0 91.0 90.0 105.0 106.0 107.0 Heige 1.50 123.7 122.0 114.0 117.0 123.0 115.0 113.0 103.0 95.0 92.0 91.0 99.0 91.0 99.0 91.0 99.0 91.0 99.0 91.0 91.0 91.0	1607 C00H	112 1	107.0	100.0	101.0	106.0	101.0	98.0	-91.0-	-0.0
Hos Hos <td>-1692 170</td> <td>110 4</td> <td>104.0</td> <td>103.0</td> <td>100.0</td> <td>105.0</td> <td>101-0</td> <td>99.0</td> <td>91.0</td> <td>-0.0</td>	-1692 170	110 4	104.0	103.0	100.0	105.0	101-0	99.0	91.0	-0.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	N602 180	107 6	101 0	101.0	98.0	102.0	98.0	-95.0	-87.0	82.0
Hoss Leve Leve <thleve< th=""> Leve Leve <thl< td=""><td></td><td>107.0</td><td>121 0</td><td>124 0</td><td>120-0</td><td>115 0</td><td>110 0</td><td>104.0</td><td>97.0</td><td>-0.0</td></thl<></thleve<>		107.0	121 0	124 0	120-0	115 0	110 0	104.0	97.0	-0.0
Boys Description Description Description Description Description Heb3 LGO 111.0 111.0 111.0 110.0 110.0 100.0 -0.3 Heb3 LGO 111.0 111.0 111.0 110.0 100.0 95.0 Heb4 LGO 112.0 111.0 111.0 110.0 100.0 95.0 Heb4 LGO 122.0 124.0 123.0 117.0 112.0 106.0 107.0 Heb4 LGO 122.0 124.0 120.0 118.0 115.0 108.0 105.0 Heb4 LGO 123.0 112.0 116.0 112.0 106.0 101.0 115.0 112.0 106.0 101.0 105.0 101.0 101.0 115.0 112.0 106.0 101.0 101.0 103.0 95.0 -0.0 H701 LGO 112.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0 1	1093 140	1)9 6	117 0	11-8 0	11-3 0	115 0	110.0	107 0	99.0	-0.0
Heg3 L60 H11.0 H10.0		110 2	111.0	111.0	110.0	112.0	110.0	108 0	100 0	-0.0
$\begin{array}{c} 1093 \ 1070 \ 116.3 \ 100.0 \ 107.0 \ 107.0 \ 107.0 \ 107.0 \ 90.0 \ 97.$	1093 LOU	770.0	100 0	108 0	112.0	172 0	110.0	100.0	100.0	05.0
H694 L40 L10.2 L10.3 L10.3 <thl10.3< th=""> <thl10.3< th=""> <thl10.3< td=""><td>H093 L/U</td><td>110.0</td><td>100.0</td><td>100.0</td><td>112.0</td><td>112.0</td><td>100.0</td><td>105.0</td><td>100.0</td><td>02.0</td></thl10.3<></thl10.3<></thl10.3<>	H093 L/U	110.0	100.0	100.0	112.0	112.0	100.0	105.0	100.0	02.0
$\begin{array}{c} h694 (140) 122.7 123.0 123.0 113.0 1123.0 1123.0 1123.0 1123.0 100.0 010.0 -0.0 \\ h694 (160) 123.0 113.0 114.0 117.0 112.0 118.0 115.0 108.0 105.0 \\ h694 (170) 124.7 112.0 114.0 117.0 122.0 118.0 115.0 108.0 105.0 \\ h694 (170) 122.4 112.0 114.0 117.0 122.0 118.0 112.0 106.0 101.0 \\ h701 (140) 122.4 112.0 114.0 113.0 105.0 99.0 \\ h701 (160) 112.7 118.0 113.0 110.0 107.0 103.0 95.0 92.0 \\ h701 (160) 113.1 113.0 110.0 110.0 106.0 103.0 95.0 92.0 \\ h701 (170) 115.2 109.0 108.0 104.0 110.0 106.0 103.0 95.0 92.0 \\ h701 (170) 115.2 109.0 108.0 104.0 110.0 106.0 103.0 95.0 91.0 \\ h702 (170) 115.2 105.0 101.0 106.0 102.0 98.0 91.0 -0.0 \\ h702 (150) 112.7 122.0 124.0 116.0 112.0 114.0 108.0 101.0 -0.0 \\ h702 (150) 127.7 122.0 124.0 116.0 112.0 113.0 110.0 102.0 102.0 \\ h702 (170) 119.3 112.0 102.0 113.0 110.0 105.0 96.0 910 \\ H703 (180) 125.0 127.0 121.0 112.0 113.0 110.0 102.0 -0.0 \\ H703 (180) 125.0 127.0 127.0 119.0 122.0 117.0 114.0 108.0 104.0 \\ H703 (150) 123.1 113.0 110.0 103.0 05.0 96.0 910 \\ H703 (150) 123.1 113.0 110.0 113.0 107.0 108.0 \\ H703 (170) 123.5 114.0 114.0 112.0 117.0 114.0 108.0 104.0 \\ H703 (170) 123.5 114.0 114.0 112.0 117.0 114.0 108.0 104.0 \\ H704 (150) 123.1 110.0 110.0 115.0 117.0 114.0 108.0 104.0 \\ H704 (160) 123.4 127.0 123.0 125.0 123.0 125.0 113.0 107.0 108.0 \\ H704 (160) 123.4 127.0 123.0 125.0 123.0 125.0 113.0 107.0 108.0 \\ H705 (160) 123.4 127.0 123.0 126.0 123.0 122.0 113.0 112.0 111.0 \\ H10.0 135.0 13$	H093 L80	110.2	102.0	100.0	122 0	142.0	109.0	112.0	106.0	107 0
H694 L60 121.0 121.0 121.0 113.0 121.0 113.0 113.0 100.0 105.0 H694 L60 115.0 115.0 115.0 115.0 105.0 105.0 H694 L80 123.6 109.0 111.0 115.0 115.0 115.0 106.0 105.0 H701 L40 122.0 113.0 113.0 106.0 117.0 103.0 95.0 92.0 H701 L80 113.0 113.0 113.0 113.0 106.0 113.0 103.0 95.0 92.0 H701 L80 111.4 105.0 103.0 103.0 103.0 103.0 103.0 103.0 95.0 92.0 H701 L80 111.4 105.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.0 103.	H694-L40	102.7	120.0	130.0	120.0	161 0	110 0	115 0	108.0	-0.0
H694 L50 122.0 112.0	-H694 L50	128.7	122.0	124.0	170°0	121.0	110.0	112.0	100.0	105.0
$\begin{array}{c} h694 k0 \\ h694 k0 \\ h694 k0 \\ h694 k0 \\ h701 k0 \\$	H694 L60	125.0	115.0	110.0	110.0	110.0	119.0	115.0	109.0	102.0
H694 L80121.6101.0111.0112.0112.0113.0112.0113.0101.0H701 L50122.7118.0119.0110.0114.0107.0103.095.091.099.0H701 L50122.7118.0113.0106.0111.0107.0103.095.092.0H701 L50115.2109.0108.0104.0110.0106.0103.095.091.0H701 L50111.4105.0105.0101.0106.0102.098.091.0-0.0H702 L50122.0116.0117.0111.0116.0102.098.091.0-0.0H702 L50122.0116.0117.0111.0116.0102.0102.0102.0102.0H702 L60122.0116.0117.0111.0112.0112.0109.0101.0-3.5H702 L50113.3127.0130.6123.0125.0119.0113.0107.0108.0H703 L50130.3124.0127.0119.0115.0117.0114.0107.0108.0H703 L50120.3124.0127.0119.0115.0117.0114.0108.0104.0H703 L50123.5114.0114.0112.0117.0117.0118.0104.0H703 L50123.5114.0114.0112.0117.0117.0118.0112.0H703 L50123.5114.0114.0112.0117.0 <td>H694 L70</td> <td>124.7</td> <td>112.0</td> <td>112.0</td> <td>11/.0</td> <td>120.0</td> <td>118.0</td> <td>112.0</td> <td>108.0</td> <td>105.0</td>	H694 L70	124.7	112.0	112.0	11/.0	120.0	118.0	112.0	108.0	105.0
H701 L40 124.0 112.0 113.0 105.0 99.0 91.0 99.0 H701 L50 112.7 118.0 119.0 110.0 110.0 107.0 103.0 95.0 92.0 H701 L50 112.1 105.0 106.0 111.0 107.0 103.0 95.0 92.0 H701 L80 111.4 105.0 106.0 101.0 106.0 102.0 98.0 91.0 -0.0 H702 L50 127.7 122.0 124.0 127.0 119.0 113.0 100.0 102.0 102.0 101.0 -0.0 H702 L50 127.7 122.0 112.0 112.0 113.0 110.0 102.0 -0.0 H702 L60 122.7 112.0 112.0 117.0 111.0 115.0 113.0 100.0 102.0 -0.0 H702 L80 116.0 105.0 106.0 104.0 112.0 117.0 113.0 100.0 102.0 102.0 102.0 113.0 107.0 108.0 <td>H694 L80</td> <td>123.6</td> <td>109.0</td> <td>111.0</td> <td>115.0</td> <td>121.0</td> <td>115.0</td> <td>112.0</td> <td>106.0</td> <td>101.0</td>	H694 L80	123.6	109.0	111.0	115.0	121.0	115.0	112.0	106.0	101.0
H701 L50 122.7 118.0 119.0 110.0 110.0 107.0 103.0 95.0 9-0.0 H701 L60 118.1 113.0 106.0 111.0 107.0 103.0 95.0 91.0 H701 L60 111.4 105.0 102.0 102.0 103.0 95.0 91.0 H701 L60 111.4 105.0 102.0 110.0 110.0 106.0 102.0 98.0 91.0 -0.0 H702 L60 127.7 122.0 112.0 114.0 112.0 111.0 106.0 102.0 102.0 102.0 -0.0 H702 L60 122.0 116.0 117.0 111.0 115.0 111.0 102.0 102.0 -0.0 H703 L60 133.3 127.0 130.6 123.0 125.0 113.0 107.0 108.0 H703 L60 123.1 113.0 114.0 114.0 114.0 114.0 106.0 104.0 H703 L60 123.1 113.0 114.0 114.0 116.0 104.0 106.0 104.0	H701 L40	126.2	121.0	124.0	112.0	.113.0	105.0	99.0	91.0	99.0
H701 L60 113.0 113.0 113.0 110.0 106.0 111.0 103.0 95.0 92.0 H701 L50 111.4 105.0 106.0 101.0 106.0 102.0 98.0 91.0 -0.0 H701 L80 111.4 105.0 127.0 119.0 121.0 114.0 108.0 i01.0 -0.0 H702 L50 127.7 122.0 124.0 117.0 112.0 119.0 102.0 102.0 102.0 102.0 102.0 102.0 -0.0 H702 L50 127.7 122.0 112.0 109.0 114.0 112.0 109.0 111.0 102.0 -0.0 100.0 -0.3 117.0 117.0 117.0 117.0 118.0 106.0 108.0 106.0 108.0 101.0 102.0 10.0 102.0 10.0 100.0 100.0 117.0 117.0 117.0 107.0 108.0 104.0 104.0 108.0 104.0 104.0 108.0 104.0 104.0 107.0 107.0 108.0	H701 L50	122.7	118.0	119.0	110.0	114.0	107.0	103.0	95.0	-0.0
H701 L70 115.2 109.0 108.0 104.0 110.0 106.0 97.0	H701 L60	118.1	113.0	113.0	106.0	111.0	107.0	103.0	95.0	92.0
H701 L80 111.4 105.0 102.0 102.0 98.0 91.0 -0.0 H702 L40 130.0 124.0 112.0 114.0 108.0 101.0 -0.0 H702 L50 127.7 122.0 114.0 115.0 112.0 100.0 102.0 102.0 H702 L60 122.0 116.0 117.0 111.0 115.0 112.0 109.0 101.0 -0.0 H702 L80 116.0 108.0 105.0 166.0 114.0 112.0 102.0 -0.0 H703 L40 133.3 127.0 130.6 123.0 125.0 119.0 113.0 107.0 108.0 H703 L60 125.1 113.0 114.0 114.0 117.0 117.0 114.0 108.0 104.0 108.0 H703 L60 125.5 114.0 114.0 112.0 117.0 117.0 117.0 117.0 117.0 117.0 117.0 117.0 117.0 117.0 117.0 117.0 117.0 1	H701 L70	115.2	109.0	108.0	104.0	110.0	106.0	103.0	95.0	91.0
H702 L40 130.3 124.0 114.0 114.0 108.0 101.0 -0.0 H702 L50 127.7 122.0 124.0 116.0 120.0 110.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0 -0.0 H702 L60 122.0 112.0 102.0 102.0 101.0 -0.0 H702 L80 116.0 108.0 106.0 111.0 112.0 111.0 102.0 -0.0 H703 L50 130.3 124.0 127.0 119.0 122.0 117.0 114.0 107.0 108.0 H703 L60 125.1 113.0 119.0 114.0 119.0 116.0 114.0 108.0 104.0 H703 L80 122.5 114.0 119.0 115.0 111.0 108.0 104.0 108.0 104.0 108.0 104.0 108.0 104.0 104.0 108.0 104.0 104.0 106.0 104.0 106.0 104.0 106.0	H701 L80	111.4	105.0	105.0	101.0	106.0	102.0	98.0	91.0	-0.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	H702 L40	130.0	124.0	127.0	119.0	121.0	114.0	108.0	101.0	-0.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	H702 L50	127.7	122.0	124.0	116.0	120.0	113.0	110.0	102.0	102.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	H702 L60	122.0	116.0	117.0	111.0	115.0	112.0	109.0	101.0	-0.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	H702 L70	119.3	112.0	112,0	109.0	114.0	112.0	111.0	102.0	-0.0
H703 L40 133.3 127.0 130.6 123.0 125.0 119.0 113.0 107.0 108.0 H703 L50 130.3 124.0 127.0 119.0 122.0 117.0 114.0 107.0 108.0 H703 L60 125.1 113.0 119.0 114.0 119.0 117.0 117.0 108.0 104.0 H703 L70 123.5 114.0 114.0 112.0 117.0 117.0 117.0 108.0 104.0 H704 L40 135.5 129.0 123.0 126.0 122.0 118.0 112.0 111.0 110.0 112.0 112.0 112.0 112.0 112.0 112.0 112.0 112.0	H702 L80	116.0	108.0	108.0	106.0	111.0	108.0	105.0	98.0	91.0
H703L50130.3124.0127.0119.0122.0117.0114.0107.0108.0H703L60123.1113.0119.0114.0119.0119.0117.0114.0108.0104.0H703L80123.5114.0114.0112.0117.0117.0117.0108.0104.0H704L80120.3110.0110.0109.0115.0115.0111.0105.0100.0H704L50133.2127.0129.0125.0128.0122.0117.0111.0111.0H704L50133.2127.0122.0128.0122.0118.0112.0111.0H704L70127.1117.0117.0115.0121.0122.0128.0120.0113.0109.0H704L80124.2112.0112.0114.0120.0113.0112.0112.0112.0H705L40136.4130.0133.0126.0128.0123.0116.0112.0112.0H705L70127.9117.0118.0117.0127.0122.0120.0113.0110.0H705L80124.9112.0112.0117.0118.0112.0110.0H705L80124.9112.0115.0121.0118.0112.0110.0H705L80124.9112.0115.0121.0119.0115.0109.0105.0H125L6	H703 L40	133.3	127.0	130.0	123.0	125.0	119.0	113.0	107.0	108.0
H703L60125.1113.0119.0114.0119.0116.0114.0108.0104.0H703L70123.5114.0114.0112.0117.0117.0117.0117.0106.0104.0H703L80120.3110.0110.0109.0115.0115.0111.0105.0100.0H704L40135.5129.0132.0125.0128.0122.0117.0111.0111.0H704L50133.2127.0129.0123.0126.0121.0118.0112.0111.0H704L60128.4121.0122.0118.0122.0120.0118.0112.0108.0H704L70127.1117.0117.0116.0121.0120.0113.0109.0H704L60128.4121.0112.0114.0120.0113.0115.0109.0H704L70127.1117.0117.0116.0113.0112.0112.0H705L40134.2128.0130.0124.0127.0122.0116.0112.0112.0H705L60128.9122.0122.0121.0118.0112.0110.0100.0H705L70127.9117.0118.0117.0119.0115.0109.0105.0H705L60128.9122.0124.0117.0119.0115.0109.0105.0H705L60127.5 <td>H703 L50</td> <td>130.3</td> <td>124.0</td> <td>127.0</td> <td>119.0</td> <td>122.0</td> <td>117.0</td> <td>114.0</td> <td>107.0</td> <td>108.0</td>	H703 L50	130.3	124.0	127.0	119.0	122.0	117.0	114.0	107.0	108.0
H703L70123.5114.0114.0112.0117.0117.0117.0108.0104.0H703L80120.3110.0110.0109.0115.0115.0111.0105.0100.0H704L40135.5129.0132.0125.0128.0122.0117.0111.0111.0H704L60128.4121.0122.0121.0118.0112.0111.0111.0H704L60128.4121.0122.0118.0112.0118.0112.0108.0H704L70127.1117.0117.0115.0121.0121.0120.0113.0109.0H704L80124.2112.0112.0114.0120.0113.0112.0109.0H705L40136.4130.0133.0126.0127.0122.0119.0113.0112.0H705L50134.2128.0130.0124.0127.0122.0119.0113.0112.0H705L60128.9122.0122.0119.0113.0112.0110.0H705L80124.9112.0115.0121.0118.0112.0110.0H705L80124.9112.0115.0121.0118.0112.0110.0H705L80124.9112.0115.0121.0119.0115.0100.0H705L80124.9112.0116.0117.0111.0108.0 <td>H703 L60</td> <td>125.1</td> <td>113.0</td> <td>119.0</td> <td>114.0</td> <td>119.0</td> <td>116.0</td> <td>114.0</td> <td>108.0</td> <td>104.Ù</td>	H703 L60	125.1	113.0	119.0	114.0	119.0	116.0	114.0	108.0	104.Ù
$H703 \ L80$ 120.3 110.0 110.0 109.0 115.0 115.0 111.0 105.0 100.0 $H704 \ L40$ 135.5 129.0 132.0 125.0 128.0 122.0 117.0 111.0 111.0 $H704 \ L50$ 133.2 127.0 129.0 123.0 126.0 121.0 118.0 112.0 111.0 $H704 \ L60$ 128.4 121.0 122.0 118.0 112.0 111.0 111.0 $H704 \ L60$ 128.4 121.0 122.0 118.0 112.0 113.0 109.0 $H704 \ L80$ 124.2 112.0 112.0 112.0 113.0 109.0 $H704 \ L80$ 124.2 112.0 112.0 112.0 113.0 109.0 $H705 \ L40$ 136.4 130.0 133.0 126.0 128.0 123.0 116.0 112.0 $H705 \ L50$ 128.9 122.0 112.0 112.0 112.0 112.0 112.0 112.0 $H705 \ L60$ 128.9 122.0 112.0 112.0 113.0 112.0 112.0 $H705 \ L80$ 124.9 112.0 112.0 112.0 112.0 113.0 112.0 $H705 \ L80$ 124.9 112.0 112.0 112.0 113.0 110.0 $H705 \ L80$ 124.9 112.0 112.0 112.0 113.0 110.0 $H125L40$ 127.5 122.0 122.0 112.0 107.0 99.0 102.0	H703 L70	123.5	114.0	114.0	112.0	117.0	117.0	117.0	108.0	104.0
H704L40135.5129.0132.0125.0128.0122.0117.0111.0111.0H704L50133.2127.0129.0123.0126.0121.0118.0112.0118.0H704L60128.4121.0122.0118.0122.0118.0112.0118.0112.0108.0H704L70127.1117.0117.0115.0121.0120.0118.0112.0108.0H704L80124.2112.0112.0114.0120.0118.0115.0109.0104.0H705L40136.4130.0133.0126.0128.0123.0116.0112.0112.0H705L60128.9122.0122.0121.0118.0112.0110.0112.0H705L60128.9122.0122.0121.0118.0112.0110.0H705L80124.9112.0115.0121.0112.0113.0110.0H705L80124.9112.0115.0121.0112.0113.0110.0H125L60121.0116.0115.0110.0116.0111.0108.0100.0100.0H1125L60121.0116.0115.0110.0114.0111.0107.0100.0-0.0H1125L60121.0116.0115.0110.0116.0111.0106.0100.0-0.0H1125L60121.0116.0112.01	H703 L80	120.3	110.0	110.0	109.0	115.0	115.0	111.0	105.0	100.0
H704L50133.2127.0129.0123.0126.0121.0118.0112.0111.0H704L60128.4121.0122.0118.0122.0120.0118.0112.0108.0H704L70127.1117.0117.0115.0121.0121.0120.0113.0109.0H704L80124.2112.0112.0114.0120.0113.0115.0109.0104.0H705L40136.4130.0133.0126.0128.0123.0116.0112.0112.0H705L50134.2128.0130.0124.0127.0122.0119.0113.0112.0H705L60128.9122.0122.0121.0118.0112.0110.0H705L80124.9112.0112.0115.0122.0122.0120.0113.0110.0H705L80124.9112.0112.0115.0121.0115.0109.0105.0H125L40127.5122.0124.0117.0119.0115.0100.0100.0H125L50125.3120.0122.0113.0110.0107.099.0102.0H125L70117.5111.0110.0106.0111.0108.0100.0100.0H125L70117.5111.0110.0106.0112.0117.0111.0101.0H125L80113.9108.0106.0102.0124.0 <t< td=""><td>H704 L40</td><td>135.5</td><td>129.0</td><td>132.0</td><td>125.0</td><td>128.0</td><td>122.0</td><td>117.0</td><td>111.0</td><td>111.0</td></t<>	H704 L40	135.5	129.0	132.0	125.0	128.0	122.0	117.0	111.0	111.0
H704L60 128.4 121.0 122.0 118.0 122.0 120.0 118.0 112.0 108.0 H704L70 127.1 117.0 117.0 115.0 121.0 121.0 120.0 113.0 109.0 H704L80 124.2 112.0 112.0 114.0 120.0 113.0 113.0 109.0 H705L40 136.4 130.0 133.0 126.0 128.0 123.0 116.0 112.0 112.0 H705L50 134.2 128.0 130.0 124.0 127.0 122.0 119.0 113.0 112.0 H705L60 128.9 122.0 122.0 119.0 113.0 112.0 110.0 H705L60 128.9 122.0 122.0 122.0 122.0 120.0 113.0 110.0 H705L80 124.9 112.0 112.0 115.0 109.0 105.0 H705L80 124.9 112.0 112.0 119.0 115.0 109.0 105.0 H125L40 127.5 122.0 122.0 123.0 112.0 107.0 99.0 102.0 H125L50 125.3 120.0 122.0 112.0 119.0 115.0 100.0 100.0 H125L60 121.0 116.0 115.0 110.0 114.0 111.0 107.0 99.0 102.0 H125L60 121.0 116.0 115.0 112.0 110.0 1	H704 L50	133.2	127.0	129.0	123.0	126.0	121.0	118.0	112.0	111.0
H704L70127.1117.0117.0115.0121.0121.0120.0113.0109.0H704L80124.2112.0112.0114.0120.0113.0115.0109.0104.0H705L40136.4130.0133.0126.0128.0123.0116.0112.0112.0H705L50134.2128.0130.0124.0127.0122.0119.0113.0112.0H705L60128.9122.0122.0120.0122.0120.0113.0110.0H705L70127.9117.0118.0117.0122.0122.0120.0113.0110.0H705L80124.9112.0115.0121.0119.0115.0109.0105.0H1125L40127.5122.0122.0113.0116.0111.0108.0100.0100.0H1125L50125.3120.0122.0113.0116.0111.0108.0100.0100.0H1125L70117.5111.0110.0114.0111.0105.0100.094.0H1126L4013.6127.0130.0123.0126.0121.0117.0111.0111.0H1126L5013.9106.0103.0126.0121.0117.0111.0101.094.0H1126L60129.1122.0123.0126.0121.0117.0111.0111.0111.0H1126L60129.1122.0 <t< td=""><td>H704 L60</td><td>128.4</td><td>121.0</td><td>122.0</td><td>118.0</td><td>122.0</td><td>120.0</td><td>118.0</td><td>112.0</td><td>108.0</td></t<>	H704 L60	128.4	121.0	122.0	118.0	122.0	120.0	118.0	112.0	108.0
H704L80124.2112.0112.0114.0120.0113.0115.0109.0104.0H705L40136.4130.0133.0126.0128.0123.0116.0112.0112.0H705L50134.2128.0130.0124.0127.0122.0119.0113.0112.0112.0H705L60128.9122.0122.0119.0122.0121.0118.0112.0110.0H705L70127.9117.0118.0 $.17.0$ 122.0122.0120.0113.0110.0H705L80124.9112.0112.0115.0121.0119.0115.0109.0105.0H125L40127.5122.0122.0113.0116.0111.0107.099.0102.6H1125L50125.3120.0122.0113.0116.0111.0108.0100.0100.0H1125L60121.0116.0115.0110.0114.0111.0107.099.0102.6H1125L70117.5111.0110.0106.0112.0110.0106.0102.097.091.0H1126L40133.6127.0130.0123.0126.0121.0117.0111.0111.0H1126L40133.6127.0130.0123.0126.0121.0117.0111.0111.0H1126L50133.9126.0129.0123.0126.0121.0116.0113.0 <t< td=""><td>H704 L70</td><td>127.1</td><td>117.0</td><td>117.0</td><td>115.0</td><td>121.0</td><td>121.0</td><td>120.0</td><td>113.0</td><td>109.0</td></t<>	H704 L70	127.1	117.0	117.0	115.0	121.0	121.0	120.0	113.0	109.0
H705L40136.4130.0133.0126.0128.0123.0116.0112.0112.0H705L50L34.2128.0L30.0124.0127.0122.0119.0113.0112.0H705L60128.9122.0122.0119.0122.0121.0118.0112.0110.0H705L60128.9122.0122.0121.0118.0112.0110.0H705L70127.9117.0118.017.0122.0122.0120.0113.0110.0H705L80124.9112.0112.0115.0121.0115.0109.0105.0H1125L40127.5122.0124.0117.0119.0112.0107.099.0102.6H1125L50125.3120.0122.0113.0116.0111.0108.0100.0100.0H125L60121.0116.0115.0110.0114.0111.0107.0100.0-0.0H1125L70117.5111.0110.0106.0112.0107.0100.0-9.0H1126L40133.6127.0130.0123.0126.0124.0117.0111.0111.0H1126L50133.9126.0129.0123.0126.0124.0127.0117.0111.0H1126L50133.9126.0129.0123.0126.0120.0126.0121.0116.0113.0H1126L60129.1122.0123.0 </td <td>H704 L80</td> <td>124.2</td> <td>112.0</td> <td>112.0</td> <td>114.0</td> <td>120.0</td> <td>113.0</td> <td>115.0</td> <td>109.0</td> <td>104.0</td>	H704 L80	124.2	112.0	112.0	114.0	120.0	113.0	115.0	109.0	104.0
H705L50134.2128.0130.0124.0127.0122.0119.0113.0112.0H705L60128.9122.0122.0119.0122.0121.0118.0112.0110.0H705L70127.9117.0118.0 117.0 122.0122.0122.0120.0113.0110.0H705L80124.9112.0112.0115.0121.0119.0115.0109.0105.0H1125L40127.5122.0124.0117.0119.0112.0107.099.0102.0H1125L50125.3120.0122.0113.0116.0111.0108.0100.0100.0H1125L50125.3120.0122.0113.0116.0111.0107.0100.0100.0H1125L50125.3120.0122.0113.0116.0111.0107.0100.0100.0H1125L50125.3120.0122.0123.0116.0111.0107.0100.099.0102.0H1125L60121.0116.0115.0110.0106.0112.0110.0106.0100.099.0102.0H1125L60123.0124.0123.0126.0123.0126.0123.0126.0121.0117.0111.0H1126L60133.9126.0129.0123.0128.0124.0121.0116.0113.0H1126L60<	H705 L40	136.4	130.0	133.0	126.0	128.0	123.0	116.0	112.0	112.0
H705L60128.9122.0122.0119.0122.0121.0118.0112.0110.0H705L70127.9117.0118.0 $\perp 17.0$ 122.0122.0120.0113.0110.0H705L80124.9112.0112.0115.0121.0119.0115.0109.0105.0H1125L40127.5122.0124.0117.0119.0112.0107.099.0102.0H1125L50125.3120.0122.0113.0116.0111.0108.0100.0100.0H1125L60121.0116.0115.0110.0114.0111.0107.099.0102.0H1125L70117.5111.0110.0106.0112.0110.0106.0100.0-0.0H1126L80113.9108.0106.0103.0108.0106.0102.097.091.0H1126L80113.9108.0106.0103.0128.0124.0121.0111.0111.0H1126L80133.9126.0129.0123.0126.0121.0117.0111.0111.0H1126L60129.1122.0123.0128.0124.0121.0116.0113.0H1126L60129.1122.0123.0124.0121.0116.0111.0106.0H1126L60129.1122.0123.0124.0120.0120.0120.0120.0<	H705 L50	134.2	128.0	130.0	124.0	127.0	122.0	119.0	113.0	112.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H705 L60	128.9	122.0	122.0	119.0	122.0	121.0	118.0	112.0	110.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H705 L70	127.9	117.0	118.0	±17.0	122.0	122.0	120.0	113.0	110.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H705 180	124.9	112.0	112.0	115.0	121.0	119.0	115.0	109.0	105.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H1125L40	127.5	122.0	124.0	117.0	119.0	112.0	107.0	99.0	102.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H1125L50	125.3	120.0	122.0	113.0	116.0	111.0	108.0	100.0	100.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H1125L60	121.0	116.0	115.0	1.10.0	114.0	111.0	107.0	100.0	-0.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H1125L70	117.5	111.0	110.0	106.0	112.0	110.0	105.0	100.0	94.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H1125180	113 9	108.0	106.0	103.0	108.0	106.0	102.0	97.0	91.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H11256160	133 6	127 0	130.0	123.0	126.0	121.0	117.0	111.0	111.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	H1126150	133 0	126 0	129.0	123.0	128.0	124.0	121.0	116.0	113.0
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	11126160	120 1	122 0	123.0	119.0	123.0	170.0	118.0	112 0	106.0
H1126L80121.4113.0112.0110.0116.0115.0112.0100.0H1126L80121.4113.0112.0110.0116.0115.0112.0107.0100.0H1127L40135.3129.0132.0124.0127.0122.0118.0112.0112.0H1127L50135.4127.0130.0125.0130.0125.0123.0118.0115.0H1127L60130.7123.0124.0121.0125.0122.0119.0114.0109.0H1127L70127.9119.0118.0116.0122.0122.0119.0114.0109.0H1127L60123.6114.0113.0112.0118.0115.0110.0 -6.0	H1126170	125 5	117 0	117.0	113.0	120.0	119.0	116.0	111.0	106.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	U1126180	121 4	113 0	112 0	110 0	116.0	115.0	112.0	107.0	100.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	H11271/0	125 3	120 0	132.0	124 0	127.0	122.0	118.0	112.0	112.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	NTT71640	135 %	127 0	130 0	125 0	130 0	125 0	122 0	118.0	115 0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	01127140	130 2	102 0	12/ 0	121 0	125.0	122.0	110 0	114.0	100 0
11127120 127.5 117.0 113.0 112.0 112.0 118.0 118.0 115.0 110.0 -0.0	11127600	130.1	110 0	118 0	116 0	122 0	122.0	110 0	114.0	100.0
	11127670	122 6	11/ 0	112.0	112 0	118 0	118.0	115 0	110 0	-0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

100





PRESSURE RATIO (P./P.)

D64

JET VELOCITY (IDEAL) ~ FPS

△----- 1500° F

⊙----⊙ 1000° F

 NOZZLE EXIT AREA (Ag): 5.9 FT2

DATA INCLUDES GROUND REFLECTION INTERFERENCE





HM-AP-18a

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 8.0)

Remarks

The HM-AP-18a nozzle was the largest area ratio nozzle of the 37 tube hexagonal array test series. Nozzles tested with the 12-spoke terminations on each of the 37 tubes were:

HM-AP-18	AR	4.64
HM-AP-18a	AR	8.0
HM-AP-40	AR	3.33
нм-ар-41	AR	4.0
HM-AP-42	AR	5.2

Test results for the HM-AP-18a nozzle are discussed in References D7, D8 and D9. Least PNL suppression was attained with this nozzle. The large area ratio provided good low frequency suppression, however the high frequency portion of the spectrum was relatively high in level. Spacing the tube elements relatively far apart reduces the effectiveness of the outer rows of jets to shield the noise generated by the tubes in the inner rows, and jet mixing noise levels are higher. HM_AP-18a

Test Facility: Annex L (Cell #1) Nozzle and Microphone Heights are 20 Inches

Date:

 T_{amb} :

R.H.:

Run No.	P_{T}/P	$\underline{\mathrm{T}}\underline{\mathrm{T}}$	V_{J} (Ideal)	Nozzle
н 596	1.8	1000°F	1660 fps	HM-AP-18a
н 597	2.2	11	1900	11
н 598	2.6	11	2070	n
H 599	3.0	u	2200	11
н 600	3.2	11	2250	11
H1134	1.8	1500°F	1930	11
H1135	2.6	11	2400	н
н1136	3.0	*1	2550	11
н 637	1.8	100°F	1660 fps	4.1-Inch Round Convergent Nozzle
н 638	2.2	11	1900	"
н 639	2.6	11	2070	11
н 640	3.0	11	2200	11
н 641	3.2	tt	2250	11
H1125	1.8	1500°F	1930	11
H1126	2.6	11	2400	11
H1127	3.0	11	2550	11

Note: Measured acoustic data is recorded in Reference D2.

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES 'CM2//25 FT

HM-AP-180-

RUN NO.	OASPL	500-	١ĸ	2K	4K	8K.	16K	32K	64K
H596 L40	106.3	101.0	99.0	93.0	1,00.0	97.0	94.0	94.0	-0.0
H596 L50	109.5	102.5	100.0	95.0	103-5	102.0	100.5	98.0	93.0
H596 L60	107.6	99.0	97.0	93.0	101.0	100.5	100.5	98.0	89.0
H596 L70	105.2	98.0	94.0	90.0	98.0	97.0	98.0	97.0	86 0
H596 L80	103.3	95.0	71.0	90.0	95.0	95.0	97.0	96.0	88.0
H597 L40	110.4	103.0	3.02.0	97.0	105.0	103.0	99.0	99.0	97.0
H597 L50	113.7	105.5	103.5	98.0	108.5	106.5	105.5	101.5	94.0
H597 L60	112.1	102.5	100.5	96.0	105.5	105.5	105.5	103.0	95 0
H597 L70	109.2	102.0	97.0	94.0	102.0	101.0	102.0	101.0	9/ 0
H597 I.SO	107.8	98.0	94.0	93.0	100.5	300.5	101.0	101.0	02 0
H598 L40	113.7	105.0	103.0	98.0	110.0	106.0	103.0	102.0	94.0
H598 L50	116.1	108.0	104.5	101.9	111.5	108.5	107.5	104.5	94.0
H598 L60	115.0	104.5	102.5	98.0	109.5	108.0	109.0	104.5	06.0
H598 L70	122.5	103.5	99.0	96.0	105.5	105.5	106.5	103 5	90.0 06.0
H598 L80	110.0	100.5	96.0	95.0	103.0	102 5	103.0	103.0	05.0
H599 L40	115.6	107.0	103.0	101.0	111.0	109.0	105.0	104.0	0.00
H599 L50	118.5	109.5	107.0	102.5	113.5	111 5	110.0	107.5	1015
H599 L60	117.6	107.0	104.0	100.5	111.5	111 5	111 5	107.5	102.5
H599 L70	114.5	105.5	101.5	97.0	107 5	107 5	108 2	107.5	99.0
H599 L80	112.6	103.0	98.0	96.0	105 0	107.5	106.5	10013	99.0
H600 L40	116.3	108.0	105.0	101.0	111 0	110.0	107 0	102.0	97.0
H600 1.50	118.9	111.0	108 5	103 5	112.0	110.0	107.0	100.0	99.0
H600 L60	117.9	107.0	105 5	101 5	112 5	112.0	117 6	107.5	103.2
1600 1.70	115.3	107.0	102 5	101.5	108 0	100 0	TT1 / G	107.0	99.0
3600 1.80	173.7	102.5	00.0	07.0	106.0	100.0	107.0	107.0	100.0
H1134(40	107.6	98.0	97.0	9/.0 9/.0	102.0	100.0	101.2	100.5	98.0
811341.59	110.2	100 0	97.0	94.0	105.0	102 O	99.0	96.0	93.0
H1134L60	110 3	08.0	95.0	95.0	100.0	102.0	102.0	99.0	94.0
311341.70	103 6	96.0	03.0	9J.0 01 0	102.0	102.0	103.0	100.0	94.0
H11341.80	105.0	0% Ď	01.0	91.0	102.0	102.0	102.0	100.0	99.0
11125140	116 6	105 0	101 0	0.60	99.0	99.0	100.0	98.0	93.0
H11351.50	117.1	106.5	101.0	90.U 00 0	110.0	100.0	120.0	102.0	93.0
111351.60	117 1	104 0	104.0	100 0	112.0	111.0	110.0	104.0	99.0
H1135170	115 /	103.0	101.0	100.0	100 0	115.0	110.0	106.0	100.0
H1135L80	112 3	100.0	06.0	90.0	102.0	100.0	107.0	106.0	102.0
H1136140	117 1	100.0	102 0	00 S	102.0	100.0	10/.0	104.0	98.0
H11361 50	110 1	100.0	102.0	101 0	114.0	112.0	110.0	104.0	100.0
811361.60	110 1	107.0	103.0	101.0	114.0	172.0	112.0	107.0	101.0
H1136L79	118 8	106.0	101.0	102.0 08 A	110 0	1-12 0	112.0	10/.0	102.0
H1136180	174 6	103.0	08 0	06.0	107.0	112.0	112.0	112.0	108.0
H637 140	126 1	120 5	126.0	112 c	112 0	109.0	109.0	106.0	100.0
H637 L50	123.7	110 5	124.0	112.0	113 0	104.0	200 5	92.0	-0.0
H637 160	118 6	112.0	116 0	100 0	173.2	106.5	102.5	95.0	-0.0
H637 170	115 2	100 0	100 0	105.0	110 0	100.2	100.2	93.0	-0.0
H637 180	112 2	105.5	105.0	102.0	110.0	104.0	101.0	94.C	-0.0
u620 1 /0	120 2	102.2	100.0	103.5	106.5	101.5	98.0	93.0	-0.0
1030 140	127.5	124.0	120.0	110.5	120.5	111.0	106.0	103.0	-0.0
NC20 LC0	127.0	122.0	124.0	110.5	119.5	112.5	109.5	103.5	-0.0
NUSO LOC	122.3	110.0		111.5	110.0	111.5	197.0	101.5	-0.0
	119.2	112.0	112.0	109.0	114.0	110.0	108.0	102.0	-0.0
1030 100	131 V	101.2	108.5	10/.5	110.5	107.5	104.5	98.5	88.0
1037 L40	100 /	122.0	128.0	122.5	124.0	116.5	113.0	110.0	-0.0
4023 720	106.4	124.0	14/.U	120.5	122.0	TT0.0	114.5	109.5	-0.0
1033 PPA	123.4	113.0	120.0	115.5	120.0	115.0	111.5	106.5	98.0
u02A P\O	123.0	E14.Q	115.0	113.0	118.0	115.0	113.0	107.0	100.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2//25 FT

HM-AP-18a

RUN NO.	OASPL	500	-1K	2К	4K	-8K	16K	32K	64K
H639 LEO	. 120.1	110.0	110.5	111.5	111.0	113.5	110.5	105.5	97.0
H640 L40	133.6	127.0	130.0	124.0	136.0	119.5	115.0	113.0	107.5
H640 L50	132.9	126.0	129.0	123.0	126.0	119.0	118.5	113.5	109.5
H640 L60	127.8	120.5	122.0	117.0	122.0	118.5	11.5.5	110.0	101.5
H649 I.70	125.6	115.0	117.0	117.0	120.0	118.0	117.0	111.0	104.0
H640 L80	123.0	111.5	112.5	1-14.5	118.0	116.5	113.5	109.5	101.5
H641 L40	135.5	128.0	132.0	127.0	128.0	121.0	117.0	113.0	108.5
H641 E59	134.2	127.0	130.0	124.0	128.0	121.5	119,0	114.5	110.5
H641 L60	1.28.7	121.0	123.0	119.0	123.0	1.19.0	116.3	112.0	-0.0
-HS41 L70	126.6	116.0	118.0	117.0	122.0	119.0	117.0	112.0	105.0
H641 L80	124.5	112.5	113.5	116.5	120.0	117.5	114.5	110.5	103.5
H1125L40	127.5	122.0	124.0	117.0	119.0	112.0	107.0	99.0	102.0
H1125L50	125:3	120.0	122.0	113.0	116.0	111.0	108.0	100.0	100.0
H1125L50	121.0	116.0	115.0	110.0	114.0	111.0	107.0	100.0	-0.0
H1125L70	117.5	111.0	110.0	106.0	112.0	110.0	105.0	100.0	94.0
H1125L80	113.9	108.0	106.0	103.0	108.0	106.0	102.0	97.0	91.0
H1126L40	133.6	127.0	130.0	123.0	126.0	121.0	117.0	111.0	111.0
H]126L50	133.9	126.0	129.0	133.0	128.0	124.0	121.0	116.0	113.0
H1126I.60	129.1	122.0	123.0	119.0	123.0	120.0	118.0	112.0	106.0
H1126L/0	125.5	117.0	117.0	113.0	120.0	119.0	116.0	111.0	106.0
H1126L80	121.4	113.0	112.0	110.0	116.0	115.0	112.0	107.0	100.0
H1127L40	135.3	129.9	132.0	124.0	127.0	122.0	118.0	112.0	112.0
H1127L50	135.4	127.0	130.0	125.0	1.30.0	1,25.0	123.0	118.0	115.0
H1127L60	130.7	123.0	124.0	121.0	125.0	122.0	119.0	114.0	109.0
H1127L70	127.9	i19.0	118.0	116.0	122.0	122.0	119.0	114.0	109.0
H1127L80	123.6	114.0	113.0	112.0	i18.0	118.0	11 5.0	110.0	-0.0





HM-AP-20 NOZZEE

(ANNULAR SLOT WITH COANDA TYPE PLUG, AR 6.5)

Description:

The HM-AP-20 nozzle has an annular slot opening and center plug. Initially the primary flow is vectored outward 60 degrees relative to the nozzle axis. The center body was designed to gradually redirect the primary flow parallel to the nozzle axis by utilizing the "Coanda effect." Thrust is obtained largely from low static pressures on the plug.

Element: Annular Slot

Area Ratio: 6.5

Flow Area: 11.4 Square Inches

Exit Cant Angle: 60 Degrees Outward

Annular Slot Width: 0.56 Inches

Outside Diameter of Annular Slot: 7.8 Inches

Material: 321 CRES





POLAR ARC OCTAVE PASS BANDS IN HERTZ 140 45 130 RE: 0.0002 DYNES/CM²//200 FT POLAR ARC 08 06 001 011 021 001 RE: 0.0002 DYNES/CM²// 200 FT 125 OVERALL SPL~dB 3.0 OCTAVE BAND LEVEL~dB 2.0 2.2 120 1.8 PR 50 115 110 50⁰ 60⁰ 30⁰ 40⁰ 70⁰ 80⁰ 900 ANGLE TO THE JET AXIS~DEGREES TOTAL TEMPERATURE (T 8) : 1500° F NOZZLE EXIT AREA (A8): 3.3 FT2 70 5 5 2 5 1 2 1 100 1000 10000 FREQUENCY IN HERTZ HM-AP-20 NOZZLE PRESSURE RATIO: 1.8 (ANNULAR SLOT WITH 'COANDA TYPE' PLUG) TOTAL TEMPERATURE: 1500° F AR 6:5 JET VELOCITY (IDEAL): 1923 FPS SCALE FACTOR: 8:1 NOZZLE EXIT AREA (Ag): 3.3 FT2 OCTAVE PASS BANDS IN HERTZ OCTAVE PASS BANDS IN HERTZ 140 140 1111 ARC -AR ARC 130 RE: 0.0002 DYNES/CM²//200 FT POLAR 08 06 001 011 021 120 11111 RE: 0.0002 DYNES/CM²//200 FT POL 08 06 001 011 021 OCTAVE BAND LEVEL~dB OCTAVE BAND LEVEL~dB 50 70' 70 Ŧ 1111 70 70 5 5 2 2 1 5 Š 1 1000 1 10000 2 5 5 2 100 1000 100 10000 FREQUENCY IN HERTZ **FREQUENCY IN HERTZ** PRESSURE RATIO: 2.2 PRESSURE RATIO: 3.0 TOTAL TEMPERATURE: 1500" F TOTAL TEMPERATURE: 1500° F JET VELOCITY (IDEAL): 2555 FPS JET VELOCITY (IDEAL): 2202 FPS NOZZLE EXIT AREA (A8): 3.3 FT2 NOZZLE EXIT AREA (A8): 3.3 FT2 DATA INCLUDES GROUND REFLECTION INTERFERENCE

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HM-AP-20 NOZZLE

(Annular Slot with "Coanda Type" Plug)

Remarks

Several configurations of the HM-AP-20 Nozzle were tested with acousticabsorbent-lined and unlined ejectors. The unlined ejector configuration did not affect perceived noise level (PNdB) suppression values relative to the nozzle configuration without ejector. A fiberglass lined ejector configuration improved suppression values by 2 to 5 PNdB at low pressure ratios, PR = 1.8 and 2.6 at $T_T = 1500^{\circ}$ F, however no improvement in suppression was noted for pressure ratios over 2.6. See Reference D10.
HM-AP-20 NOZZLE

Test	Facility:	Annex I) (Cé	ēll #1)				
		Nozzle	and	Microphone	Height	is	20	Inches

Date: February 15, 1968 T_{amb}: 58°F

R.H.: 33%

Run No.	P_{T}/P_{\bullet}	$\frac{T_{T}}{T}$	V_{J} (Ideal)	Nozzle
2440 2441 2442 2443 2444 2444 2445 2446 2447	1.8 2.6 3.0 3.4 1.8 2.6 3.0 3.4	1000°F " " 1500°F " "	1659 fp: 2073 2205 2311 1923 2402 2555 2678	HM-AP-20 "" "" "" ""
2432 2433 2434 2435 2436 2437 2438 2439	1.8 2.6 3.0 3.4 1.8 2.6 3.0 3.4	1000°F " " " 1500°F " "	1659 fps 2073 2205 2311 1923 2402 2555 2678	3.08 Inch Round Convergent Nozzle

HM-AP-20 NOZZLE TEST DATA

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2//25 FT

RUN NO.	OASPL	500	١K	2K	4K	8K	16K	32K	64K
ጋልፋብ 1 ኤር	115+9	103.0	44.0	94.0	112+0	110.0	100.0	104+0	Lyte /
2446 140	115+4	94	99.0	49 . U	111+0	117.44	jud•n	102+0	77.1
2440 170	112	100	97+0	47.0	~ 10H+U	14/+0	In2+U	102+0	4 7 e · i
2645 1 48	110.7	35	96.0	95.V	105+4	104.0	104+7	161+0	70+
2640 1.10	108+3	94	96.0	95+0	103+0	101.0	102.0	9701	• • • •
2441140	119.5	134.0	107.0	194+0	114+9	14.9	112+0	100.0	Lene
2661 160	118	105.0	107+0	103.0	113+9	113.0	115+0	107.0	1 + + + +
2441 1 70	117.	102.9	104+0	100.0	112+0	114+9	111+0	10/+0	141.00
2541 140	115.2	100.0	102+0	99.0	110+9	10400	Tna+U	100+0	1000
2441 150	113.2	100.5	100.0	99.0	107+4	104.40	10/+0	105+0	■ 11 1. • • •
2442 140	114.4	110.0	109.0	105+0	1] 4 + 0	114.0	112.0	100+0	164.01
2442 140	119.2	100-1	108.0	104+1	113+0	113.0	112+4	102+0	1020
2442 1 10	117.7	104-0	105+0	102.0	112+0	112.0V	111.0	100.0	100.00
2642 150	110.0	102.	103.0	100.0	110+0	104.0	110+0 ,	107+0	1 (14 • 1)
2442 190	114.5	101.00	102+0	100.0	107+0	101+0	109.0	107•0	10201
2443 150	121.3	112.0	111+0	107.0	116+0	11~+0	113+0	109+0	102.0
2443 140	120.4	100.	109+0	105+0	115+0	114+0	114+0	110+0	[j] D
2443170	118.4	105.0	106+0	103+0	114+0	113+11	116+0	100+0	10301
2443 140	117.1	103.0	104+0	102.0	111+0	111.0	110+0	100+0	10445
2443 190	115.7	102.0	103+0	101+0	109+0	10000	110+0	100.0	104+6
2444 1.50	118-3	10440	103.0	103.0	115.0	113+1	111+0	10/+0	106.0
2444 140	1124.4	104.1	102.0	102.0	114+0	113.0	111+0	107+9	103.0
2444 170	11641	100.0	101.0	100.0	112-0	110+0	109-1	102+0	97.0
2444 1 20	114-1	9H .:	99.0	90.0	110.0	101+0	1ú7+n	104+0	100+8
2444 L90	112.5	97.0	99.0	98+0	108+0	102+0	100+0	103.0	4 f • ft
2445 140	121.7	111.0	110.0	105+0	117+0	115.0	114+0	110+0	100.0
2445 140	120.0	1.18.	109+0	105.0	115+0	11.0	114+0	110.0	100.0
2445 1 70	117.4	100.	105.0	102.0	113.0	111.0	111+0	10/+0	101.0
2445 1 40	116.4	103.0	103+0	101+9	112+0	113.0	11 <u>n</u> +U	10/+0	در ه ک رز ز
2445 190	115+1	101.0	102.0	101+0	109+0	102+0	「リステリ	106+0	101+0
2446 150	122.5	114.9	112.0	108+0	117+0	110+0	114+0	111+9	102.0
2446 140	122.0	111.14	111+0	107+0	116.0	118+0	115+0	11140	107.45
2446 170	120.1	107.0	107.0	105+0	115+0	114-0	<u>114+n</u>	110+0	104+6
2446 1 30	117.9	105.0	105+0	102.0	113+0	111+0	111+0	100.0	104 • 1
2446 1 40	116+4	103.0	104+0	102+9	110+9	110 + 0	111+n	104+0	103.4
2647 140	123.4	116.1	114+0	110.0	118+0	117+0	112+0	111.0	107+3
2667 1 - 9	123.2	112.9	112.0	109+0	$118 \bullet 0$	-117+0	115+0	114+0	. 100.0
2441 110	120.4	108.00	109+0	100.0	113.0	115+9	114+1	111.0	104+0
2447 1 00	118+4	105.0	106+0	104.0	114+0	115+0	115+0	102+0	105.0
2447 100	117.1	105.0	105.1	103.0	110.0	119+0	111.0	107+0	103+0
2432 140	120.4	113.	117.0	110+0	114+0	106.0	100+n	96+0	92.5
2432 150	118+6	111.0	115.0	100.0	112.0	107.0	100-0	96.0	
2472 1.00	114.7	106.0	109+0	103.0	110.0	105+0	104.0	96 • 0	92.1
2432 1 70	110+7	101.0	103.0	100.0	106.0	103.0	100•n	97.0	9u+ii
2632 140	110.1	106.0	99.0	97.0	104•0	101.0	99. n	95-0	87.0
2413 140	127.4	118.0	122.0	117.0	124.0	117.0	113.0	107+0	104+6
2433 150	127.1	117.0	121+0	117+0	123.0	118+0	112+0	107+0	105+9
2433 160	121.0	111	114+0	111+0	118+0	113.0	111+0	107+0	100+0
2433 170	118.2	109-0	108.0	106+0	113.0	111.0	110+0	106+0	101.0
2413 1 40	115+4	103.0	105+0	104+0	112-0	110.0	108.0	102+0	90.0
2444 141	129-1	121-0	124.0	119+0	124+0	132-0	115+n	111+0	105+1
2474 146	 134-4	1174	123+0	120+0	126+0	121-0	116+0	112+0	100.0
24 14 1 60	124.0	113.0	116.0	113.0	120+0	41740	114+n	110+0	303.0
2434 L70	120+0	108.0	110+0	110+0	115+9	114+0	113.0	107+n	105+4
2434 (+0)	114.4	105.0	106+0	107.0	114+0	113+V	111•n	10/+0	101+0
2435 140	130	122.	126+0	121+0	125+0	112-0	115 e n	116+0	10/+-
26 45 1 40	131+4	121.	125+0	122+1	158+0	123-11	110+0	114+0	110.0
2699 L40	123.2	114.	118+0	115+0	155+0	117+4	110.0	114.0	105+6
2475 170	172.0	119.1	111+0	114+3	117+0	11/+0	115.0	111+0	10/+4
2475 140	121.7	100.0	104-0	114.00	11740	115-4	113.0	110.0	103.0

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NOTE: THIS DATA INLUDES GROUND REFLECTION INTERFERENCE

HM-AP-20 NOZZLE TEST DATA												
RUN:NO.	OASPL	500	١ĸ	2K	4K	8K	16K	32K	64K			
24-36 140	124.3	115.0	119.0	114.0	1-20.0	413.0	109-0	103.0	ن ن ن ن			
2436 650	123+1	115.0	118.0	114.0	1-18-0	112.0	107.00	102.00	97.7			
2436 640	118+6	1.09.0	113.0	108.0	1-16-0	109.0	106.0	100-0	0.4			
2436 170	114.5	104.0	107.0	103.0	1-10-0	106.0:	105-0	100.0	QÅ.			
2436 180	111.9	101.0	103.0	101.0	108.0	104.0	102.0	-98-0	90.0			
2437 140	128.1	120.0	123.0	118.0	123.0	117.0	114.0	109-0	105 0			
2437 650	130-1	119.0	124.0	120-0	12010	131 A	14240	10200	10000			
2437 60	125.1	114.1	118.0		121-11	14100	<u>1-14</u> -0	· -116+0-	100.00			
2437 170	120.6	108.0	111.0	109-0	1-16-0	114.0	112.4	100-0	103 0			
2437 1.90	117+7	105.0	107.0	106-0-	113.0	11.1 0	110.00	106.0	103.0			
2438 140	129.8	1-22.0	125.0	121-0	194 0	114+0	11.9	100.0	970) 			
2438 150	132.4	121.0	125.0	123.0	1274.0	1.23.7	11200	11100	100.0			
2438 L60	128.3	116.0	120.0	117.0	1270	229 V.	1120	114.0	110+0			
2438 1.70	122.9	110.0	1-13-0	111.0	1.1.9.0	1€"+V 3=1 ÷	11140	116.0	100.0			
2438 1.80	120.9	107.0	109-0	109.0	<u>110+0</u>	11200	11200	<u> 1110</u>	- <u>105</u> 7			
2439 140	131.2	124.0	127.0	121.0	120+0	110 9	11200	104+0	103+0			
2439 150	133.3	123.0	127.0	124.0	129.0	41-70V	110.0	1110	10/+0			
2439 1.60	128.6	117.0	121.0	118.0	195.0	120 0	117-0	11300				
2439 170	124+1	111.0	114.0	112.0	139-0		11/00	11200	101+0			
2439 1.80	122.0	108.1	110-0	110.0	11340	*10+U	1-10-0	- 114+0	105+6			

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NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE



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HM-AP-22 NOZZLE (-12 SPOKES, AR 1.4) Description: Number of Elements: 12 spokes Area Ratio: 1.4 Spoke Penetration: 70% Flow Area: 🗠 13.2 square inches Exit Cant Angle: 17.5° sutward Ventilation Gutter Cant Angle: 27.5° Nozzle Diameter: 4.62 inches PNL SUPPRESSION PNdB // 1500 FT SIDELINE 22 20 18 PNL SUPPRESSION (PNdB) 16 14 THRUST LOSS (%) 2 12 10 8 6 0 2000 2200 2400 2600 1400 1600 1800 2800 2 3 1 PRESSURE RATIO (P.A.) JET VELOCITY (IDEAL) ~ FPS ▲ 1500° F NOZZLE EXIT AREA (A.): 5.9 FT2 DATA INCLUDES GROUND REFLECTION INTERFERENCE





HM-AP-22 (12 Spokes, AR = 1.4)

Remarks

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Several different chuted ejector configurations were tested on the HM-AP-22 nozzle. The chuted ejectors improved PNL suppression by as much as 3.5 PNdB, however, the attendant increase in thrust loss (approximately 25%) more than offset any advantages gained in suppression, see Reference D11.

HM-AP-22

Test Facility · Annex D (Cell #1)

Date:

Tamb:

R.H. ·

Run No.	P_{T}/P	$\frac{\mathbf{T}\mathbf{T}}{\mathbf{T}}$	$\frac{V_{j}}{(\text{Ideal})}$	Ne	ozzle	
н 576	1.8	1500°F	1923 fps	HM-	-AP-22	
H 577	2.2	11	2202		11	
н 578	2.6	11	2402		11	
H 579	3.0	11	2555		11	
н 580	3.2	11	2610		11	
н 561	1.8	1500°F	1923 fps	4.1-Inch Round	Convergent	Nozzle
н 562	2.2	11	2202		11	
8 563	2.6	11	2402		11	
н 564	3.0	ti	2555		81	
н 565	3.2	11	2610		11	

Measured acoustic data is included in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2//25 FT

HM_AP-22

RUN NO.	OASPL	500	1K	2K	4K	ιX	-16K	32K	64K
N576L40	120.8	-117.0	117.0	106.0	111.0	105.0	100.0	95.0	0.0
H576L50	120.2	116.0	115.0	106.0	113.0	108.0	104.0	99.0	0.0
H576L60	118.0	112.0	111.0	107.0	113.0	108.0	105.0	97.0	86.0
H576L70	118.6	110.0	110.0	106.0	115.0	110.0	108.0	101.0	00.0
H576L80	114.3	106.0	106.0	103.0	108.0	107.0	106.0	102 0	20.0
H577L40	126.1	121.0	123.0	113.0	116.0	111.0	106.0	102 0	92.6
H577L50	125.5	121.0	121.0	112.0	118.0	112.0	109.0	103 0	92.0
H577L60	122.0	115.0	116.0	111.0	117.0	112.0	109 0-	103 0	03.0
H577L70	121.4	112.0	113.0	109.0	118.0	112.0	111.0	104 0	95.0
H577L80	118.4	109.0	110.0	107.0	114.0	110.0	109.0	105 0	92.0
H578L40	129.7	124.0	126.0	119.5	122.0	115.0	110.0	106 5	0.0
H578L50	128.7	123.0	125.0	116.0	121.0	116.0	112 0	106 0	0.0
H578L60	124.9	118.0	119.0	113.0	120.0	115.0	110 0	104 0	95.0
H578L70	123.2	114.0	115.0	112.0	119 0	115 0	113 0	106.0	07 0
H578L80	119.4	111.0	111.0	108.0	115.0	111.0	109.0	105.0	95 0
H579L40	132.6	125.0	129.0	123.0	126.0	118.0	113.0	170.0	103.0
H579L50	131.2	125.0	127.0	119.0	125.0	118.0	115.0	110 0	100.0
H579L60	127.3	120.0	122.0	116.0	122.0	117.0	113.0	108.0	- 98.0
H579L70	125.5	116.0	117.0	115.0	122.0	116.0	114.0	107 0	00 0
H579L80	120.8	111.0	112.0	111.0	116.0	113.0	111.0	107.0	97.0
H580L40	134.1	127.0	130.0	125.0	128.0	119.5	115.0	110.0	103.0
H580L50	133.5	127.0	129.0	121.0	128.0	120.0	117.0	112.9	107.0
H580L60	128.3	121.0	123.0	117.0	123.0	118.0	114.0	109.0	23.0
H580L70	126.5	117.0	118.0	116.0	123.0	117.0	115.0	108.0	101.0
H580L80	122.3	113.0	114.0	113.0	117.0	115.0	112.0	108.0	98.0
H561L40	128.4	122.0	125.0	119.0	121.0	111.0	106.0	103.0	0.0
H561L50	127.3	122.0	123.0	117.0	120.0	114.0	108.0	103.0	0.0
H561L60	123.5	116.0	119.0	114.0	118.0	111.0	106.0	101.0	0.0
H561L70	120.5	113.0	113.0	111.0	116.0	111.0	107.0	101.0	0.0
H561L80	114.6	107.0	106.0	104.0	111.0	105.0	101.0	96.0	86.0
H562L40	131.9	126.0	128.0	122.0	124.0	118.0	113.0	110.0	0.0
H562L50	131.8	127.0	127.0	122.0	124.0	118.0	114.0	110.0	0.0
H562L60	127.1	119.0	122.0	118.0	122.0	115.0	112.0	106.0	98.0
H562L70	123.5	116.0	116.0	113.0	119.0	114.0	111.0	106.0	99.0
H562L80	118.9	109.0	111.0	109.0	115.0	110.0	108.0	103.0	0.0
H563L40	133.0	126.0	129.0	124.5	126.0	119.0	114.0	112.5	0.0
H563L50	134.6	128.0	130.0	125.0	128.0	122.0	119.0	116.0	111.5
H563L60	132.1	124.0	127.Ò	122.0	127.0	121.0	117.0	114.0	0.0
H563L70	125.4	116.0	118.0	115.0	121.0	116.0	115.0	110.0	103.0
H563L80	122.4	112.0	113.0	112.0	118.0	115.0	113.0	109.0	100.0
H564L40	134.6	128.0	121.0	125.0	127.0	121.0	117.0	114.0	108.0
H564L50	135.3	128.0	131.0	125.5	129.0	123.0	121.0	116.0	112.0
H564L60	131.2	123.0	126.0	121.0	126.0	120.0	118.0	113.0	0.0
H564L70	127.6	118.0	120.0	118.0	123.0	119.0	117.0	112.0	106.0
H564L80	123.6	113.0	114.0	113.0	119.0	117.0	114.0	110.0	103.0
H565L40	137.0	130.0	123.0	128.0	130.0	124.0	119.0	117.0	110.0
H565L501	.135.7	128.0	131.0	126.0	130.0	124.0	121.0	118.0	1140
H565L60	131.8	124.0	121.0	122.0	126.0	120.0	119.0	114.0	0.0
H565L70	128.4	118.0	121.0	118.0	124.0	120.0	118.0	113.0	107.0
H565L80	124.6	112.0	114.0	114.0	120.0	118.0	116.0	112.0	103.0

NGTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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HM-AP- 23 NOZZEE

Description:

The HM-AP-23 nozzle has a plenum upstream of the nozzle exit plane wherein ambient air is collected from 3 hollow struts and issued through 7 round divergent tubes coplanar with the nozzle exit. The primary flow completely surrounds the 7 tubes.

Number of Elements: 7 tubes (for secondary flow)

Area Ratio: 1.8

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Material: 321 CRES







HM-AP-23 NOZZLE

(7 Tubes, Internally Ventilated, AR = 1.8)

Remarks:

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Another nozzle (HM-AP-56) with 37 tubes, internally ventilated, was tested. Internally ventilated tube nozzles potentially offer the advantage of increasing primary flow mixing with tube elements and low area ratios. See Reference D12.

HM-AP-23 Test Facility: Annex D (Cell #1) Date: Tamb: R. H.: VJ (Ideal) $\underline{\mathbf{T}}\underline{\mathbf{T}}$ PT/P Nozzle 1.8 1500°F HM-AP-23 1923 fps 2.6 11 2402 11 11 11 3.0 2555 11 11 3.4 2678 2000°F 2154 11

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Run No.

H992

H993

H994

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H996 H997 H998 H999	1.8 2.6 3.0 3.4	2000 [°] F " "	2154 2691 2862 3000	11 12 11 11
H982 H983 H984 H985 H1005 H1006 H1007 H1008	1.8 2.6 3.0 3.4 1.8 2.6 3.0 3.4	1500°F " " 2000°F " "	1923 fps 2402 2555 2678 2154 2691 2862 3000	4.1 Inch Round Convergent Nozzle " " " " " " "

Measured acoustic data for these runs are recorded in Reference D2.

		-	OZZLE	TEST	DATA								
			HN	AP 23									
OCTAVE BAND LEVEL - B RE: 0.0002 DYNES/CM ² // 25 FT													
RUN NO. OASPL 500 1K 2K 4K 8K 16K 32K 64K													
H992L40	119.8	115.5	114.0	105.0	113.0-	110.0	104.0	95.0	0.0				
H992L50	119.5	116.0	112.0	105.0	113.0	109.0	104.0	96.0	9.0				
H992L60	1-17.4	112.5	108.0	106.0	112.0	109.0	104.0	97.0	0.0				
H992L/U	116.3	110.0	107.0	103.0	111.0	109.0	106.0	. 99.0	91.0				
N992180	113.4	10/.0	105.0	101.0	108.5	105.0	103.0	96.0	0.0				
1995540	130.0	122.0	126.0	117.0	121.5	118.5	113.0	107.0	106.0				
H9931.60	103 0-	117 5	121.0	113.0	120.0	117.5	113.0	106.0	100.0				
H9931.70	122.2	11/ 6	112 0	100.0	117.0	116.0	112.5	105.0	98.0				
H993L80	119.1	111 0	110 0-	109.0	11/.0	110.0	113.0	107.0	100.0				
H994L40	132.4	126.5	128.0	121- 0	125 5	112.0	110.0	104.0	95.0				
H994L50	129.0	124.0	123.0	116.0	123.5	120.5	115 0	100.0	108.0				
H994160	125.5	119.0	116.0	114.0	120.5	118 0	114.0	109.0	104.0				
H994L70	1.23.8	115.0	113.5	110.0	118.5	118.0	115.0	109.0	102 0				
H994L80	120.6	112.0	114.0	108.0	115.0	114.0	113.0	106.0	98.0				
H995L40	133.9	128.0	130.0	123.0	126.0	122.0	118.0	112.0	110.0				
H995L50	130.5	125.0	125.0	117.0	123.5	121.5	117.0	110.0	105.0				
H995L60	126.6	120.0	118.0	115.0	121.5	119.0	115.5	109.0	102.0				
H995L70	124.4	116.0	115.0	111.0	119.0	118.0	116.0	110.0	103.0				
H995LSU	121.5	112.0	112.0	109.0	116.0	115.0	114.0	108.0	0.0				
H990L40 H006T 50	123.2	119.0	119.0	108.0	114.0	111.9	106.5	98.0	97.0				
H996L60	121.5	117.0	112.0	107.0	115.0	111.0	106.0	98.0	0.0				
H9961.70	117.6	109 0	108 0	105.0	114.0	E11.0	105.0	99.0	0.0				
H996L80	115.4	107 0	106.0	105.0	111.0	111.0	108.0	100.5	93.0				
H997L40	131.9	126.0	128.0	121 0	124.0	120.0	116.0	98.0	0.0				
H997L50	129.7	124.0	125.0	117.0	122.5	120.0	115 0	109.0	10/.0				
H997L60	126.3	119.0	118.0	114.5	121.5	119.0	115.0	108.0	101 0				
H997L70	124.3	114.5	114.0	111.0	120.0	118.0	115.0	108.5	101.5				
H997L80	121.1	111.0	111.5	109.0	117.0	114.0	112.9	105.0	97.0				
H998L40	134.2	128.0	130.5	123.5	126.0	122.0	118.0	111.0	110.0				
H998L50	132.5	126.0	128.0	121.0	126.0	122.0	118.0	112.0	107.0				
1998160	128.7	121.0	121.0	117.0	124.0	121.0	117.0	111.0	105.0				
1990170	120.1	112 0	110.0	114.0	122.0	120.0	117.0	110.5	104.0				
1990L00	125.0	120.0	121 5	111.0	118.5	116.5	114.0	108.0	0.0				
H9991.50	134 Å	127.5	130 0	124.5	127.0	123.0	119.0	112.0	111.0				
H999L60	130.0	122.0	122 0	110 0	120.0	·122 0	120.0	11.4.0	109.0				
H999L70	127.8	118.0	117.5	115.0	123.0	122.0	118 0	112.0	107.0				
H999L80	124.8	114.0	115.0	113.0	120.0	118.5	116.0	110 0	107.0				
H982L40	127.8	122.0	125.0	117.0	118,0	111.0	105.0	96.0	103.0				
H982L50	127.4	122.0	124.0	15.0	119.0	113.0	107.0	99.0	100.0				
H982L60	123.5	118.0	11.9.0	110.0	117.0	112,0	106.0	97.5	98.0				
H982L70	120.2	113.5	114.0	109.0	115.0	111.0	107.0	98.0	95.U				
H982L80	116.7	109.0	109.0	106.0	112.0	109.0	104.0	95.0	89.0				
H983L40	133.5	127.0	130.0	123.0	125.5	120.5	116.0	108.0	0.0				
1983120	134.1	128.0	130.0	123.0	127.0	122.0	118.0	111.0	107.0				
1903100	127 7	110 0	125.0	118.2	126.0	122.0	117.0	110.0	105.0				
H983180	12/ 5	114 0	115 0	112.0	123.0	119.0	117.0	110.0	1.05.0				
H9841.40	134.8	129.0	131.0	124.U	107 O	1-30 A	110.0	108.0	101.0				
H984L50	135.4	129.0	131.0	124.0	129.0	124 D	120.0	110.0	0.0				
H984L60	132.6	126.0	127.0	120.0	127.0	123.6	110 0	113 A	0.0 107 0				
H984L70	129.6	121.0	123.0	119.0	124.0	122.0	119.0	113.0	108.0				
H984L80	127.7	116.0	116.0	115.0	122.0	122.0	119.0	115.0	111.0				
H985L40	135.8	130.0	132.0	125.0	128.0	123.0	119.0	111.0	0.0				
H985L50	136.8	131.0	132.0	126.0	130.0	125.0	122.0	115.0	0.0				
H985L60	133.8	127.5	128.0	122.0	128.0	124.0	121.0	114.0	0.0				
H985L/U	130.9	123.0	124.0	120.0	125.0	123.0	121.0	114.0	0.0				
n7CJLOU	120,4	TT/"O	11/-0	110.0	143.0	124.0	119.0	112.0	0.0				
NOT	E: THIS D)a i'a inc	LUDES (ROUND	REFIEC	TION. IN	TEBEED	INCE					

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NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2/25 FT

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-HM-AP-23

RUN NO.	OASPL	500	1K	2K	4K	-8K	16K	32K	64K
H1005L40	128.0	121.0	1.25.0	118.0	1-20.0	114.0	108.0	100.0	-Û.Û
H1005L50	128.1	121.0	124.0	<u>Υ</u> 17:0-	122.0	116.0	110.5	102.0	-0.0
H1005L60	125.8	117.5	120.0	116.0	121.0	116.0	111.0	102.0	97.0
H1005L70	122.4	113.0	115.5	110.0	118.0	115.0	111.0	102.0	-0.0
H1005L80	119.0	109.0	110.0	108.0	115.0	112.0	108.0	99.5	92.0
H1006L40	132.8	126.5	129.0	122.0	125.0	121.0	117.0	109.0	108.0
H1006L50	134.0	127.0	129.5	123.0	128.0	123.0	119.0	113.0	108.0
H1006L60	133.2	123.5	126.5	123.5	129.0	124.0	121.0	114.0	108.0
H1006L70	130.2	119.0	122.5	118.0	126.0	123.0	120.0	113.0	108.0
H1006L80	126.7	114.0	116.0	114.5	123.0	120.0	118.0	111.0	14.0
H1007L40	133.9	128.0	130.0	123.0	126.0	122.0	118.0	110.0	109.0
H1007L50	135.2	128.0	131.0	124.0	129.0	124.0	121.0	114.0	109.0
H1007L60	134.8	125.0	128.0	125.0	130.5	126.0	122.0	116.0	111.0
H1007L70	131.5	121.0	124.0	120.0	127.0	124.5	121.0	115.0	110.0
H1007L80	128.3	115.5	118.0	116.0	124.0	122.0	120.0	113.5	105.0
H1008L40	135.4	129.5	132.0	125.0	126.0	123.0	119.0	112.0	110.0
H1008L50	136.4	129.5	132.0	126.0	130.0	125.0	122.0	115.0	111.0
H1008L60	135.6	126.0	129.0	126.0	131.0	127.0	123.0	117.0	112.0
H1008L70	132.2	122.0	125.0	120.5	127.5	125.0	122.0	116.0	111.0
H1008L80	129.2	116.0	119.0	117.0	125.0	123.0	121.0	114.0	107.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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HM-AP-24 NOZZLE 5 PARALLEL SLOTS, HORIZONTAL AR 3.0

Description: Number of Elements: 5 parallel convergent slots Area Ratio: 3.0 Flow Area: 13.2 square inches Nozzle Cant Angle: 0 degrees Element Length: 10.8 inches Slot Dimension: 7.2 inches x 0.367 inches Slot Aspect Ratio: 7.2/0.367 = 19.5 Nozzle Array Dimensions: 7.2 inches x 4.95 inches Distance Between Slots: 0.734 in. Material: 321 CREC



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RE. 0002 DYNES/CM<sup>2</sup>// 200 FT POLAR ARC OCTAVE PASS BANDS IN HERTZ 130 140 RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 130 125 OVERALL SPL~dB OCTAVE BAND LEVEL~uB 120 120 110 ±1.8 115 ŢΡŔ 100 110 90 300 40<sup>0</sup> 50<sup>0</sup> 600 70<sup>0</sup> 800 900 ANGLE TO THE JET AXIS~DEGREES 80 TOTAL TEMPERATURE (T 8) : 1500°P NOZZLE EXIT AREA (A 8): 5.9 FT2 70 5 5 1 10000 2 1 100 1000 FREQUENCY IN HERTZ HM-AP-- 24 NOZZLE PRESSURE RATIO: 1.8 (5 PARALLEL SLOTS, HORIZONTAL) TOTAL TEMPERATURE: 1500° F AR-3.0 JET VELOCITY (IDEAL): 1923 FPS SCALE FACTOR: 8:1 NOZZLE EXIT AREA (A8): 5.9 FT2 OCTAVE PASS BANDS IN HERTZ OCTAVE PASS BANDS IN HERTZ 140 14( RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 06 001 011 021 051 08 06 RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 06 001 071 051 051 08 06 50° 50 ÓCTAVE BAND LEVEL~dB OCTAVE BAND LEVEL~dB 70 70 Ś 1 100 1 Ś 2 1 10000 Š: 5 2 1 1000 5 1000 100 10000 FREQUENCY IN HERTZ FREQUENCY IN HERTZ PRESSURE RATIO: 2.6 PRESSURE RATIO: 3.0 TOTAL TEMPERATURE: 1500° F TOTAL TEMPERATURE: 1500° F JET VELOCITY (IDEAL): 2402 FPS JET VELOCITY (IDEAL): 2555 FPS NOZZLE EXIT AREA (A8): 5.9 FT2 NOZZLE EXIT AREA (A8): 5.9 FT2 DATA INCLUDES GROUND REFLECTION INTERFERENCE







HM-AP- 24 NOZZLE (5 Parallel Slots, AR = 3.0)

#### Remarks

The HM-AP-24 nozzle was intended to be one of a series of rectangular slot nozzles to determine the noise characteristics of this type of array. The HM-AP-25 nozzle array was similar to the HM-AP-24 since the flow parameters at the exit plane were identical. The HM-AP-24 nozzle had convergent slot sides whereas the HM-AP-25 nozzle had convergent slot ends. The HM-AP-25 nozzle was destroyed during testing. The HM-AP-26 nozzle was designed for an area ratio of 2.0 and the HM-AP-27 nozzle was designed for an area ratio of 4.0. The IM-AP-26 and HM-AP-27 nozzles were never constructed.

HM-AP-24 nozzle element length was adjusted to 10.8, 7.2, 3.6 and 0 inches by installing ventilation blockers of the appropriate dimensions. Noise suppression characteristics were substantially not affected by element length at pressure ratios of 2.6 and 3.0. Maximum noise suppression was noted when the microphones were oriented in respect to the nozzle so that the slots are viewed on-end (nozzle slots horizontal). There was 2 to 3.5 PNdB less suppression evident when the slots are viewed on the long side (nozzle slots vertical). See Reference D13. HM-AP-24

Facility; Annex D (Cell #1) Nozzle and Microphone Height are 18 Inches

Date:

T<sub>amb</sub>: R.r.:

|        | Nozzle                    | VJ(Ideal)                | $\underline{\mathbf{T}_{\mathbf{T}}}$ | $\frac{P_{T}}{P}$ | Run No.                    |
|--------|---------------------------|--------------------------|---------------------------------------|-------------------|----------------------------|
|        | HM-AP-24 <sup>1</sup>     | 1923 fps<br>2402<br>2555 | 1500°F<br>"                           | 1.8<br>2.6<br>3.0 | H 1163<br>H 1164<br>H 1165 |
|        | HM-AP-24 <sup>2</sup>     | 1923<br>2402<br>2555     | 1500°F<br>"                           | 1.8<br>2.6<br>3.0 | H 1172<br>H 1173<br>H11174 |
| Nozzle | 4.1-Inch Round Convergent | 1923<br>2402<br>2555     | 1500°F<br>"                           | 1.8<br>2.6<br>3.0 | H 1166<br>H 1167<br>H 1168 |

<sup>1</sup> Nozzle slots are horizontal

<sup>2</sup> Nozzle slots are vertical

Note: Measured acoustic data is recorded in Reference D2.

## NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2//25 FT

HM-AP-24

| RUN NO.  | OASPL  | 500   | -1K    | 2К    | 4K     | 8K    | 16K    | 32K   | 64K   |
|----------|--------|-------|--------|-------|--------|-------|--------|-------|-------|
| H1163L40 | 115.9  | 112.0 | 107.0  | 98.0  | 108.0  | 108.0 | 106 0  | 00.0  | 05.0  |
| H1163L50 | 116.3  | 111.0 | 107.0  | 98.0- | 109.0  | 109.0 | 108 0  | 102 0 | 95.0  |
| H1163L60 | 114.6  | 109.0 | 105.0  | 100.0 | 109.0- | 102.0 | 103.0  | 06.0  | 90.0  |
| H1163L70 | 114.4  | 106.0 | 104.0  | 99.0  | 109:0  | 108.0 | 106.0  | 101 0 | 0.0   |
| H1163L80 | 110.7  | 103.0 | 101.0  | 96.0  | 105.0  | 100.0 | 102.0  | 101.0 | 97.0  |
| H1164L40 | 125.3  | 123.0 | 118.0  | 107.0 | 113 0  | 114 0 | 113 0  | 106 0 | 102.0 |
| H1164L50 | 123.9  | 120.0 | 117.0  | 107.0 | 114 0  | 115 0 | 114 0  | 100.0 | 10/ 0 |
| H1164L60 | 122.3  | 117.0 | 113.0- | 107.0 | 115 0  | 115 0 | 113 0  | 100.0 | 102.0 |
| H1164L70 | 121.0  | 114.0 | 111.0  | 106.0 | 115 0  | 115.0 | 111 0  | 107.0 | 102.0 |
| H1164L80 | 117.0  | 110.0 | 107.0  | 103.0 | 111 0  | 110 0 | 108:-0 | 105 0 | 103.0 |
| H1165L40 | 128.6  | 126.0 | 123.0  | 111.0 | 116.0  | 116.0 | 114 0  | 107.0 | 105 0 |
| H1165L50 | 126.8  | 123.0 | 121.0  | 111.0 | 117.0  | 117.0 | 115.0  | 110 0 | 106 0 |
| H1165L60 | 124.2  | 119.0 | 115.0  | 110.0 | 117.0  | 117.0 | 115.0  | 110.0 | 106.0 |
| H1165L70 | 123.0  | 117.0 | 113.0  | 109.0 | 117.0  | 116.0 | 113.0  | 108 0 | 104.0 |
| H1165L80 | 118.9  | 112.0 | 109.0  | 105.0 | 113.0  | 112.0 | 110.0  | 106 0 | 100.0 |
| H1172L40 | 117.9  | 112.0 | 107.0  | 99.0  | 111.0  | 112.0 | 109.0  | 104.0 | 100 0 |
| H1172L50 | 119.1  | 111.0 | 107.0  | 100.0 | 114.0  | 113.0 | 111.0  | 106.0 | 101 0 |
| B1172L60 | 118.6  | 109.0 | 105.0  | 101.0 | 115.0  | 112.0 | 109.0  | 105.0 | 99.0  |
| H1172L70 | 117.8  | 107.0 | 103.0  | 99.0  | 115.0  | 111.0 | -107.0 | 104.0 | 101.0 |
| H1172L80 | 114.5  | 104.0 | 100.0  | 97.0  | 112.0  | 107.0 | 103.0  | 101.0 | 95.0  |
| H1173L40 | 125.2  | 123.0 | 120.0  | 109.0 | 115.0  | 117.0 | 113.0  | 109.0 | 106.0 |
| H1173LSO | 125.4  | 121.0 | 117.1  | 108.0 | 117.0  | 118.0 | 115.0  | 111.0 | 108.0 |
| H1173L60 | 123.7  | 118.0 | 113.0  | 108.0 | 117.0  | 117.0 | 115.0  | 110.0 | 106.0 |
| H1173L70 | 122.2  | 115.0 | 111.0  | 106.0 | 117.0  | 116.0 | 112.0  | 109.0 | 107.0 |
| H1173L80 | 119.3  | 111.0 | 107.0  | 103.0 | 114.0  | 114.0 | 109.0  | 107.0 | 102.0 |
| H1174L40 | 129.2  | 126.0 | 124.0  | 112.0 | 117.0  | 118.0 | 115.0  | 110.0 | 108.0 |
| H1174150 | 128.1  | 124.0 | 121.0  | 111.0 | 119.0  | 120.0 | 117.0  | 113.0 | 111.0 |
| H1174L60 | 125.7  | 120.0 | 116.0  | 111.0 | 119.0  | 119.0 | 116.0  | 112.0 | 108.0 |
| H1174L70 | 124.0  | 117.0 | 113.0  | 109.0 | 118.0  | 118.0 | 114.0  | 111.0 | 109.0 |
| H1174L80 | 120.8  | 113.0 | 109.0  | 106.0 | 114.0  | 116.0 | 111.0  | 109.0 | 103.0 |
| H1166L40 | 127.1  | 121.0 | 123.0  | 116.0 | 121.0  | 112.0 | 108.0  | 100.0 | 102.0 |
| H1166L50 | 127.2  | 121.0 | 123.0  | 115.0 | 121.0  | 114.0 | 110.0  | 103.0 | 102.0 |
| H1166L60 | 122.8  | 119.0 | 116.0  | 111.0 | 116.0  | 111.0 | 108.0  | 101.0 | 97.0  |
| H1166L70 | 120.2  | 113.0 | 113.0  | 108.0 | 116.0  | 111.0 | 107.0  | 101.0 | 96.0  |
| H1166L80 | 1.19.6 | 108.0 | 107.0  | 105.0 | 111.0  | 100.0 | 104.0  | 98.0  | 91.0  |
| H1167L40 | 132.3  | 127.0 | 128.0  | 121.0 | 125.0  | 118.0 | 116.0  | 109.0 | 108.0 |
| H1167L50 | 133.1  | 127.0 | 128.0  | 122.0 | 128.0  | 122.0 | 118.0  | 112.0 | 113.0 |
| H1167L60 | 130.8  | 123.0 | 124.0  | 121.0 | 126.0  | 121.0 | 118.0  | 113.0 | 108.0 |
| H116/L/0 | 127.0  | 118.0 | 119.0  | 115.0 | 123.0  | 119.0 | 116.0  | 110.0 | 106.0 |
| H1167L80 | 122.5  | 113.0 | 113.0  | 111.0 | 118.0  | 116.0 | 112.0  | 107.0 | 100.0 |
| HII68L40 | 133.7  | 128.0 | 130.0  | 122.0 | 126.0  | 119.0 | 116.0  | 110.0 | 110.0 |
| M1168L50 | 135.2  | 128.0 | 131.0  | 123.0 | 129.0  | 124.0 | 121.0  | 116.0 | 114.0 |
| HITPST00 | 132.8  | 124.0 | 126.0  | 123.0 | 128.0  | 124.0 | 121.0  | 115.0 | 111.0 |
| H1163L70 | 128.8  | 120.0 | 121.0  | 118.0 | 124.0  | 121.0 | 118.0  | 113.0 | 109.0 |
| RTTP8780 | 124.7  | 114.0 | 114.0  | 113.0 | 120.0  | 119.0 | 115.0  | 110.0 | 103.0 |

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#### NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE



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HM-AP-28 NOZZLE

24 SPOKES, AR 6.0

Number of Elements: 24 spokes Area Ratio: 6.0 Spoke Penetration: 92.5% Flow Area: 13.2 square inches Exit Cant Angle 0 degrees Ventilation Gutter Cant Angle: 30 degrees Nozzle Diameter: 10 inches Spoke Width: Varied from 0.15" to Material: 321 CRES





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HM-AP-28

(24 Spokes, AR 6.0)

#### Lemarks

Comparison of the 24-spoke area ratic 6.0 data with 24 spoke nozzles with area ratios of 1-9 (HT-AE-F) and 4.0 (EM-AP-32) indicate essentially no change in PNL suggression for these different area ratios. Blocking of the ventilation troughs did not affect PNL suppression values, see Reference D14.

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HM-AP-28 Facility: Annex D (Cell #1) Nozzle and Microphone Heights are 20 inches.  $T_{amb}$ : R.H.: Date: VJ (Ideal)  $\mathbf{T}_{\mathbf{T}}$  $P_T/P$ Run No. Nozzle 1500°F HM-AP-28 H 1062 1.8 1950 fps ii. Ħ H 1063 2,2 2200 11 n н 1064 2,6 2370 Ĥ 11 H 1061 3.0 2550 n n H 1065 3.4 2680 1500°F H 1036 1.8 1950 fps 4.1 Inch Round Convergent Nozzle H 1037 2.2 11 2200 n 11 IJ H 1038 2,6 2370 11 IJ H 1039 3.0 2550 11 11 2680 н 1040 3.4

Measured acoustic data is recorded in Reference D2.

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## NOZZLE TEST DATA

CCTAVE BAND-LEVEL~dB RE: 0.0002 DYNES/CM2//25 FT

#### HM-AP-28

| RUN NO.         | OASPL | 500   | ١K    | 2K    | 4K    | 8K     | 16K   | 32K   | 64K            |
|-----------------|-------|-------|-------|-------|-------|--------|-------|-------|----------------|
|                 |       |       |       |       | ×     |        |       |       |                |
| H1062L40        | 114.0 | 110.0 | 104.0 | 97.5  | 104.5 | 106.0  | 105.0 | 102.0 | 95.0           |
| H1062L50        | 116.2 | 112.0 | 109.0 | 97.0  | 107.0 | 108.0  | 106.0 | 103 0 | 97 N           |
| H1062L60        | 118.1 | 112.0 | 110.0 | 102.0 | 110.0 | 111.0  | 109.5 | 106.0 | 100.0          |
| H1062L70        | 117.8 | 111.8 | 109.0 | 102.0 | 109.5 | 111.0  | 110.0 | 107.0 | 101 0          |
| H1062L80        | 115.2 | 109.0 | 107.0 | 101.5 | 106.0 | 108.0  | 108.0 | 103 0 | 45 A           |
| H1063L40        | 116.4 | 112.0 | 106.0 | 99.0  | 107.0 | 109.0  | 108.0 | 105.0 | 90 0           |
| H1063L50        | 118.6 | 114.0 | 110.0 | 100.5 | 110.0 | 111:0  | 109.0 | 106.5 | 101 0          |
| H1063L60        | 120.6 | 115.0 | 112.5 | 104.0 | 113.0 | 113.0  | 112.0 | 108.0 | 103.0          |
| H1063L70        | 120.6 | 113.0 | 112.0 | 104.0 | 113.0 | 114.0  | 113.0 | 110.0 | 104.0          |
| H1063L80        | 118.4 | 111.0 | 110.0 | 104.0 | 110.0 | 112.0  | 111.0 | 107.0 | 98.0           |
| H1064L40        | 118.1 | 114.0 | 108.0 | 100.0 | 109.0 | 110.5  | 109.0 | 106.0 | 100.0          |
| H1064L50        | 120.6 | 116.0 | 112.0 | 102.5 | 112.5 | 113.0  | 111.0 | 108.0 | 103.0          |
| H1064L60        | 122.1 | 116.0 | 113.0 | 106.0 | 114.5 | 115.0  | 113.0 | 110.0 | 105.0          |
| H1064170        | 121.9 | 114.0 | 112.5 | 106.0 | 114.0 | 116.0  | 114.0 | 111.0 | 106.0          |
| H1064L80        | 123.1 | 112.0 | 110.0 | 104.0 | 121.0 | 113.0  | 113.0 | 108.5 | 100.0          |
| H1061L40        | 120.9 | 117.0 | 111.5 | 103.0 | 111.0 | 113.0  | 112.0 | 108.0 | 101.5          |
| <b>H1061L50</b> | 122.2 | 118.0 | 113.0 | 104.5 | 113.0 | 114.5  | 113.0 | 109.0 | 104.0          |
| H1061L60        | 123.5 | 118.0 | 15.0  | 108.0 | 116.0 | 116.0  | 114.0 | 111.0 | 105.0          |
| H1061L70        | 123.7 | 116.0 | 113.5 | 108.0 | 116.0 | 118.0  | 116.0 | 113.0 | 107.0          |
| H1061L80        | 120.5 | 113.0 | 11.0  | 106.0 | 109.0 | 115.0  | 114.0 | 110.0 | 191.0          |
| H1065L40        | 122.3 | 119.0 | 114.0 | 105.0 | 112.0 | 114.0  | 111.0 | 108.0 | 101.0          |
| H1065L50        | 123.5 | 120.0 | 115.0 | 106.0 | 114.0 | 115.0  | 113.0 | 109.0 | 104.0          |
| H1065L60        | 124.7 | 120.0 | 116.0 | 108.0 | 117.5 | 117.0  | 114.0 | 111.0 | 106.0          |
| H1065L70        | 124.7 | 113.0 | 114.0 | 115.0 | 117.5 | 113.0  | 118.0 | 115.5 | 112.0          |
| H1065L80        | 121.9 | 115.0 | 112.0 | 107.0 | 114.0 | 116.0  | 114.0 | 110.0 | 101.5          |
| H1036L40        | 127.9 | 122.0 | 125.0 | 117.5 | 118.0 | 112.0  | 107.0 | 0.0   | 0.0            |
| H1036L50        | 127.6 | 121.5 | 124.0 | 117.0 | 120.0 | 114.0  | 109,0 | 100.0 | 98.0           |
| H1036L60        | 124.5 | J18.0 | 120.0 | 114.0 | 118.0 | 113.0  | 108.0 | 99.0  | 95.0           |
| H1036L70        | 120.6 | 1'8.5 | 115.0 | 109.0 | 115.0 | 111.5  | 107.0 | 99.5  | 0.0            |
| H1036L80        | 117.3 | 109.0 | 110.0 | 105.5 | 113.0 | 109.0  | 106.0 | 97.0  | 90.0           |
| H1037L40        | 131.3 | 125.0 | 128.0 | 121.0 | 123.0 | 118.0  | 113.0 | 105.0 | 0.0            |
| H1037L50        | 131.0 | 124.0 | 127.0 | 121.0 | 124.0 | 119.0  | 115.0 | 108.0 | 104.0          |
| H103/L60        | 129.0 | 121.0 | 124.0 | 118.0 | 124.0 | 118.0  | 115.0 | 107.0 | .) .0          |
| H1037L70        | 124.2 | 116.0 | 118.0 | 118.0 | 119.0 | 116.0  | 112.5 | 105.5 | 100,0          |
| H1037L80        | 121.1 | 111.0 | 112.5 | 109.0 | 117.0 | 114.0- | 111.0 | 102.0 | 94.0           |
| H1038L40        | 133.1 | 127.0 | 129.5 | 122.0 | 125.0 | 120.0  | 116.0 | 108.0 | 108.0          |
| H1030L20        | 133.7 | 127.0 | 129.0 | 123.0 | 12/.0 | 122.0  | 118.0 | 112.0 | 107.0          |
| H1030L00        | 131.2 | 123.0 | 125.0 | 121.0 | 126.0 | 121.0  | 118.0 | 111.0 | 106.0          |
| H1030L/U        | 12/.3 | 119.0 | 121.0 | 110.0 | 122.0 | 119.0  | 116.0 | 110.0 | 104.0          |
| H1030L60        | 124.1 | 120.0 | 121 0 | 112.9 | 119.0 | 118.0  | 110.0 | 108.0 | 100.0          |
| N1039140        | 125 2 | 120.0 | 120 5 | 125.0 | 12/.0 | 122.0  | 110.0 | 111.0 | 110.0          |
| H1039150        | 123.4 | 126.0 | 128 0 | 124.0 | 129.0 | 124.0  | 121.0 | 114.0 | 109.0          |
| H1030170        | 150 6 | 121 0 | 123.0 | 118 0 | 126.0 | 123.0  | 110 0 | 112.0 | 100.0          |
| H10391 80       | 126 3 | 115 0 | 116 0 | 116 0 | 121 A | 122.0  | 110 0 | 110 0 | 103 0<br>T00.0 |
| H10401 40       | 134 9 | 120 0 | 131 0 | 124.0 | 127 0 | 123 0  | 110 0 | 110.0 | 110 0          |
| H10401.50       | 135 0 | 129.0 | 131 0 | 125 0 | 130 0 | 125.0- | 122 0 | 115 0 | 110.0          |
| H10401.60       | 134 1 | 127 0 | 128.0 | 124.0 | 129 0 | 124 0  | 121 0 | 115 0 | 100.0          |
| H10401.70       | 130 5 | 121.0 | 123.0 | 119.5 | 125 0 | 123.5  | 121.0 | 11/ 5 | 100 5          |
| H1040L80        | 128.5 | 116 0 | 117.0 | 116.0 | 123.0 | 124.0  | 120.0 | 113.0 | 105.0          |

### NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE








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HM-AP-32 NOZZLE

(24 Spokes, AR = 4.0)

### Remarks

The HM-AP-32 nozzle was tested with the ventilation troughs blocked, also. There was essentially no difference noted in the jet noise characteristics between the free and blocked ventilation cases. Another configuration of this nozzle utilized a cylinderical ejector 6.4 inches long and 9 inches in diameter (I.D.). The ejector was lined with 1 inch thick TWF fiberglass material contained by a 40% open area wire mesh. Considerable suppression of jet noise in the last four octave bands was noted with the ejector installed. The ejector was most beneficial at low angles to the jot axis, e.g. 6 to 9 dB suppression at  $40^\circ$ . At  $70^\circ$  to the jet axis the ejector had little influence on the jet noise spectrum, see Reference D15. HM-AP-32

Test Facility: Annex D (Cell #1) Nozzle and microphone height is 20 inches.

Date:

Tamb:

R.H.:

| <u>Run No</u> . | $P_{T}/P_{}$ | $\frac{T_{T}}{T}$ | V <sub>J</sub> (ideal) | Nozzle                         |
|-----------------|--------------|-------------------|------------------------|--------------------------------|
| н925            | 1.8          | 1000°F            | 1659 fps               | HM-AP-32                       |
| н926            | 2.2          | 11                | 1900                   | 11                             |
| H927            | 2.6          | 11                | 2073                   | \$ x                           |
| Н928            | 3.0          | 11                | 2205                   | 11                             |
| Н929            | 3.4          | 11                | 2311                   | 11                             |
| Н930            | 1.8          | 1500°F            | 1923                   | 11                             |
| H931            | 2.2          | 11                | 2202                   | 11                             |
| Н932            | 2.6          | u                 | 2402                   | 51                             |
| Н933            | 3.0          | 11                | 2555                   | 11                             |
| н934            | 3.4          | **                | 2678                   | 11                             |
|                 |              |                   |                        |                                |
| H982            | 1.8          | 1500°F            | 1923 4.                | 1 Inch Round Convergent Nozzle |
| пуоз            | 2.6          | 11                | 2402                   | n                              |
| H904            | 3.0          | 11                | 2000                   | 11                             |
| нубу            | 3.4          | ••                | 2010                   |                                |

Acoustic data for these runs are recorded in Reference 2.

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# NOZZLE TEST DATA

# OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2//25 FT

### HM-AP-32

| RUN NO.   | OASPL  | . 500  | ١ĸ     | 2K        | <b>4</b> K | 8K    | 16K    | 32K            | 64K           |
|-----------|--------|--------|--------|-----------|------------|-------|--------|----------------|---------------|
| H925 L40  | 113.3  | 1.09.5 | 106.0  | 96.0      | 103.0      | 104.0 | 106 0  | 100.0          | 0/ r          |
| H925 L50  | 114.6  | 110.0  | 128.0  | 97.0      | 105.0      | 106.0 | 105 0  | 102.0          | 94.5          |
| H925 L60  | 115.8  | 109.0  | 108.0  | 100.0     | 108.0      | 108 0 | 100.0  | 102.0          | -0.0          |
| H925 L70  | 114.6- | 107.0  | 106.0  | 98.0      | 107.0      | 108 0 | 109.0  | 103.0          | 95.0          |
| H925 L30  | 112.1  | 105.0  | 104.0  | 96.0      | 104 0      | 105.0 | 105.0  | 102.0          | 94.0          |
| H926 L40  | 117.6  | 115.0  | 109.0  | 99.C      | 105 0      | 107.0 | 107.0  | 100.0          | 91.0          |
| H926 L50  | 117.7  | 113.0  | 110.5  | 99.5      | 107 5      | 107.0 | 100.0  | 104.5          | 98.0          |
| H926 L60  | 1:9.2  | 113.O  | 111.0  | 103.0     | [-]_] O    | 112-0 | 1-12 0 | 106.0          | 99.0          |
| H926 L70  | 117.8  | 110.0  | 109.0  | 100.0     | 110.0      | 112.0 | 117 0  | 106.0          | 99.0          |
| H926 L80  | 115.5  | 107.0  | 106.5  | 99.0      | 107.5      | 509.0 | 100 0. | 100.0          | 98.0          |
| H927 L40  | 122.3  | 121.0  | 111.0  | 101.0     | 106.5      | 100.0 | 111 0  | 105'0<br>T05'0 | 95.0          |
| H927 L50  | 120.4  | 116.0  | 113.0  | 102.0     | 109.0      | 112 0 | 112.0  | 109.5          | 100.0         |
| H927 L60  | 121.3  | 115.5  | 11.3.0 | 105.0     | 112.0      | 114 0 | 11.6 0 | 100.0          | 101.5         |
| H927 L70  | 120.4  | 113.0  | 111.0  | 103.0     | 112.0      | 114 0 | 11% 0  | 100.0          | 101.0         |
| H927 1.80 | 118.0  | 110.0  | 108 9  | 101.0     | 109.0      | 112 0 | 112 0  | 107.0          | 191.0         |
| H928 L40  | 122.0  | 118,0  | 115.0  | 105.0     | 110.5      | 113 0 | 113 0  | 107.0          | 30.0          |
| K928 L50  | 122.0  | 118.0  | 115.0  | 104.0     | 111.0      | 113.0 | 113.0  | 100 0          | 102.0         |
| H928 L60  | 122.7  | 117.0  | 115.0  | 107.5     | 114 0      | 115 0 | 115 0  | 109.0          | 102.0         |
| H928 L70  | 121.9  | 114.0  | 113.0  | 104.5     | 114.0      | 116.0 | 115 0  | 105.0          | 102.0         |
| H928 L60  | 119.4  | 111.0  | 109.0  | 102.5     | 111.0      | 114 6 | 113.0  | 108 0          | 102.0         |
| H929 L40  | 123,9  | 121.0  | 117.0  | 107.0     | 111.5      | 114.0 | 113 0  | 100.0          | 49.0          |
| H929 L50  | 122.9  | 119.0  | 116.0  | 107.0     | 113 0      | 114.0 | 120    | 100.0          | 102.0         |
| H929 L60  | 123.5  | 119.0  | 116.0  | 109.0     | 115 0      | 115 0 | 114 0  | 109.0          | 102.0         |
| H929 L70  | 122.4  | 115.5  | 114.0  | 106.0     | 115-0      | 116.0 | 11/ 5  | 109.0          | 102.0         |
| 1929 L2C  | 120.0  | 112.0  | 113.6  | 104.0     | 113 0      | 114.0 | 112 0  | 109.0          | 102.0         |
| H930 J.40 | 115.7  | 112.0  | 109.0  | 99.5      | 105 0      | 106.0 | 106 0  | 100.0          | <i>9</i> ,    |
| H930 L50  | 117.0  | 113.0  | 111.0  | 100.0     | 106 5      | 107.0 | 100.0  | 102.0          | ~0.0          |
| H930 L60  | 121.4  | 113.0  | 111.5  | 104.0     | 110.5      | 119 0 | 100.0  | 102,5          | 37.3          |
| H930 L70  | 117.4  | 111.0  | 110.0  | 102.0     | 110.0      | 110.0 | 109.0  | 104.0          | 97.0          |
| H930 L80  | 115.0  | 108.0  | 107.0  | 100.0     | 108.0      | 108.0 | 107.0  | 102.0          | 90.0          |
| H931 L40  | 119.3  | 116.0  | 112.0  | 102.0     | 108.0      | 109.0 | 102 0  | 106.0          | 93.0          |
| H931 L50  | 120.0  | 116.0  | 114.0  | 103.0     | 109.0      | 110.0 | 100 5  | 107.0          | 100 0         |
| H931 L60  | 121.3  | 116.0  | 114.0  | 107.0     | 113.0      | 113.0 | 112 5  | 108.0          | 100.0         |
| H931 L70  | 120.3  | 113.5  | 112.0  | 104.0     | 113.0      | 114 0 | 112.0  | 107.5          | 200.0<br>60 5 |
| H931 L80  | 118.0  | 110.5  | 109.0  | 102.0     | 111.0      | 111.0 | 111 0  | 106.0          | 96.5          |
| H932 L40  | 123.2  | 121.0  | 116.0  | 105.0     | 169.0      | 111 0 | 111 5  | 100.0          | -0.0          |
| H932 L50  | 122.5  | 119.0  | 3.16.0 | 105.0     | 111.0      | 112.0 | 112 0  | 100,0          | 102 0         |
| H932 L60  | 122.9  | 118.5  | 116.0  | 108.0     | 113.0      | 114.0 | 116 0  | 100.0          | 101 0         |
| H932 L70  | 122.5  | 115.5  | 114.0  | 106.0     | 115.0      | 116.0 | 115 0  | 109.0          | 101.0         |
| H932 L80  | 119.7  | 112.0  | 111.0  | 103.0     | 112.0      | 113.0 | 113 0  | 105.0          | 99.0          |
| H933 L40  | 124.0  | 121.0  | 112.0  | 107.5     | 111.0      | 113.0 | 112.5  | 108 0          | -0.0          |
| H933 L50  | 124.2  | 121.0  | 118.0  | 107.5     | 113.0      | 114.0 | 112 0  | 109.0          | 102 0         |
| H933 L60  | 124.6  | 120.0  | 118.0  | 111.0     | 116.0      | 115.0 | 115 0  | 110 0          | 102.0         |
| H933 L70  | 123.8  | 117.0  | 116.0  | 108.0     | 117.0      | 117:0 | 115.0  | 110 0          | 102.0         |
| K933 180  | 120.7  | 113.0  | 112.0  | 105.0     | 113.0      | 115.0 | 113.0  | 108-5          | 100 0         |
| H934 L40  | 125.9  | 123.0  | 120.0  | 109.0     | 113.0      | 115.0 | 114 0  | 109 5          | -0.0          |
| H934 ISO  | 125.2  | 122.0  | 119.0  | 109.0     | 114.0      | 115.0 | 113.0  | 110 0          | -0.0          |
| H934 1.60 | 126.9  | 122.0  | 119.0  | 112.0     | 117.0      | 116.0 | 116 0  | 110 0          | 105 0         |
| H934 L70  | 125.3  | 119.0  | 117.5- | 110.0     | 118.5      | 118.0 | 116.5  | 111 0          | 104.0         |
| H934 1.80 | 122.5  | 115.0  | 114.0  | 107.0     | 115.0      | 116.5 | 115 0  | 110 0          | 101 0         |
| H982 L40  | 127.8  | 122.0  | 125.J  | 117.0     | 118.0      | 111.0 | 105.0  | 96.0           | 101.0         |
| H982 L50  | 127.4  | 122.0  | 124.0  | 115.0     | 119.0      | 113.0 | 107 0  | 99.0           | 100.0         |
| H982 L60  | 123.5  | 118.0  | 119.0  | 110.0     | 117.0      | 112.0 | 106-0  | 97.5           | 08.0          |
|           |        | -      |        | · · · · · |            |       | 200.0  | 21.5           | 20.0          |

NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE

# NOZZLE TEST DATA

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# OCTAVE BAND LEVEL- dB RE: 0.0002 DYNES / CM2// 25 FT

### HM-AP-32

| RUN NO.         | OASPL | -500  | IK    | 2K    | 4K     | 8K    | 16K   | 32K   | 64K   |
|-----------------|-------|-------|-------|-------|--------|-------|-------|-------|-------|
| H982 L70        | 120.2 | 113.5 | 114.0 | 109.0 | 115.0  | 111.0 | 107.0 | 98.0  | 95.0  |
| <b>H982</b> L80 | 116.7 | 109.0 | 109.0 | 106.0 | 112.0  | 109.0 | 104.0 | 95.0  | 89 0  |
| <b>H983</b> L40 | 133.5 | 127.0 | 130.0 | 123.0 | 125.5  | 120.5 | 116.0 | 108.0 | -0.0  |
| <b>H983 L50</b> | 134.1 | 128.0 | 130.0 | 123.0 | 127.0  | 122.0 | 118.0 | 111.0 | 107 0 |
| H983 L60        | 131.3 | 124.0 | 126.0 | 118.5 | 126.0  | 122.0 | 117.0 | 110.0 | 165 0 |
| H983 L70        | 127.7 | 119.0 | 121.0 | 116.0 | 123.0  | 119.0 | 117.0 | 110.0 | 105.0 |
| H983 L80        | 124.6 | 114.0 | 115.0 | 112.0 | 119.5  | 119.0 | 116.0 | 108.0 | 161.6 |
| H984 L40        | 134.8 | 129.0 | 131.0 | 124.0 | 127.0  | 122.0 | 118.0 | 110.0 | -0.0  |
| H984 L50        | 135.4 | 129.0 | 131.0 | 124 0 | 129.0  | 124.0 | 120.0 | 113.0 | -0.0  |
| H984 L60        | 132.6 | 126.0 | 127.0 | 120.0 | 3.27.0 | 123.0 | 119.0 | 113.0 | 107 0 |
| H984 170        | 129.6 | 121.0 | 123.0 | 119,0 | 124.0  | 122.0 | 119.0 | 113.0 | 108 0 |
| H984 L80        | 127.7 | 116.0 | 116.0 | 115.0 | 122.0  | 122.0 | 119.0 | 118.0 | 111 0 |
| H985 L40        | 135.8 | 130.0 | 132.0 | 125.0 | 128.0  | 123.0 | 119.0 | 111.0 | -0.0  |
| H985 L50        | 136.8 | 131.0 | 132.0 | 126.0 | 130.0  | 125.0 | 122.0 | 115.0 | -0.0  |
| <b>H985 L60</b> | 133.8 | 127.5 | 128.0 | 122.0 | 128.0  | 124.0 | 121.0 | 114.0 | -0.0  |
| H985 L70        | 130.9 | 123.0 | 124.0 | 120.0 | 125.0  | 123.0 | 121.0 | 114.0 | -0.0  |
| H985 L80        | 128.4 | 117.0 | 117.0 | 116.0 | 123.0  | 124.0 | 119.0 | 112.0 | -0.0  |

## NOTE: DATA INCLUDES GROUND-REFLECTION INTERFERENCE



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HM - AP - 33 . حرب • P<sub>co</sub> 36 SPOKE NOZZLE AREA RATIO = 4.0 NO EJECTOR • PT ٨s C<sub>Fg</sub> = (THRUST-DRAG) MEASURED IDEAL PRIMARY THRUST (MASS FLOW) MEASURED C<sub>D</sub> = 1.0 THRUST COEFFICIENT (C<sub>Fg</sub>) o 6 DISCHARGE COEFFICIENT (CD) Aş/AB = 35 0 4.0 1.0 2.0 3.C PRESSURE RATIO  $(P_T / P_{\infty})$ PRESSURE RATIO  $(P_T / P_{\infty})$ 1.00 1.0 PT/Pco = BASE PRESSURE RATIO (PB/Pa) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ¢1.7 THRUST COEFFICIENT (CFg) PT/Pco = 4 2.5 5 з. 0 .25 .50 .25 .50 0 VENTILATION PARAMETER (AS/AB) VENTILATION PARAMETER (AS/AB) d

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### HM-AP-35 NOZZLĒ

(270 TUBE HEXAGONAL ANNULUS ARRAY AR 7.0)

#### Description:

The HM-AP-35 nozzle consists of a hexagonal annulus array containing 270 equally spaced round convergent tubes through which passes the primary flow. Six hollow struts leading from the outside wall to the central region provide ambient air to this low pressure area.

Number of Elements: 270 tubes with RC ends

Area Ratio: 7.0

Flow Area: 28.3 square inches

Exit Cant Angle: 15 degrees (inwards)

Tube Spacing Ratio: 2 (equivalent to a local area ratio of 4.0)

Tube Exit Diametur: 0.366 inches Tube Length: 2.745 inches Material: 321 CRES







DJ-24

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### HM-AP-35 NOZZLE

(270 Tube Hexagonal Annulus)

### Remarks

Several other configurations of the HM-AP-35 Nozzle were tested. One configuration had 240 tubes, where the flow in 5 tubes at each corner of the hexagon array was blocked. This was done to reduce the jet flow interaction. The 240 tube configuration had 0.5 to 1.0 PNdB less suppression relative to the 270 tube configuration.

Another configuration had a conical plug installation in the center of the annulvs. Plug length was equal to the annulus outer diameter. Noise suppression decreased by 1.5 to 3.5 PNdB relative to the 270 tube configuration without the plug.

Other configurations used plug lengths that were 40% and 60% of the previous configuration. A slight decrease in PNL suppression was noted as plug length was shortened. See Reference D16.

# HM-AP-35 NOZZLE.

Test Facility:(HNTF)

Date: Sept. 10, 1968 (279.1-281.5), Sept. 20, 1968 (293.1-293.5) T<sub>amb</sub>: 66°F (279.1-281.5) : 58°F (293.1-293.5) R.H.: 69% (279.1-281.5) : 65% (293.1-293.5)

| Run No. | P <sub>T</sub> /P <sub>∞</sub> | $\frac{\mathbf{T}_{\mathbf{T}}}{\mathbf{T}}$ | $V_{J}$ (Ideal) | Nozzle                         |
|---------|--------------------------------|----------------------------------------------|-----------------|--------------------------------|
| 279.1   | 3.385                          | 491.°F                                       | 1837 fps        | HM-AP-35                       |
| 279.2   | 2.976                          | 489                                          | 1750            | n                              |
| 279.3   | 2.589                          | 490                                          | 1650            | 11                             |
| 279.4   | 2.200                          | 489                                          | 1535            | u                              |
| 279.5   | 1.803                          | 486                                          | 1328            | 11                             |
| 280.2   | 2.986                          | 974                                          | 2164            | 11                             |
| 280.3   | 2.596                          | 965                                          | 2032            | 11                             |
| 280.4   | 2.198                          | 952                                          | 1858            | 11                             |
| 280.5   | 1.804                          | 956                                          | 1630            | 11                             |
| 281.1   | 3.381                          | 1450                                         | 2628            | 11                             |
| 281.2   | 2.982                          | 1449                                         | 2507            | 11                             |
| 281.3   | 2.597                          | 1434                                         | 2353            | 11                             |
| 281.4   | 2.202                          | 1453                                         | 2171            | 11                             |
| 281.5   | 1.793                          | 1430                                         | 1878            | 11                             |
|         |                                |                                              |                 |                                |
| 293.1   | 1.788                          | 1430                                         | 1875            | 6 inch Round Convergent Nozzle |
| 293.2   | 2.198                          | 1441                                         | 2162            | 11 11 11                       |
| 293.3   | 2.592                          | 1440                                         | 2354            | 11 12 11                       |
| 293.4   | 2.985                          | 1452                                         | 2510            | 11 11 11                       |
| 293.5   | 3.362                          | 1461                                         | 2631            | 11 11 11                       |
|         |                                |                                              |                 |                                |

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|----------------------------------------------------|------------------------------------------|---------|--------------------------------------------------------|------------------------------------------|-----------|-------|-------|----------------|---------------|--|
|                                                    | 1000 - 1000 - 1000<br>- 1000 - 1000<br>N |         | ی در ایک<br>ه<br>می معرف<br>ایک معرف<br>ایک مرکز ایک د | n an |           |       |       |                |               |  |
|                                                    |                                          | -       | HM-AF                                                  | -35 NOZZI                                | E TEST DA | TA    |       |                |               |  |
| OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/ CM2// 25 FT |                                          |         |                                                        |                                          |           |       |       |                |               |  |
| RUN NO.                                            | OASPL                                    | 500     | IK                                                     | 2K                                       | 4K        | BK    | 16K   | 32K            | 64K           |  |
| 2732 649 .                                         | 151-3                                    | 116+1   | 112.0                                                  | 108.8                                    | 108.4     | 112.1 | 115.1 | 110.1          | 14001         |  |
| 279 150                                            | 118.0                                    | 111+0   | 110.0                                                  | 108.0                                    | 107.1     | 110.0 | 111.0 | 100+0          | 100.0         |  |
| 2791 170                                           | 116+5                                    | 104+0   | 10B+0                                                  | 107+0                                    | 106+1     | 109.0 | 110+0 | 1-16+1         | 49.1          |  |
| 5101 CHU                                           | 113.9                                    | 105+0   | 104.0                                                  | 104+0                                    | 104.3     | 107-0 | 101-0 | 100+0          | 76+0          |  |
| 2792 L40                                           | 150.5                                    | 112+7   | 109-1                                                  | 106.5                                    | 10/+4     | 112.6 | 115.5 | 1)1+0          | 103.2         |  |
| 2192 650                                           | 117.5                                    | 109.0   | 108.0                                                  | 107+0                                    | 106.1     | 110+0 | 112.0 | 198.0          | 191+0         |  |
| 2792 L60                                           | 115+9                                    | 107+0   | 106+0                                                  | 105+0                                    | 105+1     | 109.0 | 169.0 | 1118+0         | 101.0         |  |
| 2792 LHU                                           | 113.7                                    | 104+0   | 103+0                                                  | 103+0                                    | 108+1     | 110+0 | 111+0 | 1,174+0        | 100+0         |  |
| 2143 1.40                                          | 117.0                                    | 110+3   | 106.6                                                  | 104.0                                    | 104.3     | 189.4 | 111.8 | 10/40          | 99.1          |  |
| 2/33 150                                           | 115.2                                    | 107+0   | 107.0                                                  | 105.0                                    | 104 • 1   | 107.0 | 109.0 | 1.06+0         | 4/.0          |  |
| 2743 664                                           | 113.0                                    | 105+0   | 104+6                                                  | 103+0                                    | 102+1     | 106.0 | 105.0 | 105.0          | 41.0          |  |
| 2793 [.70                                          | )13.8                                    | 104.0   | 103-0                                                  | 102.0                                    | 103.1     | 107.0 | 109.0 | 194.0          | 95.0          |  |
| 2/94 140                                           | 116 6                                    | 102+0   | 97+0<br>10/ 0                                          | 100+0                                    | 100•)     | 10>•0 | 106+0 | 1-12+0         | <b>95</b> +0  |  |
| 2704 650                                           | 114.4                                    | 108+0   | 104+2                                                  | 102+8                                    | 103.1     | 109.3 | 111+9 | 107+3          | 99• <u>1</u>  |  |
| 2794 LOU                                           | 113.1                                    | 104+0   | 103.0                                                  | 102.0                                    | 102.1     | 107.0 | 100+0 | 103+0          | 9620<br>27 A  |  |
| 2794 L70                                           | 112.5                                    | 103+0   | 100.0                                                  | 100+0                                    | 101.1     | 106.0 | 108.0 | 103.0          | 93.0          |  |
| 2794 180                                           | 109+]                                    | 99+0    | 97.0                                                   | 97.0                                     | 98.1      | 103.0 | 104.0 | 100+0          | 91+9          |  |
| 2745 140                                           | 114+2                                    | 108+3 . | 103.0                                                  | 101+5                                    | 102+0     | 106.4 | 108.4 | 103+7          | 74.6          |  |
| 2795 L60                                           | 109.9                                    | 102+0   | 10.3+0                                                 | 101+0                                    | 100+1     | 103+0 | 105+0 | 191+0          | 92.0          |  |
| 2795 L70                                           | 108.8                                    | 191+0   | 97.0                                                   | 97.0                                     | 99.9      | 102.0 | 103.0 | 99+0           | 89.0          |  |
| 2795 LBU                                           | 106.4                                    | 97+0    | 94.0                                                   | 94+0                                     | 95.1      | 101.0 | 101.0 | 97+0           | 87.0          |  |
| 2800 LAV<br>2801 150                               | 120.0                                    | 161+0   | 115.5                                                  | 111+6                                    | 110.7     | 114.0 | 116.0 | 111.0          | 103.0         |  |
| 2801 L60                                           | 120.0                                    | 113+0   | 112.0                                                  | 111.0                                    | 107+7     | 112.0 | 112-0 | 147+0          | 99.0          |  |
| 2801 L70                                           | 118.5                                    | 111+0   | 110.0                                                  | 109+0                                    | 108.0     | 111.0 | 112.0 | 107+0          | 44-0          |  |
| 5807 FR0                                           | 116+1                                    | 104+0   | 106+0                                                  | 106.0                                    | 106.3     | 109.0 | 110.0 | 106+0          | 98.0          |  |
| 2502 140                                           | 122+3                                    | 118+0   | 112+0                                                  | 109+0                                    | 109.1     | 113.0 | 110+0 | 111+0          | 103.0         |  |
| 2802 LSV                                           | 118.4                                    | 110+0   | 109.0                                                  | 107+0                                    | 107+7     | 111.0 | 113+0 | 109+0          | 101.0         |  |
| 2802 L70                                           | 117.9                                    | 109+0   | 108+0                                                  | 107+0                                    | 108•0     | 111.0 | 112.0 | 108+0          | 101+0         |  |
| 5805 FRA                                           | 115.7                                    | 106+0   | 105.0                                                  | 105.0                                    | 105.1     | 109.0 | 110.0 | 10/+0          | 100.0         |  |
| 2803 L40                                           | 120.8                                    | 114+0   | 109.0                                                  | 106+0                                    | 107.1     | 113.0 | 116+0 | 112.0          | 104+0         |  |
| 2803 150                                           | 117.9                                    | 110+0   | 107+0                                                  | 106.0                                    | 106+3     | 111.0 | 113.0 | 109+0          | 101+0         |  |
| 2803 L70                                           | 117.5                                    | 106+0   | 107+0                                                  | 107+0                                    | 107+0     | 111.0 | 112.0 | 110.0          | 102.0         |  |
| 2803 L8V                                           | 114+7                                    | 104+0   | 107.0                                                  | 102.0                                    | 103.1     | 108.0 | 110.0 | 107+0          | 101.0         |  |
| 2814 L40                                           | 119•1                                    | 110+0   | 105+0                                                  | 104.0                                    | 106+1     | 112.0 | 115.0 | 111.0          | 102.7         |  |
| 2804 L50<br>2804 L60                               | 115.2                                    | 105+0   | 105+0                                                  | 104+0                                    | 105+1     | 110.0 | 112.0 | 108+0          | 100+0         |  |
| 2804 L70                                           | 114.9                                    | 104+0   | 104.0                                                  | 104+0                                    | 104+5     | 108.0 | 110+0 | 107+0          | 99+0          |  |
| 2804 L80                                           | 112.1                                    | 102+0   | 100+0                                                  | 100.0                                    | 101+1     | 106.0 | 107.0 | 103+0          | 94.0          |  |
| 2802 L40                                           | 115.0                                    | 105.0   | 101.0                                                  | 101+0                                    | 103.0     | 109.0 | 111+0 | 105+0          | 96.0          |  |
| 2805 150                                           | ]]3•J                                    | 103•0   | 102.0                                                  | 103+0                                    | 103.9     | 107.0 | 108.0 | 103.0          | 94+0          |  |
| 2805 170                                           | 110.3                                    | 100+0   | 100+0                                                  | 100+0                                    | 101+1     | 104.0 | 105+0 | 100+0          | 91+0          |  |
| 2805 680                                           | 108+0                                    | 48+0    | 97+0                                                   | 97.0                                     | 97+1      | 103.0 | 102.0 | 97+0           | 87.0          |  |
| 2811 L4U                                           | 156.5                                    | 124+0   | 118+0                                                  | 113-0                                    | 112+1     | 114+0 | 115.0 | 110+0          | 102+0         |  |
| 2011 L50                                           | 113+0                                    | 109+0   | 106.0                                                  | 103.0                                    | 101+1     | 103.0 | 103.0 | 91+0           | 90.n          |  |
| 2511 L70                                           | 119.5                                    | 113+0   | 111.0                                                  | 111+0                                    | 107+7     | 111.0 | 111+0 | 107+0          | 100.0         |  |
| 2ALI LOU                                           | 117+1                                    | 110+0   | 108.0                                                  | 107.0                                    | 107.0     | 110.0 | 110.0 | 100+0          | 70+0<br>98=0  |  |
| 28].2640 -                                         | 124.7                                    | 122+0   | 115.0                                                  | 111+0                                    | 111+1     | 114.0 | 116.0 | 111+0          | 103.0         |  |
| 281-2650                                           | 129.6                                    | 115.0   | 112.0                                                  | 110.0                                    | 109.1     | 112.0 | 114.0 | 109+0          | 102.0         |  |
| 281.71                                             | 119.3                                    | 111+0   | 110-0                                                  | 111-0                                    | 107+7     | 111+0 | 112.0 | 109+0          | 102.0         |  |
| 2H1+2LHU                                           | 116.5                                    | 199+0   | 107.0                                                  | 106.0                                    | 106.1     | 110-0 | 110-0 | ]9¥+0<br>107≖n | 100+0         |  |
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NOTE: THESE ARE FREE FIELD VALUES

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| RUN NO.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                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HM-AP-36 NOZZLE (Annulus Array of 60 Slots)

#### Remarks

The 60-slot annulus array (HM-AP-36) nozzle was compared with a simple annulus (HM-AP-12) nozzle. About 7 PNdB greater noise suppression was observed with the 60-slot annulus array. Reference D13. The 60-slot annulus nozzle provided 6 to 12 dB more suppression in the first four octave bands than the pure annulus nozzle. When ambient air was blocked (effective 0-inch length slots) from entering the slot array and with the nozzle center ventilation abrupted, there was a 1 to 2 PNdB improvement in PNL suppression.

One configuration of the 60-slot annulus array nozzle tested (HM-AP-36-A) had three concentric rings added which divides each slot into four parts. This increases the number of nozzle elements from 60 to 240. The HM-AP-36-A Nozzle configuration had an area ratio of 7.3. This nozzle attained a maximum noise suppression level of 18.8 PNdB (PR = 2.6 and  $T_T = 1500^{\circ}F$ ), however thrust loss was considerable, about 22%. See Reference D17.

Another 60-slot annulus array configuration investigated the effect of nozzle exit cant angle  $(-10^{\circ})$  and centerbody plugs on noise and performance. Reference D13. Four different plug lengths were tried. There was no significant difference observed in noise suppression when compared to the uncanted and unplugged HM-AP-36 Nozzle.

# HM-AP-36 NOZZLE

| Test Facility: | Annex D<br>Microphone | and | no%zle | height | is | 20 | Inches |
|----------------|-----------------------|-----|--------|--------|----|----|--------|
| Date:          |                       |     |        |        |    |    |        |

T<sub>amb</sub>: R.H.:

| Run No.                                      | PT/P.                                  | $\underline{\mathbf{T}_{\mathbf{T}}}$ | $v_{J}$ (Ideal)                                  | Nozzle                                                    |
|----------------------------------------------|----------------------------------------|---------------------------------------|--------------------------------------------------|-----------------------------------------------------------|
| 2621<br>2622<br>2623<br>2624<br>2625<br>2625 | 1.8<br>1.0<br>2.2<br>2.6<br>3.0        | 540°F<br>1000<br>150C<br>"<br>"       | 1350 fps<br>1659<br>1923<br>2202<br>24J2<br>2555 | HM-AP-36<br>""""""""""""""""""""""""""""""""""""          |
| 2639<br>2640<br>2641<br>2642<br>2643<br>2643 | 1.8<br>1.8<br>1.8<br>2.2<br>2.6<br>3.0 | 540°F<br>1000<br>1500<br>"<br>"       | 1350 fps<br>1659<br>1923<br>2202<br>2402<br>2555 | 4.1 Inch Round Convergent Nozzle<br>"<br>"<br>"<br>"<br>" |

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HM-AP-36 NOZZLE TEST.DATA

OCTAVE BAND LEVEL-dB RE: 0,9002 DYNES/CH2 // 25 FT

| RUN NO.   | -<br>OASPL | 500   | 1K    | 2K    | 4K     | 8K    | 16K   | 32K   | 64K           |
|-----------|------------|-------|-------|-------|--------|-------|-------|-------|---------------|
|           |            |       |       | 04 0  | 100.0  | 99.0  | 100.0 | 56.6  | 56.0          |
| 2621 L40  | 107.7      | 102.0 | 99.0  | 94.0  | 101.0  | 101.0 | 166.6 | 56.0  | 50.0          |
| 2621 L50  | 168.2      | 102.0 | 99.0  | 94.0  | 100-0  | 100.0 | 102.0 | 97.C  | £5.C          |
| 2621 L60  | 107.0      | 100.0 | 70.0  | 91.0  | 66.0   | 98.0  | 55.0  | \$5.0 | £9.C          |
| 2621 L70  | 105.0      | 90.0  | 95+0  | 88.0  | 96-0   | 97.0  | 58.C  | 54.0  | 87.C          |
| 2621 L80  | 103.0      | 94.0  | 91.0  | 67.0  | 103.0  | 102-0 | 104.0 | 55.0  | 52.C          |
| 2622 L40  | 111.0      | 105-0 | 103.0 | 97.0  | 104.0  | 104.0 | 164.6 | 100.0 | <b>93.</b> 0  |
| 2622 L50  | 111.0      | 103.0 | 100.0 | 95.0  | 104-0  | 103.0 | 105.0 | 100.0 | 52.C          |
| 2622 LOU  | 170.5      | 100.0 | 97.0  | 94.0  | 101.0  | 101.0 | 103.0 | 58.C  | \$1.C         |
| 2622 L/C  | 107.3      | 98-0  | 95.0  | 92.0  | 99.0   | 101.0 | 102.0 | \$7.C | 85.0          |
| 2622 140  | 113.0      | 106-0 | 104.0 | 99.0  | 105.0  | 104.0 | 167.0 | 102.0 | \$5.0         |
| 2023 150  | 113.9      | 167.0 | 104.0 | 99.0  | 106.0  | 105.0 | 168.6 | 103.0 | 57.C          |
| 2023 140  | 114.0      | 105.0 | 103.0 | 99.0  | 107.0  | 106.0 | 165.0 | 103-0 | \$5.0         |
| 2623 170  | 112.1      | 102.0 | 100.0 | 97.0  | 104.0  | 104.0 | 108.0 | 102.0 | 56.0          |
| 2623 180  | 111.0      | 100.0 | 98.0  | 94.0  | 101.0  | 102.0 | 108.0 | 101.0 | <b>93.</b> 0  |
| 2625 260  | 117-0      | 110.0 | 107.0 | 105.0 | 110.0  | 109.0 | 110.C | 165.0 | 59.0          |
| 2624 150  | 117-2      | 110.0 | 107.0 | 104.0 | 110.0  | 110.0 | 110.0 | 166.6 | 100.0         |
| 2624 1.60 | 116.6      | 108.0 | 106.0 | 102.0 | 110-0  | 109.0 | 111.0 | 165.0 | 5E-C          |
| 2624 170  | 114.0      | 105.0 | 102.0 | 100-0 | 107.0  | 107.0 | 108-0 | 104.0 | 57.0          |
| 2624 180  | 112.2      | 103.0 | 100.0 | 99.0  | 104.0  | 106.0 | 106.0 | 103.C | 54.C          |
| 2625 140  | 120.1      | 114.0 | 110.0 | 107.0 | 113.0  | 113.0 | 112.C | 107-0 | 101.0         |
| 2625 150  | 119.8      | 113.0 | 110.0 | 106.0 | 113.0  | 113.C | 112.0 | 167.6 | 161.0         |
| 2625 L60  | 119.0      | 111.0 | 108.0 | 104.0 | 113.0  | 112.0 | 112.0 | 167.6 | 100.0         |
| 2625 L70  | 116.0      | 107.0 | 105.0 | 102.0 | 110.0  | 109.0 | 169.6 | 105-0 | 55.0          |
| 2625 L80  | 114.2      | 105.0 | 102.0 | 100.0 | 107.0  | 108.0 | 108.0 | 104.0 | 50.0          |
| 2626 140  | 122.4      | 116.0 | 112.0 | 110.0 | 116.0  | 116.0 | 113.C | 168.6 | 102.0         |
| 2626 150  | 122.4      | 116.0 | 112.0 | 109.0 | 116.0  | 116.0 | 113-C | 109.0 | 103.0         |
| 2626 L60  | 121.5      | 114.0 | 110.0 | 107.0 | 116.0  | 115.0 | 113.0 | 169.0 | 161.6         |
| 2626 L70  | 117.7      | 109.0 | 107.0 | 105.0 | 112.0  | 111.0 | 110.0 | 106.0 |               |
| 2626 L80  | 115.7      | 107.0 | 104.0 | 103.0 | 109.0  | 110.0 | 166.6 | 105+0 | 97.0          |
| 2639 L40  | 122.0      | 119.0 | 118.0 | 107.0 | 109.0  | 104.0 | 56.0  | £5.C  | 89.0          |
| 2639 L50  | 119.7      | 117.0 | 114-0 | 106.0 | 110.0  | 105.0 | 55.0  | 91.0  | 27.L          |
| 2639 L60  | 116.0      | 112.0 | 109.0 | 103.0 | 110.0  | 105.0 | 100.0 | 53.0  | 27.0          |
| 2635 L70  | 112.3      | 107.0 | 105.0 | 101.0 | 107.0  | 102.0 | 52.0  | 52+0  | 65.0          |
| 2639 L80  | 109.2      | 103.0 | 102.0 | 99.0  | 103.0  | 101-0 | 57.0  | 91+0  | 61.0          |
| 2640 L40  | 126.6      | 122.0 | 123.0 | 116.0 | 117-0  | 110-0 | 105.0 | 57.0  | 9 <b>4</b> •0 |
| 2640 L50  | 125.7.     | 122.0 | 121.0 | 113.0 | 117-0. | 112.0 | 104.0 | 7/.0  | 52.00         |
| 2640 L60  | 121.8      | 117.0 | 116.0 | 109.0 | 116.0  | 111.0 | 103-0 | 57.0  | F5-C          |
| 2640 L70  | 117.0      | 111.0 | 110.0 | 106.0 | 100 0  | 107.0 | 101-0 | 35-0  | 85.0          |
| 2640 L80  | 114.3      | 127.0 | 125.0 | 119.0 | 122-0  | 116.0 | 111.0 | 163.0 | 100.0         |
| 2041 L40  | 127+1      | 123.0 | 124.0 | 117.0 | 122.0  | 116.0 | 110.0 | 103.C | 58.C          |
| 2041 150  | 125.3      | 119.0 | 120-0 | 113.0 | 120.0  | 114.0 | 111.C | 103.0 | 56.C          |
| 2641 170  | 120.2      | 113.0 | 114.0 | 110.0 | 115.0  | 111.G | 167.6 | 100.0 | \$3.0         |
| 2641 180  | 117.4      | 109.0 | 109.0 | 107.0 | 113.0  | 110.0 | 165.6 | 58.C  | 85.C          |
| 2642 140  | 132.1      | 125.0 | 127.0 | 124.0 | 126.0  | 120.0 | 116.C | 110.C | 164.6         |
| 2642 L50  | 132.3      | 125.0 | 126.0 |       | 127.0  | 123.0 | 117.C | 111.C | 167.6         |
| 2642 L60  | 129.0      | 122.0 | 123.0 | 118.0 | 124.0  | 119.0 | 116.0 | 109.0 | 102.0         |
| 2642 L70  | 124.2      | 117.0 | 117.0 | 114-0 | 119.0  | 116.0 | 112.0 | 106.0 | 100.0         |
| 2642 L80  | 120.7      | 111.0 | 112.0 | 111.0 | 116.0  | 114.0 | 165.6 | 112 4 | 100 0         |
| 2643 L40  | 133.6      | 127.0 | 129.0 | 124.0 | 127.0  | 122.0 | 118.0 | 112+6 | 116-0         |
| 2643 L50  | 135.0      | 128.0 | 129.0 | 125.0 | 130.0  | 123+0 | 116 0 | 113.0 | 167-0         |
| 2643 L60  | 132.3      | 125.0 | 126.0 | 124.0 | 121-0  | 119.0 | 115-0 | 109-0 | 107-0         |
| 2643 L70  | 126.3.     |       |       |       | 119.0  | 117.0 | 114.0 | 109-0 | 55-0          |
| 2643 L80  | 123.2      | 113.0 | 114.0 | 127 0 | 127.0  | 122-0 | 119.0 | 113-0 | 106-0         |
| 2644 L40  | 134.7      | 128.0 | 130.0 | 1200  | 121-0  | 124.0 | 121.6 | 114.0 | 111_0         |
| 2644 LOU  | 1 2 2 4 2  | 124.0 | 127.0 | 124.0 | 129-0  | 125-0 | 121_0 | 116-0 | 110.0         |
| 2644 LOU  | 120 5      | 120.0 | 120-0 | 110-0 | 124-0  | 120-0 | 117.0 | 112.0 | 166.0         |
| 2044 100  | 12007      | 114.0 | 116-0 | 116-0 | 120-0  | 120.0 | 117.0 | 111.0 | 103.0         |
| 2044 100  | 14340      | 11010 | /     |       |        |       |       |       | <b>-</b>      |

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NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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RE: 0.0002 DYNES/CM<sup>2</sup>// 200 FT POLAR ARC OCTAVE PASS BANDS IN HERTZ 130 140 RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 06 01 01 021 021 08 06 01 01 021 021 125 OVERALL SPL~dB OCTAVE BAND LEVEL~dB. 3.0 -2.6 120 2.2 11111 115 PF. 110 30<sup>0</sup> 40<sup>0</sup> 50<sup>0</sup> 60<sup>0</sup> 90<sup>0</sup> 70<sup>0</sup> -80<sup>0</sup> ANGLE TO THE JET AXIS~DEGREES TOTAL TEMPERATURE (T 8) : 1500° F NOZZLE EXIT AREA (A 8): 5.9 FT2 70 Ś 5 2 1 100 1000 10000 FREQUENCY IN HERTZ HM-AP-37 NOZZLE PRESSURE RATIO: 1.8 (37 TUBE HEXAGONAL ARRAY) TOTAL TEMPERATURE: 1500° F AR 4.65 JET VELOCITY (IDEAL): 1923 FPS SCALE FACTOR: 8:1 NOZZLE EXIT AREA (A8): 5.9 FT2 OCTAVE PASS BANDS IN HERTZ OCTAVE PASS BANDS IN HERTZ 140 140 RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 06 001 011 051 051 RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 8 6 00 01 01 02 05 RC 50° OCTAVE BAND LEVEL~dB OCTAVE BAND LEVEL~dB 111111 70 70 Ś 1 1000 1 100 5 1 10000 5 1 1000 1 100 2 5 2 10000 FREQUENCY IN HERTZ FREQUENCY IN HERTZ PRESSURE RATIO: 2.2 PRESSURE RATIO: 3.0 TOTAL TEMPERATURE: 1500° F TOTAL TEMPERATURE: 1500° F JET VELOCITY (IDEAL): 2255 FPS

JET VELOCITY (IDEAL): 2202 FPS NOZZLE EXIT AREA (A8): 5.9 FT2

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DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE EXIT AREA (A8): 5.9 FT2

D13<sup>1</sup>

## HM-AP-37 NOZZLE

(37 Tube Hexagonal Array, AR = 4.65)

### Remarks

The HM-AP-37 Nozzle was part of  $\epsilon$  parametric study to study the effect of area ratio on noise suppression. Area ratios of 3.33, 4.0, 4.65, 5.2 and 8.0 (HM-AP-43, HM-AP-39, HM-AP-37, HM-AP-44 and HM-AP-38) were tested. At pressure ratios  $\leq 3.0$  and  $T_{\rm T} = 1500^{\circ}$ F better PNL suppression could be obtained with area ratios of 3.33 or 4.0. See Reference D19.

A retest of the HM-AP-37 Nozzle, Reference  $D^{20}$ , indicated substantial agreement in OASPL and PNL suppression. However, a  $\mu$  to 9 dB difference in first and second octave band levels was noted.

# HM-AP-37 NOZZLE

Test Facility: Annex D Microphone and Nozzle Height is 20 Inches Date: ca. March 1968 T<sub>amb</sub>: not available

R.H.: not available

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| Run No.                                      | P <sub>T</sub> /P               | $\frac{\mathbf{T_{T}}}{\mathbf{T}}$ | VJ (Ideal)                                       | Nozzle                                                      |
|----------------------------------------------|---------------------------------|-------------------------------------|--------------------------------------------------|-------------------------------------------------------------|
| 2855<br>2856<br>2857<br>2858<br>2859<br>2860 | 1.8<br>1.8<br>2.2<br>2.6<br>3.0 | 540°F<br>1000<br>1500<br>"<br>"     | 1370 fps<br>1659<br>1923<br>2202<br>2402<br>2555 | HM-AP-37<br>""<br>""<br>"                                   |
| 2849<br>2850<br>2851<br>2852<br>2853<br>2854 | 1.8<br>1.8<br>2.2<br>2.6<br>3.0 | 540°F<br>1000<br>1500<br>"<br>"     | 1370 fps<br>1659<br>1923<br>2202<br>2402<br>2555 | 4.1 Inch Round Convergent Nozzle<br>""<br>""<br>"<br>"<br>" |

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# HM-AP-37 NOZZLE TEST DATA

OCTAVE BAND LEVEL- dB RE: 0:0002 DYNES CH2// 25 FT

|                  |           |          | _              |             |          |         |        |          |                                       |
|------------------|-----------|----------|----------------|-------------|----------|---------|--------|----------|---------------------------------------|
| RUN NO.          | OASPL     | 500      | 1K             | 2K          | 4K       | -8K     | 16K    | 32K      | 64K                                   |
| 2655 140         | -111 - 9. | 106.0    | 100.0          | 93.0        | 106-0    | 105.0   | 103.0  | 98.0     | -85.0                                 |
| 2000 140         | 1.11.0    | 100.0    | 101 0          | 05.0        | 107 0    | 107 0   | 3.63.0 | 1:00.0   | C 2 . A                               |
| 2855 650         | 1-13-0    | 107.0    | 101.0          | 9.5 • 0*    | 107-0    | -107.0- | 103.0  |          | 73.0                                  |
| 2855 L60         | 113.8     | 167.0    | 101.0          | 9610        | -10-/=•0 | 0.801   | 10.0.0 | 102.0    | 95.0                                  |
| 2855 L70         | 110.2     | 103.0    | 97.0           | 93.0        | 102.0    | 104.0   | 164.6  | 100-0    | 52.0                                  |
| 2855 L80         | 168.2     | 100.0    | 94.0           | 91.0        | -101.0   | 101.0   | 102.0  | 100.0    | 93 <u>.</u> 0                         |
| 2246 1 0         | 115.3     | -109-0   | 104.0          | 95.0        | 108.0    | 110.0   | 107.0  | 102.0    | 53.0                                  |
| 2: 46 1.56       | 115.5     | 109.0    | 105.0          | 97.0        | 108.0    | 110.0   | 107.C  | 103.6    | \$5.G                                 |
|                  | 117.4     | 109.0    | 104.0          | 99.0        | 111.0    | 112.0   | 110.0  | 105.0    | 56.0                                  |
| 2079 201         | 1-16 0    | 166 0    | 102 0          | 65 0        | 164 0    | ານີ້ອ.ດ | 108.0  | 163.0    | 66.0                                  |
| 2800 670         | 1-1-4+0   | 100.0    | 102,0          | 0.0         | 100.0    | 105.0   | 106.0  | 103-0    | 65- 6                                 |
| 2856 210         | 111.4.7   | 104.0    | 90.0           | 52.0        | 1.03.0   | 102.0   | 106+0  | 103.00   | , , , , , , , , , , , , , , , , , , , |
| 2857 640         | 115.9     | 166.0    | 102.0          | 96 - U      | 108.0    | 115-0   | 165.0  | 10450    | 50.0                                  |
| 2857 L50         | 115.6     | 106.0    | 10 <u>2</u> .0 | 97.0        | 109.0    | 111.0   | 166-6  | 164.6    | 57.0                                  |
| 2857 L60         | 119.2     | 108.0    | 103.0          | 101.0       | 113.0    | 115.0   | 112.9  | 167-0    | 55.0                                  |
| 2857 L70         | 1-16.8    | 105.0    | 101.0          | 97.0        | 110.0    | 112.0   | 1-11.C | 166-6    | 59.0                                  |
| 2857 180         | 114-5     | 102.0    | 98.0           | -<br>94.0   | 106-0    | 109.0   | 109.0  | 1 C7=+ C | 100.0                                 |
| 2858 140         | 110.0     | 110 0    | 105 0          | 00 0        | 1-1-7 0  | 1:1:4 0 | 117 0  | 1.09 0   | 100.0                                 |
| 2000 140         | 119.0     | 111 0    | 102.0          | 101 0       | 112.0    | 114+0   | 115+0  | 100.0    | 103 0                                 |
| 2350 150         | 119.0     | 111+0    | 107.0          | 101.0       | 112.0    | 115.0   | 112+0  | 109.0    | 1(5.6                                 |
| 2858 60          | 121.5     | 112.0    | 107.0          | 104.0       | 114.0    | 117.0   | 115+6  | 110.0    | 103+0                                 |
| 2858 L70         | 119.5     | 168.0    | 104.0          | 101.0       | 110.0    | 114.C   | 114.0  | 109.0    | 110.0                                 |
| 2858 L80         | 117.4     | 105.0    | 101.0          | <b>98.0</b> | 107.0    | 111.0   | 113.0  | :110.C   | 163.6                                 |
| 2859 L40         | 121.0     | 112.0    | 108.0          | 100.0       | 113.0    | 116.0   | 115.0  | 110.Č    | 102.0                                 |
| 2859 L50         | 121-3     | 114.0    | 109-0          | 102.0       | 113.0    | 115.0   | 114.0  | 111.0    | 105.0                                 |
| 2859 160         | 123.6     | 115.0    | 110-0          | 105.0       | 116-0    | 119.0   | 116.0  | 119.0    | 165.0                                 |
| 2055 200         | 121 0     | 111 0    | 109 0          | 102 0       | 314 0    | 117 0   | 316 0  | 112 0    | 105 0                                 |
| 2057 110         | 110 6     | 160 0    | 106:0          | 102.0       | 100 0    | 112 0   | 116.0  | 112.00   | 100.0                                 |
| 2039 200         | 11202     | 100-0    | _105-0         | 100.0       | 109.0    | 113.0   | 115+6  | 112+6    | ICC-U                                 |
| 2860 L40         | 122.3     | 112.0    | 111.0          | 103.0       | 114.0    | 117.0   | 115.0  | 111-0    | 104.0                                 |
| 2860 L50         | 123.3     | 11/40    | 113-0          | 105+0       | 114+0    | 118-0   | 125.0  | 112+6    | 160+6                                 |
| 2860 L60         | 122.8     | 116.0    | 112.0          | 105.0       | 115.0    | 117.0   | 115.0  | 1-12•C   | 104.0                                 |
| 2860 L70         | 122.5     | 114.G    | 111.0          | 105+0       | 114.0    | 117.0   | 116.G  | 113.C    | 106.0                                 |
| 2860 <u>L</u> 80 | 120-9     | 112.0    | 108.0          | 101.0       | 110.0    | 114.0   | 116.0  | 113.0    | 166.6                                 |
| 2849 140         | Ī17.9     | 114.0    | 114.0          | 103.0       | 108.0    | 103.C   | 55.0   | 92.0     | 86.C                                  |
| 2849 150         | 115.8     | 111-0    | 110-0          | 104-0-      | 105.0    | 105-0   | 100.0  | 55.0     | 88.0                                  |
| 2027_020         | 115 2     | 111 0    | 107.0          | 103.0       | 109.0    | 106.0   | 101.0  | 56.0     | -88.0                                 |
| 2049 200         | 111 1     | 103 0    | 103 0          | 100-0       | 106 0    | 104-0   | 100.0  | 54.5     | 86.0                                  |
| 2049 100         | 100 0     | 103.0    | 103.0          | 100.0       | 104 0    | 102-0   | 10000  | 67 6     | C1 C                                  |
| 2049 200         | 102.0     | toto     | 120 0          | 99.0        | 11440    | 102.0   | 205 0  |          | 51+6                                  |
| 2850 L40         | 123.1     | 119+0    | 120+0          | 1.10.0      | 115.0    | 103.0   | 105.0  | 77.0     | 52.0                                  |
| 2850 L50         | 121-4     | 116.0    | 117-0          | 110+0       | 114.0    | 110.0   | 105+0  | 100.0    | 0.55                                  |
| 285G L60         | 119.1     | 114.0    | 112.0          | 107.0       | 113.0    | 110.0   | 106-0  | 161.4    | 52+0                                  |
| 2850 L70         | 116-1     | 107.0    | 108.0          | 165.0       | 111.0    | 109.0   | 106°C  | 101.0    | 53.0                                  |
| 2850 L80         | 113.4     | 104.0    | 105-0          | 102.0       | 108.0    | 106.0   | 164.6  | 101.0    | 56.G                                  |
| 2851 L40         | 126-1     | 121.0    | 122.0          | 113.0       | 119.0    | 113.0   | 108.0  | 102.0    | 56.0                                  |
| 2851 1.50        | 125.5     | 120.0    | 122.0          | 114.0       | 117.0    | 112.0   | 108.G  | 102.0    | 56.0                                  |
| 2851 160         | 123.7     | 118.0    | 118.0          | 113.0       | 117.0    | 114-0   | 105.0  | 105-0    | 57-0                                  |
| 2051 200         | 110 3     | 11040    | 112 0          | 108 0       | 114 0    | 111 0   | 106.0  | 103 0    | 6 42                                  |
| 2031 210         | 11945     | 112.0    | 112.00         | 100.0       | 11110    | 300 0   | 10000  | 103+0    |                                       |
| 2001 LOU         | 110+0     | 108+0    | 109-0          | 105.0       | 100      | 105.0   | 116 0  | 10400    | 102.0                                 |
| 2852 L40         | 130+1     | 125.0    | 125-0          | 118.0       | 123.0    | 119.0   | 115.0  | 110+0    | 103.0                                 |
| 2852 L50         | 130.1     | 124+0    | 125.0          | 119.0       | 124.0    | 119.0   | 115.0  | 111.0    | 105+0                                 |
| 2852 L6G         | 127.9     | 121.0    | 122.0          | 117.0       | 122+0    | 1-19.0  | -115.0 | 111.0    | 103+0                                 |
| 2852 L70         | 123.8     | 115.0    | 116.0          | 112.0       | 119.0    | 116.6   | 314-0  | 168.C    | 102-0                                 |
| 2852 L80         | 120.5     | 111.0    | 112.0          | 109.0       | 115.0    | 11-3.0  | 112.0  | 108.0    | 102.0                                 |
| 2853 140         | 122 4     | 127.0    | 128.0          | 120.0       | -126.0   | 121.0   | 118.0  | 112.0    | 167.0                                 |
| 2863 160         | 122 4     | 1-74 - 0 | 127 0          | 122.0       | 127.0    | 172.0   | 110.0  | 115.0    | 110.0                                 |
| 2 62 140         | 132+0     | 177 4    | 10/0           | 121 0       | 121.00   | 125 0   | 116.0  | 11/ 6    | 103 0                                 |
| 2 33 100         | 120.0     | 123.0    | 124+0          | 121.0       | 122.0    | 162.00  | 115.0  | 114-5    | 10700                                 |
| 2855 L10         | 125.9     | 117.0    | 117.0          | 114+0       | 121.0    | 11240   | Lic.C  | 111.0    | 112.0                                 |
| 2853 L80         | 123.1     | 112.0    | 114.0          | 112.0       | 118.0    | 116.0   | 114.6  | 112.0    | 1(7.0                                 |
| 2854 L40         | 134.0     | 129.0    | 130.0          | 121.0       | 126.0    | 121.0   | 117.C  | 113.C    | 107.0                                 |
| 2854 L50         | 134.5     | 127.0    | 129.0          | 125.0       | 129.0    | 124.0   | 120.0  | 116.0    | 111.0                                 |
| 2854 L60         | 132-4     | 124.0    | 126:0          | 123.0       | 127.0    | 124.0   | 120.0  | 116.0    | 110.0                                 |
| 2854 L70         | 128-1     | 118-0    | 120.0          | 117.0       | 123.0    | 121.0   | 115.0  | 114.0    | 108-0                                 |
| 2854 L80         | 124-9     | 114.0    | 115.0          | 114-0       | 119-0    | 738-0   | 117-0  | 114-6    | 105-0                                 |
|                  | ~~        |          |                |             |          |         |        |          | ~~~~~                                 |

# NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE





#### BASE PLATE WITH TUBES REMOVED

### HM-AP-38 NOZZLE

### ( 37 TUBE HEXAGONAL ARRAY, AR 8.0 )

#### Description:

The HM-AP-38 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with round convergent ends Area Ratio: 8.0

Flow Area: 13.2 square inches

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Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches Tube Exit Diameter: 0.674 inches Material: 321 CRES







## HM-AP-38 NOZZLE

(37 Tube Hexagonal Array, AR = 8.0)

### Remarks

The HM-AP-38 nozzle had the largest area ratio of a 37 tube nozzle parametric study where area ratios varies from 3.33 to 8.0. Very good jet merging noise suppression was evident in the low frequency portion of the spectrum. This advantage was off-set by the relative high levels in the high frequency portion of the spectrum attributed to pre-merging jet mixing noise. See Reference D19.
HM\_AP\_38

Test Facility: Annex D

Date:

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| <u>Run No</u> .         | $\frac{P_{T}/P}{P}$ | $\frac{\mathrm{T_{T}}}{\mathrm{T}}$ | VJ (Ideal)               | Nozzle                                |
|-------------------------|---------------------|-------------------------------------|--------------------------|---------------------------------------|
| H1257<br>H1258<br>H1259 | 1.8<br>2.6<br>3.0   | 1500°F<br>"                         | 1923 fps<br>2402<br>2555 | HM-AP-38<br>"                         |
| H1227<br>H1228<br>H1229 | 1.8<br>2.6<br>3.0   | 1500 <sup>0</sup> F<br>"            | 1923 fps<br>2402<br>2555 | 4.1 Inch Round Convergent Nozzle<br>" |

Measured acoustic data is included in Reference D2.

# NOZZLE TEST DATA

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2/25-FT

| HM-AP | 38 |
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| RUN NO.  | OASPL  | 500   | ١K    | 2K    | 4K                  | -8K          | 16K    | 32K   | 64K     |
|----------|--------|-------|-------|-------|---------------------|--------------|--------|-------|---------|
|          |        |       |       |       |                     |              |        |       |         |
| H1257L40 | 118.3  | 102.0 | 102.0 | 100.0 | 113 <sup>-</sup> .0 | 113.0        | 112.0  | 108.0 | 103.O   |
| H1257L50 | 120.3  | 103.0 | 103.0 | 101.0 | 115.0               | 115.0        | 114.0  | 110.0 | 105.0   |
| H1257L60 | 120.9  | 102.0 | 101.0 | 100.0 | 114.0               | 117.0        | 115.0  | 110.0 | 105.0   |
| H1257L70 | 117.4  | 100.0 | 97.0  | 96.0  | 110.0               | 112.0        | 112.0  | 109.0 | 105.0   |
| H1257L80 | 112.6  | 97.0  | 94.0  | 94.0  | 105.0               | 107.0        | 107.0  | 105.0 | 100.0   |
| H1258L40 | 122.8  | 106.0 | 105.0 | 104.0 | 117.0               | 117.0        | 117.0  | 113.0 | 110.0   |
| H1258L50 | 124.3  | 108.0 | 108.0 | 104.0 | 118.0               | 118.0        | 119.0  | 115.0 | 112.0   |
| H1258L60 | 126.0  | 107.0 | 106.0 | 104.0 | 119.0               | 122.0        | 120.0  | 116.0 | 111.0   |
| M1258L70 | 123.0  | 104.0 | 102.0 | 101.0 | 115.0               | <b>118.0</b> | 118.0  | 114.0 | 111.0   |
| H1258L80 | 119.0  | 101.0 | 99.0  | 98.0  | 110.0               | 113.0        | 114.0  | 112.0 | 107.0   |
| H1259L40 | 123.8  | 108.0 | 107.0 | 106.0 | 118.9               | 118.0        | 110.0  | 114.0 | 111.0   |
| H1259L50 | 125.8  | 110.0 | 110.0 | 106.0 | 120.0               | 120.0        | 120.0  | 116.0 | 111.0   |
| H1259L60 | 1-27.3 | 109.0 | 108.0 | 106.0 | 121.0               | 123.0        | 121.0  | 117.0 | 112.0   |
| H1259L70 | 124.4  | 106.0 | 104.0 | 103.0 | 117.0               | 119.0        | 119.0- | 116.0 | 113.0   |
| H1259L80 | 120.1  | 103.0 | 101.0 | 100.0 | 112.0               | 114.0        | 115.0  | 113.0 | 108.0   |
| H1227L40 | 127.9  | 122.0 | 124.0 | 116.0 | 121.0               | 114.0        | 110.0  | 104.0 | 103.0   |
| H1227L50 | 126.6  | 121.0 | 122.0 | 115.0 | 120.0               | 114.0        | 110.0  | 104.0 | 103.0   |
| H1227L60 | 122.9  | 116.0 | 116:0 | 111.0 | 118.0               | 114.0        | 110.0  | 105.0 | 100.0   |
| H1227L70 | 120.8  | 112.0 | 113.0 | 108.0 | 117.0               | 112.0        | 109.0  | 104.0 | 101.0   |
| H1227L80 | 116.3  | 108.0 | 108.0 | 105.0 | 112.0               | 108.0        | 105.0  | 101.0 | 96.0    |
| H1228L40 | 134.4  | 128.0 | 130.0 | 123.0 | 128.0               | 122.0        | 119.0  | 114.0 | · 113.0 |
| H1228L50 | 134.4  | 127.0 | 128.0 | 123.0 | 130.0               | .124.0       | 121.0  | 115.0 | 115.0   |
| H1228L60 | 130.2  | 121.0 | 123.0 | 119.0 | 126.0               | 122.0        | 118.0  | 114.D | 109.0   |
| H1228L70 | 127.9  | 117.0 | 119.0 | 116.0 | 124.0               | 120.0        | 118.0  | 113.0 | ·110.0  |
| H1228L80 | 123.1  | 113.0 | 113.0 | 111.0 | 119.0               | 116.0        | 113.0  | 110.0 | 105.0   |
| H1229L40 | 135.4  | 130.0 | 131.0 | 124.0 | 128.0               | 123.0        | 119.0  | 114.0 | 113.0   |
| H1229L50 | 136.0  | 129.0 | 130.0 | 125.0 | 131.0               | 125.0        | 122.0  | 117.0 | 117.0   |
| H1229L60 | 132.1  | 123.0 | 124.0 | 121.0 | 128.0               | 124.0        | 120.0  | 116.0 | 112.0   |
| H1229L70 | 129.8  | 119.0 | 120.0 | 118.0 | 126.0               | 122.0        | 120.0  | 116.0 | 113.0   |
| H1229L80 | 125.6  | 115.0 | 115.0 | 114.0 | 121.0               | 119.0        | 115.0  | 113.0 | 108.0   |
|          |        |       |       |       |                     |              |        |       |         |

NOTE: DATA INCLUDES GROUND RELECTION INTERFERENCE



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# ( 37 TUBE, HEXAGONAL KRRAY, AR4.0)

### Description:

The HM-AP-39 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter baseplate and were removable.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 4.0

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Exit Diameter: 0.674 inches Material: 321 CRE3



NO PICTURE AVAILABLE





D15.

# HM-AP-39 NOZZLE

(37 Tube Hexagonal Array, AR = 4.0)

# R marks

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The HM-AP-39 nozzle was tested with several different tube lengths (Ref. D19). Nozzle configurations with effective tube lengths of 7 inches, 5 inches, 3 inches or 1 inch showed essentially no differences in jet noise characteristics. HM-4P-39

Test Facility: Annex D Nozzle and Microphone Height is 20 Inches

Date:

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 $T_{amb}$ : not available

R.H.: not available

| Run No.                 | $\frac{P_{T}/P}{P}$ | $\frac{\mathrm{T}\mathrm{T}}{\mathrm{T}}$ | VJ (Ideal)               | Nozzle                           |
|-------------------------|---------------------|-------------------------------------------|--------------------------|----------------------------------|
| H1236<br>H1237<br>H1238 | 1.8<br>2.6<br>3.0   | 1500°F<br>"                               | 1923 fps<br>2432<br>2555 | HM-AP-39<br>"                    |
| H1227<br>H1228<br>H1229 | 1.8<br>2.6<br>3.0   | 1500°F<br>"                               | 1923<br>2402<br>2555     | 4.1-Inch Round Convergent Nozzle |

Measured acoustic data is included in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM<sup>2</sup>//25 FT HM-AP-39

| RUN   | NO.        | OASPL  | 500   | ΙK    | 2K    | 4K     | 8K    | 16K    | 32K   | -64K  |
|-------|------------|--------|-------|-------|-------|--------|-------|--------|-------|-------|
|       |            |        |       |       |       |        |       |        |       |       |
| H1236 | 1.40       | 116 4  | 105 0 | 103.0 | 96.0  | 109.0- | 112 0 | 110 Ō  | 105 O | 102 0 |
| 11236 | 2.50       | 117 3  | 106.0 | 104.0 | 97.0  | 111.0  | 112.0 | 111 0  | 106 0 | 102.0 |
| H1236 | 60         | .18 1  | 105.0 | 102.0 | 99.0  | 112.0  | 113 0 | 112 0  | 108.0 | 102.0 |
| H1236 | 1.20       | 110.7  | 103.0 | 101.0 | 96.0  | 310.0  | 111.0 | 111.0  | 107 0 | 104.0 |
| H1236 | L80        | 112.1  | 100.0 | 98.0  | 93.0  | 104.0  | 106.0 | 106.0  | 105.0 | 99.0  |
| H1237 | I 40       | 121.6  | 113.0 | 109.0 | 102.0 | 114.0  | 116.0 | 115.0  | 111.0 | 107.0 |
| H1237 | 1.50       | 122.6  | 114.0 | 111.0 | 102.0 | 115.0  | 117.0 | 116.0  | 111.0 | 109.0 |
| H1237 | L60        | 122.5  | 112.0 | 109.0 | 103.0 | 116.0  | 117.0 | 116.0  | 112.0 | 107.0 |
| H1237 | L70        | 121.8  | 110.0 | 107.0 | 101.0 | 114.0  | 116.0 | 116.0  | 113.0 | 110.0 |
| H1237 | L80        | 107.7  | 97.0  | 94.0  | 88.0  | 98.0   | 101.0 | 102.0  | 101.0 | 95.0  |
| H1238 | L40        | 123.3- | 116.0 | 112.0 | 104.0 | 115.0  | 118.0 | 116.0  | 111.0 | 108.0 |
| H1238 | L50        | 123.7  | 115.0 | 113.0 | 104.0 | 116.0  | 118.0 | 117.0  | 112.0 | 111.0 |
| H1238 | L60        | 123.5  | 113.0 | 111.0 | 105.0 | 117.0  | 118.0 | 117.0  | 113.0 | 108.0 |
| H1238 | lĵo        | 123.2  | 112.0 | 109.0 | 103.0 | 115.0  | 117.0 | 116.0  | 113.0 | 116.0 |
| H1238 | L80        | 318.5  | 108.0 | 105.0 | 100.0 | 109.0  | 112.0 | 113.0. | 111.0 | 106.0 |
| H1227 | L40        | 127.9  | 122.0 | 124.0 | 116.0 | 121.0  | 114.0 | 110.0  | 104.0 | 103.0 |
| H1227 | L50        | 126.6  | 121.0 | 122.0 | 115.0 | 120.0  | 114.0 | 110.0  | 104.0 | 103.0 |
| H1227 | L60        | 122.9  | 116.9 | 116.0 | 111.0 | 118.0  | 114.0 | 110.0  | 105.0 | 100.0 |
| H1227 | L7C        | 120.8  | 112.0 | 113.0 | 108.0 | 117.0  | 112.0 | 109.0  | 104.0 | 101.0 |
| H1227 | ĩ80        | 116.3  | 108.0 | 108.0 | 105.0 | 112.0  | 108.0 | 105.0  | 101.0 | 96.0  |
| H1228 | L40        | 134.4  | 128.0 | 130.0 | 123.0 | 128.0  | 122.0 | 119.0  | 114.0 | 113.0 |
| H1228 | L50        | 134.4  | 127.0 | 128.0 | 123.0 | 130.0  | 124.0 | 121.0  | 115.0 | 115.0 |
| H1228 | L60        | 130.2  | 121.0 | 123.0 | 119.0 | 126.0  | 122.0 | 118.0  | 114.0 | 109.0 |
| H1228 | L70        | 127.9  | 117.0 | 119.0 | 116.0 | 124.0  | 120.0 | 118.0  | 113.0 | 110.0 |
| H1228 | 180        | 123,1  | 113.0 | 113.0 | 111.0 | 119.0  | 116.0 | 113.0  | 110.0 | 105.0 |
| H1229 | L40        | 135.4  | 130.0 | 131.0 | 124.0 | 128.0  | 123.0 | 119.C  | 114.0 | 113.0 |
| H1229 | L50        | 136.0  | 129.0 | 130.0 | 125.0 | 131.0  | 125.0 | 122.0  | 117.0 | 117.0 |
| H1229 | L60        | 132.1  | 123.0 | 124.0 | 121.0 | 128.0  | 124.0 | 120.0  | 116.0 | 112.0 |
| H1229 | l70        | 129.8  | 119.0 | 120.0 | 118.0 | 126.0  | 122.0 | 120.0  | 116.0 | 113.0 |
| H1229 | <b>L80</b> | 125.6  | 115.0 | 115.0 | 114.0 | 121.0  | 119.0 | 116.0  | 113.0 | 108.0 |

NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE

D156



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D158





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HM-AP-40

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 3.33)

### Remarks

The HM-AP-40 nozzle was one of a series of 37 tube nozzles that were tested to determine the effect of area ratio on jet noise characteristics. The HM-AP-40 nozzle had the smallest area ratio and attained the best suppression values of the series when  $PR \leq 2.6$ . At higher pressure ratios the low frequency portion of the spectrum becomes dominant due to jet coalescing noise and suppression values diminish. Tube length was varied from 1 inch to 7 inches with no effect on noise characteristics, see Reference D8.

Other 37 tube nozzles with 12 spoke terminations on each tube that were tested in this series ar

| HM-AP-18  | AR | 4.65 |
|-----------|----|------|
| HM-AP-18a | AR | 8.0  |
| HM-AP-40  | AR | 3.33 |
| HM-AP-41  | AR | 4.0  |
| HM-AP-42  | AR | 5.2  |

See Reference D9.

| HMAP40                     |                   |                                   |                             |                                  |  |  |  |  |  |
|----------------------------|-------------------|-----------------------------------|-----------------------------|----------------------------------|--|--|--|--|--|
|                            |                   |                                   |                             |                                  |  |  |  |  |  |
| Test                       | Facility          | v: Annex D<br>Nozzle              | (Cell #1)<br>and Microphone | Heights are 20 Inches            |  |  |  |  |  |
| Date                       | : Novemb          | per 20, 196                       | 7                           |                                  |  |  |  |  |  |
| $T_{amb}$                  | :                 |                                   |                             |                                  |  |  |  |  |  |
| R.H.                       | :                 |                                   |                             |                                  |  |  |  |  |  |
| Run No.                    | -PT/P             | $\frac{\mathbf{T_T}}{\mathbf{T}}$ | VJ (Ideal)                  | Nozzle                           |  |  |  |  |  |
| H 1137                     | 1.8               | 1500°F                            | 1930 fps                    | нм-ар-40                         |  |  |  |  |  |
| H 1130<br>H 1139           | 2.0<br>3.0        | 12                                | 2400<br>2550                | 11                               |  |  |  |  |  |
| н 1144<br>н 1145<br>н 1146 | 1.8<br>2.6<br>3.0 | 1500°F<br>"                       | 1930 fps<br>2400<br>2550    | 4.1-Inch Round Convergent Nozzle |  |  |  |  |  |

Measured acoustic data is recorded in Reference D2.

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# NOZZLE TEST DATA

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OCTAVE BAND LEVEL - dB RE: 0.0002 DYNES / CM2// 25 FT

HM-AP-40

| RUN NO.  | OASPL | 500   | 1K    | 2K    | 4K       | 8K     | 16K   | 32K         | 64K   |
|----------|-------|-------|-------|-------|----------|--------|-------|-------------|-------|
|          |       |       |       |       |          |        |       |             |       |
| H1137L40 | 107.7 | 105.0 | 101.0 | 91.0  | .0<br>95 | 94.0   | 9Ŝ.O  | 95.0        | 93.0  |
| H1137L50 | 108.5 | 105.0 | 101.0 | 92.0  | . 97.5-  | · 97.5 | 98.0  | <b>97.0</b> | 94.0  |
| H1137L60 | 107.7 | 103.0 | 100.0 | 93.0  | . 98.0   | ·97.0  | 98.0  | 98.0        | 94.0  |
| H1137L70 | 106.6 | 101.0 | 99.0- | 91.0  | 98.0     | 96.0   | 97.0  | 97.0        | 96.0  |
| H1137L80 | 104.5 | 99.0  | 96.0  | 90.0  | 95.0     | 95.0   | 95.0  | 96.0        | 93.0  |
| H1137L40 | 117.2 | 115.0 | 111.0 | 100.0 | 105.0    | 102.0  | 102.0 | 100.0       | 97.0  |
| H1137L50 | 116.1 | 113.0 | 109.0 | 100.0 | 105.0    | 105.0  | 105.0 | 102.0       | 98.0  |
| H1137L60 | 114.7 | 111.0 | 107.0 | 101.0 | 106.0    | 104.0  | 104.0 | 101.0       | 98.0  |
| H1138L70 | 113.0 | 108.0 | 105.0 | 98.0  | 105.0    | 103.0  | 103.0 | 102.0       | 100.0 |
| H1138L80 | 111.5 | 106.0 | 103.0 | 97.0  | 103.0    | 103.0  | 102.0 | 102.0       | 98.0  |
| H1139L40 | 121.3 | 119.5 | 115.0 | 103.0 | 108.0    | 105.0  | 104.0 | 101.0       | 0.0   |
| H1139L50 | 119.2 | 116.J | 112.0 | 104.0 | 110.0    | 108.0  | 107.0 | 104.0       | 99.0  |
| H1139L60 | 117.0 | 114.0 | 109.0 | 104.0 | 110.0    | 107.0  | 106.0 | 103.0       | 99.0  |
| H1139L70 | 115.7 | 111.0 | 108.0 | 101.0 | 108.0    | 106.0  | 105.0 | 103.0       | 101.0 |
| H1139L80 | 112.6 | 108.0 | 104.0 | 99.0  | 104.0    | 104.0  | 103.0 | 101.0       | 97.0  |
| H1144L40 | 127.0 | 122.0 | 123.0 | 116.0 | 119.0    | 112.0  | 107.0 | 99.0        | 100.0 |
| H1144L50 | 125.7 | 122.0 | 121.0 | 113.0 | 117.0    | 111.0  | 107.0 | 98.0        | 97.0  |
| H1144L60 | 121.2 | 117.0 | 116.0 | 111.0 | 111.5    | 110.0  | 105.0 | 98.0        | 0.0   |
| H1144L70 | 118.1 | 112.0 | 111.0 | 106.0 | 113.0    | 109.0  | 105.0 | 99.0        | 94.0  |
| H1144L80 | 113.9 | 108.0 | 106.0 | 103.0 | 108.0    | 105.0  | 102.0 | 96.0        | 91.0  |
| H1145L40 | 132.3 | 127.0 | 128.0 | 121.0 | 125.0    | 119.0  | 115.0 | 108.0       | 109.0 |
| H1145L50 | 133.0 | 126.0 | 127.0 | 122.0 | 128.0    | 123.0  | 120.0 | 113.0       | 109.8 |
| H1145L60 | 128.3 | 121.0 | 122.0 | 118.0 | 123.0    | 119.0  | 115.0 | 109.0       | 104.0 |
| H1145L70 | 125.2 | 117.0 | 116.0 | 113.0 | 121.0    | 117.0  | 115.0 | 109.9       | 104.0 |
| H1145L80 | 120.4 | 112.0 | 111.0 | 109.0 | 115.0    | 114.0  | 111.0 | 105.0       | 99.0  |
| H1146L40 | 133.6 | 128.0 | 130.0 | 123.0 | 125.0    | 120.0  | 116.0 | 110.0       | 109.0 |
| H1146L50 | 134.7 | 128.0 | 129.0 | 124.0 | 129.0    | 125.0  | 121.0 | 115.0       | 110.0 |
| H1146L60 | 130.0 | 123.0 | 125 0 | 120.0 | 125.0    | 121.0  | 117.Ô | 111 Q       | 107.0 |
| H1146L70 | 126.9 | 118.0 | 112.0 | 115.0 | 122.0    | 120.0  | 118.0 | 112.0       | 108.0 |
| H1146L80 | 122.7 | 113.0 | 110.0 | 112.0 | 117.0    | 117.0  | 114.0 | 109.0       | 103.0 |

NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE



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D165





D167

# HM-AP-41 NOZZLE

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 4.0)

#### Remarks

The HM-AP-41 nozzle was one of a series of 37 tube hexagonal arrays tested where area ratio was a variable. This nozzle with an area ratio of 4.0 attained 'be best suppression value of 17.2 at PR = 3.0 and  $T_T = 1500^{\circ}F$ . When effective tube length was varied from 7 inches to 1 inch, there was substantially no affect on the acoustic noise characteristics (Reference D8).

Several lined and unlined ejectors were tested with the HM-AP-41 nozzle (Reference D2). The unlined ejectors did not affect PNL suppression values significantly. One unlined ejector that was about 4 nozzle diameters (33.33 inches) in length did improve suppression by 0.7 PNdB. The lined ejectors demonstrated the potential of additional suppression of jet noise quite adequately. A one-inch thick TWF fiberglass blanket held in place by 0.035 inch stainless steel, 40% open mcsh, was used for an acoustic absorbent liner. Additional suppression up to 7 PNdB was attained with a lined ejector. The lined ejector was most effective at low primary gas pressure ratios, e.g. PR = 1.8. At higher pressure ratios more low frequency noise is generated in the region of jet coalescence downstream of the exit plane and attenuation by the ejector diminishes. A peak suppression value of 22.8 PNdB was attained with the HM-AP-41 nozzle with lined ejector at PR = 2.2 and  $T_{\rm T}$  = 1500°F. See Reference D9.

HM-AP-41 Test Facility: Annex D (Cell #1) Nozzle and Microphone Heights are 20 Inches Date:  $T_{amb}$ : R.H.:  $\mathbf{T}_{\mathbf{T}}$  $V_{J}$  (Ideal)  $P_T/P$ Run No. Nozzle  $1000^{\circ}F$ HM-AP-41 3309 1.8 1659 fps 3310 1.8 1500°F 1923 11 11 н 3311 2.2 2202 11 11 3312 2.6 2402 n n 3313 3.0 2555 3304 i.8 1000°F 1659 fps 4.1-Inch Round Convergent Nozzle 1500°F 1.8 3305 1923 11 11 2202 3306 2.2 11 2402 ti 3307 2.6 11 2555 11 3308 3.0

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# HM-AP-41 NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/ CM2// 25 FT

| 3304AL40   126.2   121.0   123.0   113.0   117.0   111.0   107.0   101.0     3304AL50   124.2   119.0   120.0   112.0   117.0   111.0   107.0   98.0     3304AL60   120.5   115.0   114.0   108.0   105.0   105.0   105.0   105.0   99.0     3304AL70   116.2   110.0   106.0   106.0   106.0   103.0   99.0     3305AL50   128.2   122.0   124.0   125.0   116.0   112.0   104.0     3305AL60   128.2   122.0   124.0   140.0   100.0   107.0   104.0     3305AL60   132.7   126.0   128.0   127.0   121.6   113.0   100.0   107.0   104.0     3306AL50   132.8   125.0   127.0   124.0   140.0   110.0   107.0   100.0   107.0   100.0   105.0   110.0   107.0   120.0   110.0   110.0   107.0   120.0   111.0<                                                                                                                                                                                                                  | 93.0<br>94.0<br>91.0<br>92.0<br>92.0<br>101.0<br>99.0<br>96.0<br>96.0<br>107.0<br>105.0<br>107.0<br>105.0<br>107.0<br>109.0<br>110.0<br>109.0<br>110.0<br>110.0<br>110.0            |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3304ALS0   124.2   119.0   120.0   112.0   117.0   111.0   107.0   98.0     3304ALK0   120.5   115.0   114.0   108.0   115.0   111.0   107.0   98.0     3304AL70   116.2   110.0   109.0   105.0   111.0   103.0   98.0     3304AL70   116.2   110.0   108.0   104.0   110.0   105.0   113.0   105.0   99.0     3304AL50   122.5   124.0   125.0   116.0   113.0   107.0   98.0     3305AL50   128.2   122.0   124.0   116.0   113.0   107.0   101.0   107.0   104.0     3305AL60   114.4   110.0   100.0   107.0   104.0   103.0   114.0   110.0   107.0   104.0     3306AL60   132.7   126.0   123.0   114.0   110.0   107.0   104.0   109.0   135.0   123.0   123.0   123.0   123.0   123.0   123.0   123.0 <td>94.0<br/>91.0<br/>92.0<br/>92.0<br/>101.0<br/>99.0<br/>96.0<br/>96.0<br/>107.0<br/>105.0<br/>107.0<br/>105.0<br/>107.0<br/>109.0<br/>211.0<br/>109.0<br/>211.0<br/>109.0<br/>110.0<br/>110.0<br/>110.0</td>     | 94.0<br>91.0<br>92.0<br>92.0<br>101.0<br>99.0<br>96.0<br>96.0<br>107.0<br>105.0<br>107.0<br>105.0<br>107.0<br>109.0<br>211.0<br>109.0<br>211.0<br>109.0<br>110.0<br>110.0<br>110.0  |
| 3304AL60   120.5   115.0   114.0   100.0   115.0   111.0   109.0   98.0     3304AL70   116.2   110.0   109.0   105.0   111.0   109.0   105.0   111.0   109.0   99.0     3: 134L00   115.0   108.0   108.0   104.0   110.0   106.0   103.0   99.0     3:05AL40   129.5   124.0   125.0   117.0   123.0   116.0   112.0   104.0     3:05AL60   124.4   118.0   119.0   113.0   110.0   107.0   104.0   100.0   107.0   104.0   105.0   104.0     3:05AL60   124.4   118.0   117.0   124.0   110.0   107.0   101.0   107.0   104.0   105.0   114.0   110.0   107.0   104.0   105.0   114.0   110.0   107.0   104.0   105.0   104.0   105.0   106.0   113.0   127.0   127.0   128.0   127.0   128.0   114.0   100.0   105                                                                                                                                                                                                              | 91.0<br>92.0<br>92.0<br>92.0<br>101.0<br>99.0<br>96.0<br>96.0<br>96.0<br>107.0<br>105.0<br>105.0<br>105.0<br>105.0<br>105.0<br>105.0<br>105.0<br>110.0<br>105.0<br>110.0<br>105.0   |
| 3304AL70   116.2   110.0   109.0   105.0   111.0   103.0   105.0   99.0     3   33L400   115.0   108.0   108.0   104.0   110.0   106.0   103.0   98.0     3305AL50   128.2   124.0   115.0   107.0   123.0   116.0   113.0   107.0     3305AL60   124.4   118.0   119.0   113.0   110.0   109.0   104.0     3305AL60   124.4   118.0   111.0   107.0   114.0   110.0   109.0   104.0     3306AL60   132.7   126.0   122.0   124.0   116.0   113.0   117.0   124.0   118.0   113.0   113.0   113.0   113.0   113.0   113.0   114.0   109.0   135.0   128.0   123.0   118.0   115.0   119.0   115.0   119.0   115.0   130.0   124.0   122.0   115.0   130.0   124.0   122.0   115.0   130.0   124.0   122.0   115.0 <td>92.0<br/>92.0<br/>92.0<br/>101.0<br/>99.0<br/>96.0<br/>96.0<br/>107.0<br/>105.0<br/>105.0<br/>102.0<br/>105.0<br/>105.0<br/>105.0<br/>105.0<br/>105.0<br/>105.0<br/>105.0<br/>105.0<br/>110.0<br/>105.0</td> | 92.0<br>92.0<br>92.0<br>101.0<br>99.0<br>96.0<br>96.0<br>107.0<br>105.0<br>105.0<br>102.0<br>105.0<br>105.0<br>105.0<br>105.0<br>105.0<br>105.0<br>105.0<br>105.0<br>110.0<br>105.0 |
| 3: 14AL00   115.0   108.0   104.0   110.0   106.0   103.0   90.0     3305AL40   129.5   124.0   125.0   117.0   123.0   116.0   113.0   107.0     3305AL50   128.2   122.0   124.0   116.0   122.0   116.0   112.0   104.0     3305AL60   124.4   118.0   119.0   113.0   110.0   103.0   103.0     3305AL60   124.4   118.0   111.0   107.0   114.0   110.0   107.0   101.0     3305AL60   118.6   111.0   117.0   124.0   110.0   107.0   101.0     3306AL60   128.6   122.0   128.0   127.0   124.0   116.0   113.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   116.0   11                                                                                                                                                                                                                | 92.0<br>101.0<br>99.0<br>96.0<br>96.0<br>107.0<br>105.0<br>103.0<br>102.0<br>102.0<br>102.0<br>102.0<br>102.0<br>102.0<br>105.0<br>110.0<br>105.0<br>110.0<br>110.0<br>110.0        |
| 2305AL40   129.5   124.0   125.0   117.0   123.0   116.0   113.0   107.0     3305AL50   128.2   122.0   124.0   116.0   122.0   116.0   112.0   104.0     3305AL60   124.4   118.0   119.0   113.0   110.0   100.0   103.0     3205AL60   118.6   113.0   113.0   113.0   113.0   113.0   113.0   113.0   113.0   113.0   113.0   113.0   103.0     3305AL60   118.6   111.0   117.0   124.0   110.0   107.0   101.0     3306AL60   132.7   126.0   123.0   117.0   124.0   119.0   115.0   119.0   115.0   119.0   115.0   119.0   115.0   119.0   115.0   119.0   115.0   119.0   115.0   119.0   115.0   119.0   115.0   110.0   106.0   130.0   124.0   122.0   115.0   130.0   124.0   122.0   115.0   122.0   1                                                                                                                                                                                                              | 101.0<br>99.0<br>96.0<br>96.0<br>96.0<br>107.0<br>105.0<br>103.0<br>102.0<br>102.0<br>102.0<br>102.0<br>102.0<br>102.0<br>105.0<br>110.0<br>110.0<br>110.0<br>110.0                 |
| 3305AL50 128.2 122.0 124.0 116.0 122.0 116.0 112.0 104.0   3305AL60 124.4 118.0 119.0 113.0 119.0 113.0 119.0 103.0   3305AL60 124.4 118.0 119.0 113.0 114.0 110.0 109.0 104.0   3305AL80 118.6 111.0 111.0 107.0 114.0 110.0 107.0 114.0   3306AL40 132.7 126.0 128.0 121.0 127.0 121.0 118.0 111.0   3306AL40 132.7 126.0 127.0 122.0 128.0 123.0 118.0 111.0   3306AL40 132.8 125.0 127.0 122.0 128.0 114.0 110.0 109.0   3306AL40 132.6 113.0 113.0 114.0 114.0 110.0 106.0   3307AL40 135.0 129.0 131.0 123.0 128.0 122.0 119.0 115.0   3307AL70 126.5 118.0 119.0 115.0 122.0 121.0 <td>99.0<br/>96.0<br/>96.0<br/>96.0<br/>107.0<br/>105.0<br/>103.0<br/>103.0<br/>102.0<br/>101.0<br/>109.0<br/>110.0<br/>110.0<br/>110.0<br/>110.0<br/>110.0</td>                                                                                                                                                                         | 99.0<br>96.0<br>96.0<br>96.0<br>107.0<br>105.0<br>103.0<br>103.0<br>102.0<br>101.0<br>109.0<br>110.0<br>110.0<br>110.0<br>110.0<br>110.0                                            |
| 5305AL60   124.4   118.0   119.0   113.0   119.0   113.0   119.0   103.0     37(15AL70   119.6   113.0   113.0   114.0   110.0   109.0   104.0     3305AL80   118.6   111.0   111.0   107.0   114.0   110.0   107.0   101.0     3306AL40   132.7   126.0   128.0   121.0   127.0   121.0   118.0   118.0   111.0     3306AL50   132.8   125.0   127.0   122.0   117.0   124.0   119.0   115.0   114.0   109.0     3306AL60   128.6   120.0   123.0   118.0   111.0   106.0   113.0   114.0   111.0   106.0   109.0   135.0   129.0   130.0   124.0   130.0   124.0   130.0   124.0   130.0   122.0   117.0   144.0   110.0   115.0     3307AL70   126.5   118.0   119.0   115.0   122.0   117.0   116.0   122.0   1                                                                                                                                                                                                                | 96.0<br>96.0<br>96.0<br>107.0<br>105.0<br>103.0<br>102.0<br>102.0<br>101.0<br>109.0<br>110.0<br>110.0<br>110.0<br>110.0<br>110.0                                                    |
| 37:(5AL70 119.6 113.0 113.0 113.0 114.0 110.0 109.0 104.0   3305AL80 118.6 111.0 111.0 107.0 144.0 110.0 107.0 101.0   3305AL80 132.7 126.0 128.0 121.0 127.0 121.0 118.0 113.0   3306AL50 132.8 125.0 127.0 122.0 128.0 118.0 111.0   3306AL60 128.6 120.0 123.0 117.0 124.0 119.0 115.0 109.0   3306AL80 121.6 113.0 113.0 119.0 115.0 114.0 109.0   3307AL50 135.1 127.0 130.0 124.0 122.0 115.0 115.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3307AL70 126.5 118.0 131.0 121.0 117.0 116.0 122.0 124.0 </td <td>96.0<br/>96.0<br/>107.0<br/>105.0<br/>103.0<br/>102.0<br/>102.0<br/>102.0<br/>102.0<br/>105.0<br/>105.0<br/>110.0<br/>113.0<br/>110.0<br/>110.0</td>                                                                                                                                                                           | 96.0<br>96.0<br>107.0<br>105.0<br>103.0<br>102.0<br>102.0<br>102.0<br>102.0<br>105.0<br>105.0<br>110.0<br>113.0<br>110.0<br>110.0                                                   |
| 3305AL80   118.6   111.0   117.0   107.0   114.0   110.0   107.0   101.0     3306AL50   132.7   126.0   128.0   121.0   127.0   121.0   113.0   113.0     3306AL50   132.8   125.0   127.0   122.0   128.0   123.0   118.0   111.0     3306AL60   128.6   120.0   123.0   117.0   124.0   119.0   115.0   114.0   109.0     3306AL60   121.6   113.0   113.0   117.0   124.0   114.0   114.0   114.0   114.0   109.0     3306AL60   121.6   113.0   113.0   117.0   124.0   122.0   115.0   115.0     3307AL70   126.5   118.0   119.0   115.0   122.0   117.0   116.0   112.0     3307AL70   126.5   118.0   119.0   115.0   122.0   117.0   116.0   112.0     3308AL60   135.7   130.0   121.0   121.0   116.                                                                                                                                                                                                                    | 96.0<br>107.0<br>105.0<br>103.0<br>102.0<br>101.0<br>109.0<br>111.0<br>107.0<br>106.0<br>105.0<br>110.0<br>110.0<br>110.0<br>110.0                                                  |
| 3306AL40 132.7 126.0 128.0 121.0 127.0 121.0 118.0 113.0   3306AL50 132.8 125.0 127.0 122.0 128.0 123.0 118.0 111.0   3306AL60 123.6 120.0 123.0 117.0 124.0 119.0 115.0 109.0   3306AL60 123.6 113.0 113.0 119.0 115.0 114.0 109.0   3306AL60 121.6 113.0 113.0 111.0 117.0 114.0 111.0 109.0   3307AL50 135.1 127.0 130.0 124.0 122.0 119.0 115.0   3307AL70 126.5 118.0 119.0 115.0 122.0 119.0 115.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3308AL40 135.7 130.0 131.0 122.0 121.0 116.0 122.0 121.0 <td>107.0<br/>105.0<br/>103.0<br/>102.0<br/>101.0<br/>109.0<br/>111.0<br/>107.0<br/>106.0<br/>105.0<br/>110.0<br/>110.0<br/>110.0<br/>109.0</td>                                                                                                                                                                                         | 107.0<br>105.0<br>103.0<br>102.0<br>101.0<br>109.0<br>111.0<br>107.0<br>106.0<br>105.0<br>110.0<br>110.0<br>110.0<br>109.0                                                          |
| 3306AL50 132.8 125.0 127.0 122.0 128.0 123.0 118.0 111.0   3306AL60 128.6 120.0 123.0 117.0 124.0 119.0 115.0 109.0   3306AL70 123.9 116.0 116.0 113.0 119.0 115.0 114.0 109.0   3307AL70 123.9 116.0 113.0 111.0 114.0 111.0 106.0   3307AL70 135.0 129.0 131.0 123.0 124.0 122.0 115.0   3307AL50 135.1 127.0 130.0 124.0 122.0 116.0 112.0   3307AL70 126.5 118.0 119.0 115.0 122.0 116.0 112.0   3308AL40 135.7 130.0 131.0 125.0 122.0 126.0 116.0   3308AL50 137.0 128.0 127.0 123.0 120.0 116.0 132.0 121.0 116.0   3308AL60 133.9 124.0 127.0 123.0 120.0 116.0 130.0 121.0 116.0 <td>105.0<br/>103.0<br/>102.0<br/>101.0<br/>109.0<br/>111.0<br/>107.0<br/>106.0<br/>105.0<br/>110.0<br/>113.0<br/>110.0<br/>110.0</td>                                                                                                                                                                                                   | 105.0<br>103.0<br>102.0<br>101.0<br>109.0<br>111.0<br>107.0<br>106.0<br>105.0<br>110.0<br>113.0<br>110.0<br>110.0                                                                   |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 103.0<br>102.0<br>101.0<br>109.0<br>211.0<br>107.0<br>106.0<br>105.0<br>110.0<br>113.0<br>110.0<br>109.0                                                                            |
| 3306AL70   123.9   116.0   116.0   113.0   119.0   115.0   114.0   109.0     3306AL80   121.6   113.0   113.0   111.0   117.0   114.0   111.0   109.0     3307AL80   135.0   129.0   131.0   123.0   128.0   122.0   119.0   115.0     3307AL80   135.1   127.0   130.0   124.0   130.0   124.0   122.0   115.0     3307AL70   126.5   118.0   119.0   115.0   122.0   117.0   116.0   112.0     3307AL80   124.9   115.0   116.0   113.0   121.0   117.0   116.0   112.0     3308AL40   135.7   130.0   131.0   125.0   122.0   123.0   120.0   116.0     3308AL50   137.0   126.0   132.0   126.0   132.0   120.0   117.0   124.0   118.0     3308AL60   127.5   116.0   117.0   124.0   120.0   114.0   106.                                                                                                                                                                                                                    | 102.0<br>101.0<br>109.0<br>111.0<br>107.0<br>105.0<br>110.0<br>110.0<br>110.0<br>109.0                                                                                              |
| 3306AL80 121.6 113.0 113.0 111.0 114.0 114.0 111.0 106.0   3307AL40 135.0 129.0 131.0 123.0 128.0 122.0 119.0 115.0   3307AL50 135.1 127.0 130.0 124.0 130.0 124.0 122.0 115.0   3307AL50 135.1 127.0 130.0 124.0 120.0 127.0 122.0 115.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3307AL80 124.9 115.0 116.0 113.0 121.0 117.0 116.0 112.0   3308AL40 135.7 130.0 131.0 125.0 129.0 123.0 120.0 116.0   3308AL60 133.9 124.0 127.0 124.0 120.0 117.0 114.0 114.0 114.0   3308AL80 127.5 116.0 117.0 124.0 120.0 119.0 116.0   3309AL40 106.3 103.0 100.0 87.0 95.0                                                                                                                                                                                                                                                                                                                                            | 101.0<br>109.0<br>111.0<br>107.0<br>106.0<br>105.0<br>110.0<br>113.0<br>110.0<br>109.0                                                                                              |
| 3307AL40 135.0 129.0 131.0 123.0 128.0 122.0 119.0 115.0   3307AL50 135.1 127.0 130.0 124.0 130.0 124.0 122.0 115.0   3307AL50 131.6 123.0 126.0 120.0 127.0 122.0 116.0 112.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3308AL40 135.7 130.0 131.0 125.0 123.0 120.0 116.0   3308AL60 133.9 124.0 127.0 123.0 130.0 126.0 144.0 146.0   3308AL60 127.5 116.0 117.0 124.0 120.0 114.0 146.0   3309AL40 106.3 103.0 100.0 87.0 95.0 95.0 95.0                                                                                                                                                                                                                                                                                                                                              | 109.0<br>111.0<br>107.0<br>106.0<br>105.0<br>110.0<br>113.0<br>110.0<br>109.0                                                                                                       |
| 3307AL50 135.1 127.0 130.0 124.0 124.0 122.0 115.0   3507AL60 131.6 123.0 126.0 120.0 127.0 122.0 116.0 112.0   3507AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3507AL80 124.9 115.0 116.0 113.0 121.0 117.0 116.0 112.0   3507AL80 124.9 115.0 116.0 113.0 121.0 117.0 116.0 112.0   3508AL40 135.7 130.0 131.0 125.0 123.0 120.0 116.0   3508AL60 133.9 124.0 127.0 123.0 120.0 116.0   3508AL60 133.9 124.0 127.0 123.0 120.0 116.0   3508AL60 133.9 124.0 127.0 123.0 120.0 116.0   3509AL40 106.3 103.0 100.0 87.0 95.0 95.0 95.0   3509AL40 106.7 102.0 91.0 96.0                                                                                                                                                                                                                                                                                                                                                 | 111.0<br>107.0<br>106.0<br>105.0<br>110.0<br>110.0<br>110.0<br>109.0                                                                                                                |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 107.0<br>106.0<br>105.0<br>110.0<br>110.0<br>113.0<br>110.0<br>109.0                                                                                                                |
| 3307AL70 126.5 118.0 119.0 115.0 122.0 117.0 116.0 112.0   3307AL80 124.9 115.0 116.0 113.0 121.0 117.0 115.0 110.0   3308AL40 135.7 130.0 131.0 125.0 129.0 123.0 120.0 116.0   3308AL60 133.9 124.0 127.0 126.0 132.0 126.0 127.0 124.0 116.0   3308AL60 133.9 124.0 127.0 126.0 130.0 125.0 121.0 116.0   3308AL60 133.9 124.0 127.0 123.0 120.0 117.0 116.0 121.0 116.0   3308AL80 127.5 116.0 117.0 116.0 122.0 120.0 119.0 116.0   3309AL40 106.3 103.0 100.0 87.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0 95.0                                                                                                                                                                                                                                                                                                                                                       | 106.0<br>105.0<br>110.0<br>113.0<br>110.0<br>109.0                                                                                                                                  |
| 3303AL80 124.9 115.0 116.0 113.0 121.0 117.0 115.0 110.0   3308AL40 135.7 130.0 131.0 125.0 129.0 123.0 120.0 116.0   3308AL50 137.0 128.0 132.0 126.0 132.0 127.0 124.0 118.0   3308AL60 133.9 124.0 127.0 123.0 130.0 125.0 121.0 116.0   3308AL60 133.9 124.0 127.0 123.0 130.0 125.0 121.0 116.0   3308AL60 127.5 116.0 117.0 124.0 120.0 119.0 116.0   3308AL80 127.5 116.0 117.0 124.0 120.0 120.0 120.0 144.0   3309AL40 106.3 103.0 100.0 87.0 95.0 94.0 95.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 104.1 99.0 97.0 87.0 92.0 93.0 95.0 95                                                                                                                                                                                                                                                                                                                                                      | 105.0<br>110.0<br>113.0<br>110.0<br>109.0                                                                                                                                           |
| 3308AL40 135.7 130.0 131.0 125.0 129.0 123.0 120.0 116.0   3308AL50 137.0 128.0 132.0 126.0 132.0 127.0 124.0 118.0   3308AL60 133.9 124.0 127.0 123.0 130.0 125.0 121.0 116.0   3308AL60 133.9 124.0 127.0 123.0 130.0 125.0 121.0 116.0   3308AL60 127.5 116.0 127.0 124.0 120.0 119.0 116.0   3308AL80 127.5 116.0 117.0 116.0 123.0 120.0 120.0 114.0   3309AL40 106.3 103.0 100.0 87.0 95.0 95.0 94.0 95.0   3309AL40 108.1 104.0 102.6 91.6 98.0 97.0 98.0 97.0   3309AL40 106.7 102.0 99.0 90.0 97.0 97.0 98.0 97.0   3309AL40 106.7 102.0 99.0 90.0 97.0 95.0 95.0 <td>110.0<br/>113.0<br/>110.0<br/>109.0</td>                                                                                                                                                                                                                                                                                                            | 110.0<br>113.0<br>110.0<br>109.0                                                                                                                                                    |
| 3308AL50 137.0 128.0 132.0 126.0 132.0 127.0 124.0 118.0   3308AL60 133.9 124.0 127.0 123.0 130.0 125.0 121.0 116.0   3308AL70 128.5 119.0 120.0 117.0 124.0 120.0 119.0 116.0   3308AL80 127.5 116.0 117.0 124.0 120.0 120.0 119.0 116.0   3309AL40 106.3 103.0 100.0 87.0 95.0 95.0 94.0 95.0   3309AL40 106.3 103.0 100.0 87.0 95.0 97.0 96.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 104.1 99.0 97.0 87.0 92.0 93.0 97.0   3309AL60 104.1 99.0 97.0 87.0 92.0 93.0 95.0 95.0   3310AL60 104.0 102.0 90.0 97.0 96.0 97.0 97.0                                                                                                                                                                                                                                                                                                                                                                          | 113.0<br>110.0<br>109.0                                                                                                                                                             |
| 3308AL60 133.9 124.0 127.0 123.0 130.0 125.0 121.0 116.0   3306AL70 128.5 119.0 120.0 117.0 124.0 120.0 119.0 116.0   3306AL80 127.5 116.0 117.0 124.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 124.0 120.0 120.0 120.0 124.0 120.0 120.0 120.0 124.0 120.0 120.0 120.0 120.0 124.0 120.0 124.0 120.0 124.0 120.0 120.0 120.0 124.0 120.0 120.0 120.0 124.0 120.0 120.0 124.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0 120.0                                                                                                                                                                                                                                                                                                                                   | 110.0                                                                                                                                                                               |
| 3308AL70 128.5 119.0 120.0 117.0 124.0 120.0 119.0 116.0   3308AL80 127.5 116.0 117.0 116.0 123.0 120.0 120.0 120.0 144.0   3309AL40 106.3 103.0 100.0 87.0 95.0 95.0 94.0 95.0   3309AL50 108.1 104.0 102.0 91.0 98.0 96.0 97.0 96.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL80 104.1 99.0 97.0 87.0 92.0 93.0 95.0 95.0   3310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL50 109.5 105.0 103.0 93.0 100.0 98.0 99.0 98.0   3310AL50 109.5 105.0 102.0 93.0 99.0 102.                                                                                                                                                                                                                                                                                                                                                                     | 109.0                                                                                                                                                                               |
| 3508AL80 127.5 116.0 117.0 116.0 123.0 120.0 120.0 114.0   3309AL40 106.3 103.0 100.0 87.0 95.0 95.0 94.0 95.0   3309AL50 108.1 104.0 102.0 91.0 98.0 96.0 97.0 96.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 104.1 99.0 97.0 87.0 92.0 53.0 95.0 95.0   3310AL60 104.1 99.0 97.0 87.0 92.0 53.0 95.0 95.0   3310AL60 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL50 109.5 105.0 103.0 93.0 100.0 98.0 99.0 98.0   3310AL60 108.7 103.0 102.0 93.0 99.0 106.0 98.0                                                                                                                                                                                                                                                                                                                                                                            | 100 -                                                                                                                                                                               |
| 3309AL40 106.3 103.0 100.0 87.0 95.0 95.0 94.0 95.0   5309AL50 108.1 104.0 102.0 91.0 98.0 96.0 97.0 96.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 104.1 99.0 97.0 87.0 92.0 53.0 95.0 95.0   3309AL80 104.1 99.0 97.0 87.0 92.0 53.0 95.0 95.0   3310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL50 109.5 105.0 103.0 90.0 97.0 98.0 99.0 98.0   3310AL60 106.7 103.0 102.0 93.0 99.0 100.0 98.0 93.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0 102.0                                                                                                                                                                                                                                                                                                                                                                             | 175 <b>5</b> °C-                                                                                                                                                                    |
| 5309AL50 108.1 104.0 102.0 91.0 98.0 96.0 97.0 96.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 107.4 103.0 100.0 90.0 97.0 97.0 98.0 97.0   3309AL60 104.1 99.0 99.0 90.0 94.0 94.0 98.0 99.0   3309AL80 104.1 99.0 97.0 87.0 92.0 53.0 95.0 95.0   3310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL50 109.5 105.0 103.0 93.0 100.0 98.0 99.0 98.0   3310AL60 108.7 103.0 102.0 93.0 99.0 100.0 98.0   3310AL70 109.0 103.0 100.0 93.0 97.0 98.0 102.0 102.0   3310AL70 109.0 103.0 100.0 93.0 97.0 98.0 102.0 102.0                                                                                                                                                                                                                                                                                                                                                                             | 92.0                                                                                                                                                                                |
| 3309AL60 107.4 103.0 100.0 90.0 97.0 98.0 97.0   3309AL70 106.7 102.0 99.0 90.0 94.0 94.0 98.0 99.0   3309AL80 104.1 99.0 97.0 87.0 92.0 53.0 95.0 95.0   3310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL50 109.5 105.0 103.0 93.0 100.0 98.0 99.0 98.0   3310AL60 108.7 103.0 102.0 93.0 99.0 100.0 98.0   3310AL70 109.0 103.0 100.0 93.0 99.0 102.0 102.0   3310AL80 106.9 101.0 98.0 90.0 96.0 97.0 98.0 102.0 102.0   3311AL40 113.0 109.0 105.0 95.0 104.0 102.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                              | 94.0                                                                                                                                                                                |
| 3509AL76 106.7 102.0 99.0 90.0 94.0 94.0 98.0 99.0   3309AL80 104.1 99.0 97.0 87.0 92.0 93.0 95.0 95.0   3310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL50 109.5 105.0 103.0 93.0 100.0 98.0 99.0 98.0   3310AL50 109.5 105.0 103.0 93.0 99.0 99.0 98.0   3310AL60 106.7 103.0 102.0 93.0 99.0 99.0 100.0 98.0   3310AL60 106.7 103.0 102.0 93.0 99.0 100.0 98.0   3310AL70 109.0 103.0 100.0 93.0 97.0 98.0 102.0 102.0   3310AL80 106.9 101.0 98.0 90.0 96.0 97.0 98.0 99.0   3311AL40 113.0 109.0 105.0 95.0 104.0 102.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                               | 94.0                                                                                                                                                                                |
| S319AC80 104.1 99.0 97.0 87.0 92.0 93.0 95.0 95.0 95.0   \$310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   \$310AL40 109.5 105.0 103.0 93.0 100.0 98.0 99.0 97.0   \$310AL60 106.7 103.0 102.0 93.0 99.0 99.0 98.0   \$310AL70 109.0 103.0 100.0 93.0 99.0 99.0 102.0 98.0   \$310AL80 106.9 101.0 98.0 90.0 96.0 97.0 98.0 102.0   \$311AL40 113.0 109.0 105.0 95.0 104.0 102.0 103.0 102.0   \$311AL20 113.3 109.0 105.0 96.0 104.0 103.0 102.0   \$311AL20 113.3 109.0 105.0 96.0 104.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                                                                        | 95.0                                                                                                                                                                                |
| 3310AL40 108.0 104.0 102.0 90.0 97.0 96.0 97.0 97.0   3310AL50 109.5 105.0 103.0 93.0 100.0 98.0 99.0 98.0   3310AL60 108.7 103.0 102.0 93.0 99.0 99.0 100.0 98.0   3310AL60 108.7 103.0 102.0 93.0 99.0 99.0 100.0 98.0   3310AL70 109.0 103.0 100.0 93.0 97.0 98.0 102.0 102.0   3310AL80 106.9 101.0 98.0 90.0 96.0 97.0 98.0 102.0 102.0   3311AL40 113.0 109.0 105.0 95.0 104.0 102.0 103.0 102.0   3311AL20 113.3 109.0 105.0 96.0 104.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 94.0                                                                                                                                                                                |
| 3310AL50 109.5 105.0 103.0 93.0 100.0 98.0 99.0 98.0   3310AL60 106.7 103.0 102.0 93.0 99.0 99.0 100.0 98.0   3310AL60 108.7 103.0 102.0 93.0 99.0 99.0 100.0 98.0   3310AL70 109.0 103.0 100.0 93.0 97.0 98.0 102.0 102.0   3310AL80 106.9 101.0 98.0 90.0 96.0 97.0 98.0 99.0   3311AL40 113.0 109.0 105.0 95.0 104.0 102.0 103.0 102.0   3311AL20 113.3 109.0 105.0 96.0 104.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 94.0                                                                                                                                                                                |
| 3310ALCO 108.7 103.0 102.0 93.0 99.0 99.0 100.0 98.0   3310AL70 109.0 103.0 100.0 93.0 97.0 98.0 102.0 102.0   3310AL80 106.9 101.0 98.0 90.0 96.0 97.0 98.0 99.0   3311AL40 113.0 109.0 105.0 95.0 104.0 102.0 103.0 102.0   3311AL20 113.3 109.0 105.0 96.0 104.0 105.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 96.0                                                                                                                                                                                |
| 3310AL70 103.0 103.0 100.0 93.0 97.0 98.0 102.0 102.0   3310AL80 106.9 101.0 98.0 90.0 96.0 97.0 98.0 99.0   3311AL40 113.0 109.0 105.0 95.0 104.0 102.0 103.0 102.0   3311AL50 113.3 109.0 106.0 96.0 104.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 96.0                                                                                                                                                                                |
| 3311AL80   108.9   101.0   98.0   90.0   96.0   97.0   98.0   99.0     3311AL40   113.0   109.0   105.0   95.0   104.0   102.0   103.0   102.0     3311AL50   113.3   109.0   106.0   96.0   104.0   103.0   102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 97.0                                                                                                                                                                                |
| 3511AL40   115.0   109.0   105.0   95.0   104.0   102.0   103.0   102.0     3311AL20   113.3   109.0   106.0   96.0   104.0   105.0   103.0   102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 98.0                                                                                                                                                                                |
| 5511A250 115.5 105.0 105.0 96.0 104.0 105.0 103.0 102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 99.0                                                                                                                                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 99.0                                                                                                                                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 99.0                                                                                                                                                                                |
| 33114180 109-9 103-0 101-0 93-0 101-0 101-0 104-0 104-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 99.0                                                                                                                                                                                |
| 3124145 145 3 142 5 150 6 150 5 100.0 101.0 102.0 102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 100.0                                                                                                                                                                               |
| 33124L40 115.5 112.0 109.0 100.0 107.0 106.0 105.0 105.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 101.0                                                                                                                                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 101.0                                                                                                                                                                               |
| <b>33124</b> 170 114.3 109.0 105.0 99.0 103.0 104.0 106.0 104.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 102.0                                                                                                                                                                               |
| 3312AL80 113.0 107.0 105.0 97.0 102.0 103.0 104.0 105.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 102.0                                                                                                                                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 103.0                                                                                                                                                                               |
| 3313AL50 119.9 117.0 112.0 104.0 109.0 109.0 109.0 109.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 102.0                                                                                                                                                                               |
| 3313AL60 118.5 115.0 111.0 103.0 109.0 109.0 107.0 405.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 102.0                                                                                                                                                                               |
| 3313AL70 116.4 112.0 108.0 102.0 105.0 105.0 108.0 107.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 103 0                                                                                                                                                                               |
| 3313AL80 115.3 110.0 107.0 100.0 105.0 106.0 106.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                     |

# DATA INCLUDES GROUND REFLECTION INTERFERENCE





D172





1)174

# HM-AP-42

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 5.2)

#### Remarks:

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The HM-AP-42 nozzle was one of a series of 37 tube nozzles that were tested to determine the effect of area ratio on jet noise characteristics. Tube length was varied from 1 inch to 7 inches with no significant differences noted in jet noise characteristics, see Reference D8. Other 37 tube nozzles with 12 spoke terminations on each tube that was tested in this series are:

| HM-AP-18  | AR | 4.65 |
|-----------|----|------|
| HM-AP-18a | AR | 8.0  |
| HM-AP-40  | AR | 3.33 |
| нм-ар-41  | AR | 4.0  |
| HM-AP-42  | AR | 5.2  |

See Reference D9.

HM-AP-42 Test Facility: Annex D (Cell #1) Nozzle and Microphone Heights are 20 Inches Date: lamb: R.H.:  $V_{\rm J}$  (Ideal)  $\frac{T_T}{T}$ Run No.  $P_T/P$ Nozzle 11 1158 2.6 1500°F 2400 fps HM-AP-42 Н 1159 3.0 11 2550 11 н 1126 1500°F " 2.6 4.1-Inch Round Convergent Nozzle 2400 fps H 1127 3.0 2550

Measured acoustic data is recorded in Reference D2.

# NOZZLE TEST DATA

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OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2/25:FT

HM-AP-42

| RUN NO.   | OASPL | 500    | -1K    | 2K                | 4K    | 8K     | 16K          | 32K   | -64K          |
|-----------|-------|--------|--------|-------------------|-------|--------|--------------|-------|---------------|
| H1158L40  | 113.3 | 108.0  | 103.0  | 96.0              | 105.0 | 106.0  | 105.0        | 102 0 | <u>ōà ō</u> * |
| H1158L50  | 115.1 | 109.0  | 105.0  | -96.0             | 108.0 | 107.0- | 107.0        | 102.0 | 102 0         |
| H1158L60  | 114.6 | 107.0  | 103.0  | -97.0             | 107.0 | -108.0 | 108.0        | 104-0 | 102.0         |
| H1158L70  | 114.2 | 105.0  | 101.0  | 95.0              | 106.0 | 108.0  | 108:0        | 105.0 | 102.0         |
| H1158L80  | 111.8 | 102.0  | 99.0   | 94.0              | 100.0 | 106.0  | 106.0        | 104.0 | 100 0         |
| H1159L40  | 116.4 | 111.0  | 106.0  | 99.0              | 108.0 | 110.0  | 108.0        | 104.0 | 101.0         |
| H1159L50  | 117.5 | 111.0- | 107.0  | 99.0              | 110.0 | 110.0  | 110.0        | 107.0 | 104.0         |
| H1159L60  | 116.1 | 109.0  | 105.0  | 99.0              | 109.0 | 109.0  | 109.0        | 106.0 | 101.0         |
| H1159L70- | 116.1 | 107.0  | 104.0  | 98.0 <sup>-</sup> | 108,0 | 110.0  | 110.0        | 106.0 | 103.0         |
| H1159L80  | 113.8 | 105.0  | 1.02.0 | 97.0              | 10Ć.O | 108.0  | 108.0        | 106.0 | 101.0         |
| H1126L40  | 133.6 | 127.0  | 130.0  | 123.0             | 126.0 | 121.0  | 117.0        | 111.0 | 111.0         |
| H1126L50  | 133.9 | 126.0  | 129.0  | 123.0             | 128.0 | 124.0  | 121.0        | 116.0 | 113.0         |
| H1126L60  | 129.1 | 122.0  | 123.0  | 119.0             | 123.0 | 120,0- | 118.0        | 112.0 | 106.0         |
| H1126L70  | 125.5 | 117.0  | 117.0  | 113.0             | 120.0 | 119.0  | <b>116.0</b> | 111.0 | 106.0         |
| H1126L80  | 121.4 | 113.0  | 112.0  | 110.0             | 116.0 | 115.0  | 112.0        | 107.0 | 100.0         |
| H1127L40  | 135.3 | 129.0  | 132.0  | 124.0             | 127.0 | 122.0  | 118.0        | 112.0 | 112.0         |
| H1127L50  | 135.4 | 127.0  | 130.0  | 125.0             | 130.0 | 125.0  | 123.0        | 118.0 | 115.0         |
| H1127L60  | 130.7 | 123.0  | 124.0  | 121.0             | 125.0 | 122.0  | 119.0        | 114.0 | 109.0         |
| H1127L70  | 127.9 | 119.0  | 118.0  | 116.0             | 122.0 | 122.0  | 119.0        | 114.0 | 109.0         |
| H1127L80  | 123.6 | 114.0  | 113.0  | 112.0             | 118.0 | 118.0  | 115.0        | 110.0 | 0.0           |

THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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D178

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BASE PLATE WITH-TUBES REMOVED

# HM-AP-43 NOZZLE

# (-37 TUBE HEXAGONAL ARRAY, AR3.33)

#### Description:

The HM-AP-43 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter base plate and were removeable.

Number of Elements: 37 tubes with round convergent ends Area Ratio: 3.33

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Exit Diameter: 0.674 inches

Material: 321 CRES







D181

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# HM-AP-43

(37 Tube Hexagonal Airay, AR = 3.33)

### Remarks

The HM-AP-43 nozzle was tested with several different tube lengths, see Reference D19. Nozzle configurations with effective tube lengths of 7 inches, 5 inches, 3 inches or 1 inch showed essentially no differences in jet noise characteristics.

A close-fitting unlined hexagonal ejector was tested with the HM-AP-43 nozzle, Ref. D22. The length of the ejector was six inches. PNL suppression with the ejector installed improved by 1.5 to 2.5 PNdB. The ejector was most effective at the lower pressure ratios (PR < 3.0) affecting the high frequency portion of the spectrum.

|                                              |                                        | н                                   | 1-AP-43                                          |                                                  | | | | | |
|---|---|---|---|---|---|---|---|---|---|
|                                              |                                        |                                     |                                                  | · · ·                                            |
|                                              | Test Fac                               | eility: Ann<br>No:                  | nex D<br>zzle and Micro                          | ophone Heights are 20 Inches                     |
|                                              | Date: N                                | farch 28, 19                        | 968                                              |                                                  |
|                                              | Tamb: r                                | not availab                         | le                                               |                                                  |
|                                              | R.H.: r                                | not availab                         | le                                               |                                                  |
| <u>Run No</u> .                              | PT/P                                   | TT                                  | V <sub>J</sub> (Ideal)                           | Nozzle                                           |
| 2867<br>2868<br>2869<br>2870<br>2871<br>2872 | 1.8<br>1.8<br>1.8<br>2.2<br>2.6<br>3.0 | 540°F<br>1000°F<br>1500°F<br>"<br>" | 1370 fps<br>1659<br>1923<br>2202<br>2402<br>2555 | HM-AP-43<br>"""""""""""""""""""""""""""""""""""" |
| 2873<br>2874<br>2875<br>2876<br>2877<br>2878 | 1.8<br>1.8<br>2.2<br>2.6<br>3.0        | 540°F<br>1000°F<br>1500°F<br>"<br>" | 1370 fps<br>1659<br>1923<br>2202<br>2402<br>2555 | 4.1-Inch Round Convergent Nozzle                 |
| 2867 L40             | UASPL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 500                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1K                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2K                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 4K                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 8K                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 10K                                                  | 32K                                                  | 64K-                                                 |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|
| 2867 L40             | 112.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                             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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | _                                                    |                                                      |                                                      |
| 2007 1 301           | 111-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 108.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 100.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 93.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 104.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 107.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 102.0                                                | 57.0                                                 | 53.                                                  |
| 2867 160             | 111+0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 107.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 101.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 94.U<br>04 D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 104.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                  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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 160.0                                                | 55.0                                                 | 53.                                                  |
| 2867 L70             | 109.9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 104.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 98.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 162.6                                                | 57.0                                                 | 53                                                   |
| 2867 L80             | 107.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 101.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 95.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 59.0                                                 | 55.0                                                 | 88.                                                  |
| 2868 L40             | 116.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 113.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 108.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 105.0                                                | 99.0                                                 | 54.                                                  |
| 2860 L50             | 117.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 114.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 111.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2868 160             | _117.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | _ 114.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 111.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              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| 2868 L70             | 1-15+3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 111.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 108.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 107.0                                                | 101.0                                                | 56.                                                  |
| 2569 140             | 112.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 102.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 104+0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2869 L50             | 117.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 111.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 104.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2869 LFO             | 110.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 111.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 106.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2865 L70             | 116.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 168.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 104.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 116.0                                                | 103.0                                                | 57.0                                                 |
| 2869 180             | 112.8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 105.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | .100.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           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| 2876 150             | 120.8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 114.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 108.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 114.0                                                | 168.0                                                | 168.0                                                |
| 287C L60             | 119.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 113.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 109.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 112.0                                                | 167.0                                                | 104.0                                                |
| 287C L70             | 119.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 111.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 107.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 287C L80             | 115.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 106.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 103.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2871 1.40            | 122-8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 118.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 113.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2871-150             | 122.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 117.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 112.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2871 170             | 121.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 112.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 109.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2871 L80             | 117.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 109.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 106.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2872 L40             | 125.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 121.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 117.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 116.0                                                | 110-0                                                | 107.0                                                |
| 2872 L50             | 124.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 120.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 115.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2012 LOU<br>2872 170 | 122.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2872 180             | 119 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 112.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 112_0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2873 L40             | 119.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 114.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 116.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 28~3 L50             | 116.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 113.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 110.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2873 L60             | 113.9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 109.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | .107.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           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| 2873 L70             | 112.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 107.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 104.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2072 100             | 109.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 103.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 101.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2874 L50             | 125.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 122-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 121.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2874 L60             | 120.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 116.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 115.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2874 L70             | 118.6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 114.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 112.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2874 L80             | _1.14+5 _                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 109.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 107.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2875 L40             | 126.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 121.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 121.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2015 150             | 125.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 120.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 121.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2875 LTO             | 119.8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 112-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 112.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2875 L80             | 116.3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2876 L40             | 130.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2876_L50_            | 129.7                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2876 L60             | 126.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 119.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 120.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            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| 2876 180             | 120-1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2877 L40             | 132.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2877 L50             | 132.8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2877 L60             | 129.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2877 1.80            | 122.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2878 L40             | 134.1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2878 L50             | 134.2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2878 L60             | 130.8                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 0000 100             | 128.5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 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| 2878 L70             | 3 3 4 -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |      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| -                    | 2867 L80<br>2868 L40<br>2868 L40<br>2868 L50<br>2868 L50<br>2868 L70<br>2869 L50<br>2869 L40<br>2869 L50<br>2869 L60<br>2869 L60<br>2869 L60<br>2870 L50<br>2870 L60<br>2871 L60<br>2871 L60<br>2871 L60<br>2871 L60<br>2871 L60<br>2872 L40<br>2872 L40<br>2872 L40<br>2873 L60<br>2873 L40<br>2873 L60<br>2873 L60<br>2873 L60<br>2873 L60<br>2873 L60<br>2873 L60<br>2874 L60<br>2875 L60<br>2876 L60<br>2876 L60<br>2877 L60 | 2867 $180$ $107.1$ $2867$ $180$ $107.1$ $2868$ $140$ $116.1$ $2868$ $150$ $117.4$ $2868$ $160$ $117.4$ $2868$ $170$ $115.3$ $21.8$ $180$ $112.4$ $2569$ $140$ $117.7$ $2869$ $140$ $117.7$ $2869$ $140$ $117.7$ $2869$ $140$ $117.7$ $2869$ $160$ $112.8$ $2870$ $160$ $112.8$ $2877$ $150$ $120.3$ $2876$ $140$ $122.8$ $2877$ $150$ $122.2$ $2871$ $140$ $122.8$ $2871$ $140$ $122.8$ $2871$ $140$ $122.2$ $2871$ $140$ $122.2$ $2871$ $140$ $122.2$ $2871$ $140$ $125.2$ $2871$ $160$ $117.3$ $2872$ $160$ $117.3$ | 2867 $100$ $107.1$ $101.0$ $2867$ $180$ $107.1$ $101.0$ $2868$ $140$ $116.1$ $113.0$ $2868$ $150$ $117.4$ $114.0$ $2868$ $170$ $114.0$ $2868$ $170$ $116.0$ $2868$ $170$ $116.0$ $2869$ $140$ $117.3$ $111.0$ $2869$ $140$ $117.3$ $111.0$ $2869$ $140$ $112.8$ $105.0$ $2870$ $120.3$ $114.0$ $2870$ $2870$ $120.3$ $114.0$ $2870$ $2870$ $120.3$ $114.0$ $2870$ $2870$ $120.3$ $114.0$ $2870$ $2871$ $140$ $122.8$ $118.0$ $2871$ $140$ $122.2$ $117.0$ $2871$ $160$ $121.2$ $117.0$ $2871$ $160$ $122.5$ $117.0$ $2871$ | 2867 $100$ $107.1$ $101.0$ $95.0$ $2864$ $140$ $116.1$ $113.0$ $108.0$ $2864$ $150$ $117.4$ $114.0$ $111.0$ $2864$ $150$ $117.4$ $114.0$ $111.0$ $2864$ $150$ $112.4$ $109.0$ $104.0$ $2567$ $140$ $117.3$ $111.0$ $106.0$ $2869$ $150$ $112.3$ $111.0$ $106.0$ $2869$ $160$ $112.7$ $110.0$ $106.0$ $2867$ $160$ $112.7$ $110.0$ $106.0$ $2867$ $160$ $112.7$ $110.0$ $106.0$ $2867$ $160$ $112.8$ $105.0$ $102.0$ $2867$ $160$ $112.8$ $105.0$ $102.0$ $2872$ $120$ $115.0$ $112.0$ $107.0$ $2871$ $140$ $122.2$ $117.0$ $112.0$ $2871$ $160$ $1$ | 2267 $100$ $101.0$ $95.0$ $90.0$ $2267$ $160$ $117.4$ $111.0$ $95.0$ $90.0$ $22668$ $150$ $117.4$ $114.0$ $111.0$ $97.0$ $2868$ $127.4$ $114.0$ $111.0$ $97.0$ $2168$ $180$ $112.4$ $109.0$ $104.0$ $93.0$ $2169$ $140$ $117.7$ $110.0$ $104.0$ $97.0$ $2169$ $140$ $117.7$ $110.0$ $104.0$ $97.0$ $2869$ $150$ $112.3$ $111.0$ $105.0$ $98.0$ $2869$ $150$ $112.3$ $111.0$ $105.0$ $98.0$ $2869$ $160$ $112.8$ $105.0$ $100.0$ $98.0$ $2869$ $160$ $112.8$ $105.0$ $100.0$ $98.0$ $2869$ $160$ $112.8$ $105.0$ $100.0$ $98.0$ $2876$ $120.3$ $114.0$ $108.0$ $100.0$ $2877$ $120.3$ $114.0$ $108.0$ $100.0$ $2877$ $140$ $122.3$ $118.0$ $113.0$ $102.0$ $2871$ $140$ $122.2$ $117.0$ $112.0$ $104.0$ $2871$ $160$ $121.2$ $117.0$ $112.0$ $104.0$ $2871$ $160$ $122.2$ $117.0$ $112.0$ $103.0$ $2871$ $160$ $122.2$ $117.0$ $112.0$ $103.0$ $2871$ $160$ $122.2$ $117.0$ $112.0$ $105.0$ $2872$ $160$ $122.5$ $122.0$ <td< td=""><td>2867       180       107.1       101.0       95.0       90.0       106.0         2868       140       116.1       113.0       108.0       92.0       104.0         2868       140       117.4       114.0       111.0       97.0       106.0         2868       107       115.3       111.0       108.0       97.0       105.0         2168       140       117.7       110.0       104.0       93.0       102.0         2169       147.7       110.0       104.0       93.0       108.0         2869       140       116.7       110.0       104.0       98.0       108.0         2865       170       116.1       168.0       104.0       98.0       108.0         2867       140       120.8       114.0       108.0       100.0       110.0         2872       120.8       114.0       109.0       101.0       112.0       104.0       112.0         2871       140       122.2       117.0       102.0       117.0       106.0       112.0       124.0       127.0         2871       140       122.2       117.0       102.0       113.0       122.0       113.0</td><td><math display="block">\begin{array}{cccccccccccccccccccccccccccccccccccc</math></td><td><math display="block">\begin{array}{cccccccccccccccccccccccccccccccccccc</math></td><td><math display="block">\begin{array}{cccccccccccccccccccccccccccccccccccc</math></td></td<> | 2867       180       107.1       101.0       95.0       90.0       106.0         2868       140       116.1       113.0       108.0       92.0       104.0         2868       140       117.4       114.0       111.0       97.0       106.0         2868       107       115.3       111.0       108.0       97.0       105.0         2168       140       117.7       110.0       104.0       93.0       102.0         2169       147.7       110.0       104.0       93.0       108.0         2869       140       116.7       110.0       104.0       98.0       108.0         2865       170       116.1       168.0       104.0       98.0       108.0         2867       140       120.8       114.0       108.0       100.0       110.0         2872       120.8       114.0       109.0       101.0       112.0       104.0       112.0         2871       140       122.2       117.0       102.0       117.0       106.0       112.0       124.0       127.0         2871       140       122.2       117.0       102.0       113.0       122.0       113.0 | $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | $\begin{array}{cccccccccccccccccccccccccccccccccccc$ |

D184



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### HM-AP-44 NOZZLE



### BASE PLATE WITH TUBES REMOVED

### ( 37 TUBE, HEXAGONAL ARRAY, AR 5.2

### Description:

The HM-AP-bh nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 5.2

Material: 321 CRES

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees Length of Tubes: 7 inches Tube Exit Diameter: 0.674 inches

PNL SUPPRESSION PNdB // 1500 FT SIDELINE 22 7 20 18 6 PNL SUPPRESSION (PNdB) 16 14 THRUST LOSS (%) 5 12 10 3 2 C -2 0 1600 1800 2000 2200 2400 2600 1400 2800 2 3 1 JET-VELOCITY (IDEAL) ~ FPS PRESSURE RATIO (P./P.) △ \_ △ 1500° F NOZZLE EXIT AREA (A.): 5.9 FT2 DATA INCLUDES GROUND REFLECTION INTERFERENCE

D186





HM-AP-44 NOZZLE

(37 Tube Hexagonal Array, AR 5.2)

### Remarks

The HM-AP-44 nozzle is one of a series of 37 tube hexagonal arrays to study the effect of area ratio on jet noise characteristics. The tubes in this series have round-convergent terminations. The HM-AP-44 nozzle was tested with various tube length configurations, e.g. 7, 5, 3 and 1 inches. Tube length had little effect on jet noise characteristics ((Ref. D19). Nozzles in this test series were:

| HM-AP-16  | AR 3.33 | (water  | cooled | base | plate) |
|-----------|---------|---------|--------|------|--------|
| HM-AP-37  | AR 4.65 |         |        |      |        |
| HM-AP-38  | AR 8.0  |         |        |      |        |
| HM-AP-39  | AR 4.0  |         |        |      |        |
| HM-AP-43  | AR 3.33 |         |        |      |        |
| HM-AP-44  | AR 5.2  |         |        |      |        |
| HM-AP-55A | AR 4.0  | (3000°F | model  | )    |        |
| HM-AP-55B | AR 5.2  | 11      | 11     |      |        |
| HM-AP-55C | AR 3.33 | tr      | ft     |      |        |

HM-AP-44 Test Facility: Nozzle and microphone heights are 20 inches. ate: Tamb: R. H.: P<sub>T</sub>/P VJ (Ideal)  ${
m T}_{
m T}$ Run No. Nozzle 1.8 111251 1500°F 1923 fps HM-AP-44 111252 2.6 11 2402 11 11 11 3.0 11253 2555 H1227 1.8 1500°F 1923 fps 4.1 Inch Round Convergent Nozzle 11 2402 H1228 2.6 11 11 11 H1229 3.0 2555

1.12

Measured acoustic data is recorded in Reference D2.

# HM-AP-44 NOZZLE TEST DATA

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|             |       | OCTAVE | BAND L | EVEL~dB | KE: U. | JULZ DINE | 3/ CM // 4 | ΥΓ1       |       |
|-------------|-------|--------|--------|---------|--------|-----------|------------|-----------|-------|
| RUN NO:     | OASPL | 500    | -1K    | 2K      | -4K    | 8K        | 16K        | 32K       | 64K   |
| 112271 40   | 123.7 | 118.1  | 119.9  | 1-11.7  | 116.5  | 109.2     | 104.9      | 98.3      | 96.6  |
| 1 2 2 71 50 | 124.2 | 118.7  | 119.6  | 112.5   | -117.5 | 111.3     | 107.1      | 100.8     | 99.4  |
| 1227560     | 121.6 | 114.8  | 114.8  | 109.7   | 116.7  | 112.6     | 108.5      | 103.4     | 98.2  |
| 11 2271 70  | 120.3 | 111.6  | 112.6  | 107.6   | 116.5  | 111.5     | 108.5      | 103.4     | 100.3 |
| 12271 80    | 116.2 | 107.9  | 107.9  | 104.9   | 111.9  | 107.9     | 104.9      | 100.9     | -95.9 |
| 11228140    | 134.4 | 128.0  | 130.0  | 123.0   | 128-0  | 122.0     | 119.0      | 114.0     | 113.0 |
| 112281 50   | 134.4 | 127.0  | 128-0  | 123.0   | 130.0  | 124.0     | 121.0      | 115.0     | 115.0 |
| 11228160    | 130.2 | 121.0  | 123.0  | 119.0   | 126.0  | 122.9     | 118.0      | 114.0     | 109.0 |
| 11228170    | 127.9 | 117.0  | 119.0  | 116.0   | 124.0  | 120.0     | 118.0      | 113.0     | 110.0 |
| 1228180     | 123.1 | 113.0  | 113.0  | 111.0   | 119.0  | 116.0     | . 113.0 _  | _ 110.0 _ | 105.0 |
| 11229140    | 135.4 | 130.0  | 131.0  | 124.0   | 128.0  | 123.0'    | 119.0      | 114.0     | 113.0 |
| 12291 50    | 136.0 | 129.0  | 130.0  | 125.0   | 131.0  | 125.0     | 122.0      | 117.0     | 117.0 |
| 12291-60    | 132.1 | 123.0  | 124.0  | 121.0   | 128.0  | 124.0     | 120.0      | 116.0     | 112.0 |
| 1229170     | 129.8 | 119.0  | 120.0  | 118.0   | 126.0  | 122.0     | 120.0      | 116.0     | 113.0 |
| 1229180     | 125.6 | 115.0  | .115.0 | 114.0   | 121.0  | 119.0     | 116.0      | 113.0     | 108.0 |
| 11251L40    | 118.0 | 104.0  | 102.0  | 98.0    | 112.0  | 113.0     | 112.0      | 107.0     | 103.0 |
| 1251150     | 119.1 | 105.0  | 103.0  | 99.0    | 113.0  | 114.0     | 113.0      | 109.0     | 105.0 |
| 1251160     | 120.6 | 104.0  | 101.0  | 98.0    | 114.0  | 116.0     | 115.0      | 110.0     | 105.0 |
| 1251170     | 116.7 | 101.0  | 99.0   | 96.0    | 110.0  | 111.0     | 111.0      | 108.0     | 105.0 |
| 11251180    | 112.7 | 99.0   | 96.0   | 93.0    | 106.0  | _106.0_   | 107.0 _    | 105.0     | 100.0 |
| 11252640    | 122.0 | 109.0  | 107.C  | 103.0   | 115.0  | 117.0     | 116.0      | 112.0     | 108.0 |
| 11252150    | 123.1 | 110.0  | 108.0  | 102.0   | 116.0  | 118.0     | 117.0      | 114.0     | 110.0 |
| 11252L60    | 124.7 | 109.0  | 107.0  | 103.0   | 118.0  | 120.0     | 119.0      | 114.0     | 110.0 |
| 11252170    | 121.8 | 106.0  | 104.0  | 100.0   | 114.0  | 116.0     | 117.0      | 113.0     | 110.0 |
| 11252180    | 118.0 | 104.0  | 100.0  | 97.0    | 110.0  | 111.0     | 113.0      | 111.0     | 106.0 |
| 11253140    | 123.4 | 112.0  | 109.0  | 104.0   | 117.0  | 118.0     | 117.0      | 113.0     | 109.0 |
| 11253L5Q    | 124.8 | 113.0  | 111.0  | 104.0   | 118.0  | 119.0     | 119.0      | 115.0     | 112.0 |
| 11253L60    | 125.0 | 112.0  | 110.0  | 105.0 - | 118.0  | 120.0     | 119.0      | 115.0     | 110.0 |
| 11253170    | 123.4 | 109.0  | 107.0  | 102.0   | 115.0  | 118.0     | 118.0      | 115.0     | 111.0 |
| 11253180    | 119.5 | 106.0  | 103-0  | 100-0   | 111.0  | 113.0     | 114.0      | 113.0     | 107-0 |

### CONTAVE RAND LEVEL - 48 PE. 0 0002 DYNES/CM2//25 FT

DATA INCLUDES GROUND REFLECTION INTERFERENCE



D192

ALL AND



### HM-AP-45 NOZZLE

### (36 SPOKES, AR 2.05)

### Description:

36 Spokes

Area Ratio (AT/AF): 2-06

Spoke Penetration: Varies from 60% to 90%

Flow Area: 28.3 inches<sup>2</sup>

Material: 321 CRES







FREE FIELD VALUES

HM-AP-45 NOZZLE (36 Spokes, AR 2.06)

### he marks

The  $h_1 - h_2 - h_2$  not the loses suppression rapidly as pressure ratio increases above 2.6. This shows up in a high rate of increase in Low frequency noise  $h_2$  pressure ratic increases, considered to be generated by the merging of adjacent jet efflux. The individual jets tend to merge close to the exit plane where considerable kinetic nergy is available in the flow, thus resulting in high values of shear, and turbulence, where the jets coalesce.

Other configurations of the HM-AP-45 nozzle included ejector installations. All ejectors were approximately 14-inches long (equivalent to 112-inches full scale). One ejector had an inside diameter to primary nozzle diameter (Ds/Dp) ratio of 1.2. The ejector was lined with fiber-glass batting for absorption of acoustic energy. This lined ejector resulted in 3 to 5 PNdB more suppression. Suppression in the last four octave bands was noted with the Ds/Dp = 1.2 lined ejector installed. When a hardwall ejector was installed only 2 to 3 PNdB additional suppression was evident.

A smaller ejector with a Ds/Dp = 1.0 was installed, alow No improvement was noted relative to the basic nozzle. See Reference D23. See Reference D24 for a comparison of model-scale and full-scale nozzle test results. HM-AP-45 NOZZLE

Test Facility: HNTF Date: July 15, 1968 T<sub>amb</sub>: 72°F R.H.: 37%

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| Run No. | P <sub>T</sub> /P <sub>∞</sub> | $\frac{T_{T}}{T}$ | VJ (Ideel) | Nozzle                         |
|---------|--------------------------------|-------------------|------------|--------------------------------|
|         |                                |                   |            |                                |
| 162.1   | 3.385                          | 977°F             | 2269 fps   | HM-AP-45                       |
| 162.2   | 3.003                          | 980               | 2173       | 11                             |
| 162.3   | 2.597                          | 972               | 2037       | 11                             |
| 162.4   | 2.203                          | 982               | 1880       | 11                             |
| 162.5   | 1.801                          | 977               | 1640       | "                              |
| 163.1   | 3.388                          | 1471              | 2645       | **                             |
| 163.2   | 2.997                          | 1463              | 2521       | 11                             |
| 163.3   | 2.591                          | 1458              | 2365       | "                              |
| 163.4   | 2.191                          | 1459              | 2142       | 11                             |
| 163.5   | 1.794                          | 1412              | 1870       | n                              |
|         |                                |                   |            |                                |
| 160.1   | 3.394                          | 1468              | 2644       | 6-inch Round Convergent Nozzle |
| 160.2   | 3.032                          | 1451              | 2524       | 11 11 11                       |
| 160.3   | 2.601                          | 1458              | 2369       | 11 11 11                       |
| 160.4   | 2.205                          | 1461              | 2178       | 11 11 11                       |
| 160.5   | 1.813                          | 1462              | 1911       | и п н                          |
| 161.1   | 3.410                          | 945               | 2248       | 11 11 11                       |
| 161.2   | 2.993                          | 944               | 2143       | 11 12 11                       |
| 161.3   | 2.618                          | 954               | 2032       | 11 11 11                       |
| 161.4   | 2.210                          | 950               | 1862       | 11 11 11                       |
| 161.5   | 1.803                          | 951               | 1626       | 11 11 11                       |

# HM-AP-45-NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM<sup>2</sup>//25 FT

|   | RUN:NO.   | OASPL    | 500    | ١K     | 2K        | 4K       | 8K      | 16K          | 32K   | 64K    |
|---|-----------|----------|--------|--------|-----------|----------|---------|--------------|-------|--------|
|   | 160.1L40  | 137.8    | 132.0  | 134.0  | 131.0     | 127.0    | 121.0   | 118.0        | 111.0 | 108-0- |
|   | 160.11.00 | 137.1    | 129.0  | 132.0  | 132.0     | 128.0    | 125.0   | 121.0        | 115.0 | 109-0  |
|   | 160.1160  | 133.1    | 123.0  | 127.0  | 128.9     | 120.0    | 123.0   | 120.0        | 114.0 | 197.0  |
|   | 160.;L70  | 129.0    | 113.0  | 122.0  | 124,0     | 123.0    | 122.0   | 119.0        | 115.0 | 106.0  |
|   | 160.1.40  | 128.9    | 118.0  | 121.0  | 124.0     | 123.0    | 120.0   | 115.0        | 106.0 | 98.0   |
|   | 160.2140  | 35.8     | 136.0  | 131.0  | 130.0     | 125.0    | 1.21.0  | 117.0        | 110.0 | 106.0  |
|   | 160.1.50  | 135.5    | 127.0  | 131.0  | 130.0     | 127.0    | 123.0   | 119.0        | 113.0 | 108.0  |
| Į | 160. 160  | 131.9    | 122.0  | 126-0  | 127.0     | 124.0    | 122.0   | 1.1.80       | 112.0 | 105-0  |
| 1 | 1n0.2170  | 127.7    | 117.0  | 120.0  | 122.0     | 121.0    | 123.0   | 116.0        | 112.0 | 103.0  |
|   | 160.2180  | 127.1    | 116.0  | 119.0  | 122.0     | 121.0    | 119.0   | 114.0        | 105.0 | 97.0   |
|   | 160.3L40  | 134.9    | 123.0  | 130.0  | 130.0     | 125.0    | 123.0   | 115.0        | 109.0 | 103.0  |
|   | 160.3L50  | 134.4    | 125.0  | 129.0  | 130.0     | 126.0    | 122.0   | 119.0        | 113.0 | 1.06.0 |
| ļ | 160.3160  | 129.1    | 119.0  | 123.0  | 124.0     | 122.0    | 113.0   | 115.0        | 109.0 | 102.0  |
|   | 100.3170  | 1-25 - 9 | 115.0  | 117.0  | 120.0     | 119.0    | 119.0   | 115.0        | 111.0 | 101.0  |
| ł | 160.3L80  | 127.5    | 116.0  | 118.0  | 122.0     | 122.0    | 120.0   | 116.0        | 108.0 | 99.0   |
|   | 160LuO    | 132.9    | 126.0  | 120.0  | 128.0     | 123.0    | 113.0   | 114.0        | 107.0 | 101.0  |
|   | 160.4150  | 131.2    | 123.0  | 127.0  | 126.0     | 121.0    | 113.0   | 114.0        | 107.0 | 101.0  |
|   | 160L60    | 126.8    | 118.0  | 121.0  | 121.0     | 119.0    | 115.0   | 112.0        | 106.0 | 98.0   |
|   | 160.4L70  | 122.8    | 113.0  | 115.0  | 117.0     | 116.0    | 115.0   | 111.0        | 107.0 | 97.0   |
| İ | 160.4L80  | 121.6    | 112.0  | 114.0  | 116.0     | 115.0    | 113.0   | 110.0        | 102.0 | 940    |
| ĺ | 160.⊋L40  | 128.4    | 123.0  | 124.0  | 123.0     | 115.0    | 103.0   | 103.0        | 95.0  | 92.0   |
| ļ | 160.0150  | 126.5    | 120.0  | 123.0  | 120.0     | 115.0    | 110.0   | 105.0        | 96.0  | 91.0   |
|   | 160.5L60  | 122.6    | 115.0  | 117.0  | 118.0     | 114.0    | 119.0   | 104.0        | 96.0  | 89.0   |
| 1 | 160.3170  | 119.3    | 110.6  | 113.0  | 114.0     | 112.0    | 110.0   | 105.0        | 100.0 | 89.0   |
|   | 160.ºL80  | 117.6    | 109.0  | 111.0  | 112.0     | 111.0    | 103.9   | 104.0        | 94.0  | 85.0   |
|   | 161.1140  | 136 -9   | 131.0  | 1.32-0 | 131.0     | 127.0    | 122.0   | 118.0        | 111.0 | 107.0  |
|   | 161.1L50  | 134.7    | 127.0  | 130.0  | 123.0     | 126.0    | 122.0   | 118.0        | 113.0 | 106.0  |
|   | 161.1160  | 132.1    | 122.0  | 126.0  | 127,0     | 125.0    | 122.0   | 118.0        | 112.0 | 106.0  |
| 1 | 161.1L70  | 128.ĉ    | 117.G  | 121.0  | 123.0     | 122.0    | 121.0   | 117.0        | 113.0 | 104.0  |
| I | 161.1130  | 123.6    | 117.0  | 121.0  | 123.0     | 123.0    | 120.0   | 116.0        | 109.0 | 101.0  |
|   | 161.2L4J  | 135.7    | 130.0  | 131.0  | 130.0     | 125.0    | 120.0   | 116.0        | 109.0 | 105.0  |
| I | 161.2150  | 132.5    | 125.0  | -128-0 | 127.0     | 123.0    | 120.0   | 116.0        | 109.0 | 103.0  |
| I | 161.2160  | 130.1    | 120.0  | 124.0  | 125.0     | 123.0    | 12).0   | 116.0        | 110.0 | 103.0  |
| I | 161.2L70  | 126.4    | 115.0  | 119.0  | 121.0     | 120.0    | 113.0   | 114.0        | 110.0 | 100.0  |
| I | 161.2180  | 126.9    | 116.0  | 119.0  | 122.0     | 121.0    | 113.0   | 113.0        | 105.0 | 96.0   |
| I | 161.3L40  | 133.8    | 127.0  | 129.0  | 129.0     | 123.0    | 113.0   | 114.0        | 106.0 | 102.0  |
| l | 161.3650  | 129.5    | 122.0  | 125.0  | 124.0     | 120.0    | 113.0   | 112.0        | 105.0 | 39.0   |
| l | 161.3160  | 126 -7   | 11.4.0 | 120.0  | 122.0     | 119.0    | 117.0   | 113.0        | 106.0 | 98.0   |
| I | 161.3L70  | 122.9    | 112.0  | 115.0  | 117.0     | 117.0    | 115.0   | 110.0        | 106.0 | 96.0   |
| ļ | 161.3L30  | 122.8    | 111.0  | 113.0  | 11/.0     | 118.0    | 115.0   | 110.0        | 102.0 | 93.0   |
| Į | 161.4L40  | 130.2    | 124.0  | 126.0  | 125.0     | 118.0    | 112.0   | 107.0        | 100.0 | 96.0   |
| l | 161.4L50  | 125.2    | 119.0  | 121.0  | 119.0     | 115.0    | 111.0   | 106.0        | 98.0  | 91.0   |
| ļ | 161.+L60  | 123.2    | 115.0  | 110.0  | 118.0     | 115.0    | 112.0   | 107.0        | 99.0  | 92.0   |
| l | 161L/U    | 119.4    | 110.0  | 1130   | 114.0     | 112.0    | 110.0   | 106.0        | 101.0 | 90.0   |
|   | 161.4L80  | 118.6    | 109.0  | 112.0  | 113.0     | 112.0    | 110.0   | 105.0        | 96,0  | 86.0   |
|   | 161.JL40  | 124.5    | 170.0  | 121.0  | 116.0     | 110.0    | 10+.0   | 99.0         | 90.0  | 88.0   |
|   | 161.0150  | 120.8    | 115.0  | 117.0  | 114.0     | 110.0    | 105.0   | 100.0        | 92.0  | 87.0   |
|   | 161.JL60  | 119.2    | 111.0  | 114.0  | 114.0     | 111.0    | 107.0   | 102.0        | 94.0  | 86.0   |
|   | 161.71/0  | 115.5    | 10/.0  | 109.0  | 110.0     | 108.0    | 105.0   | 101.0        | 96.0  | 84.0   |
|   | 191.250   | 114.4    | 100.0  | -1.080 | 109.0     | 10-7-0-0 | 1-050-  | - 1, U-0_o-0 | 91.0  |        |
| 2 |           |          |        | NUL    | I HESE AR |          | PID VAL | <b></b>      |       |        |

|                  |       | ۰<br>۶    |           |       |         |           |                |                    |               |
|------------------|-------|-----------|-----------|-------|---------|-----------|----------------|--------------------|---------------|
|                  |       |           | HM-       | AP-45 | NOZZLE  | TEST DAT  | A              |                    | · .           |
| RUN NO.          | OASPL | 500       | 1K        | 2K    | '4K     | 8K        | 16K            | 32K                | 64K           |
| 162.1140         | 130.5 | 127.0     | 126.0     | 121.0 | 118.0   | 11+.0     | 110.0          | 103.0              | 98.0          |
| 162.1150         | 125.3 | 120.0     | 120.0     | 118.0 | 116.0   | 11+.0     | 110.0          | 104.0              | 97.0          |
| <b>162.</b> 1L60 | 123.9 | 116.0     | 118.0     | 118.0 | 116.0   | 11+.0     | 111.0          | 105.0              | 97.0          |
| 162.1L70         | 120.2 | 112.0     | 113.0     | 114.0 | 112.0   | 112.0     | 109.0          | 106.0              | 97.0          |
| 162.1L80         | 118.6 | 112.0     | 111.0     | 111.0 | 111.0   | 110.0     | 108.0          | 102.0              | 93.0          |
| 162.2140         | 128.1 | 125.0     | -123.0    | 118.0 | 116.0   | 113.0     | 110.0          | 104.0              | 98.0          |
| 162.2L50         | 122.7 | 113.0     | 117.0     | 115.0 | 113.0   | 111.0     | 109.0          | 104.0              | 97 <b>.</b> Û |
| 162.2L60         | 121.5 | 114.0     | 115.0     | 115.0 | 114.0   | 112.0     | 110.0          | 104.0              | 98.0          |
| 162.2L70         | 118.5 | 111.0     | 111.0     | 112.0 | 110.0   | 110.0     | 108.0          | 105.0              | 98.0          |
| 162.2L80         | 110.4 | 116.0     | 100.0     | 109.0 | 109.0   | 163.0     | 106.0          | 100.0              | 93.0          |
| 162.L40          | 123.8 | 121.0     | 118.0     | 113.0 | 111.0   | 110.0     | 108.0          | 101.0              | 95.0          |
| 162.3L50         | 119.0 | 114.0     | 113.0     | 111.0 | 110.0   | 103.0     | 106.0          | 100.0              | 87.0          |
| 162.3L60         | 118.6 | 111.0     | 112.0     | 113.0 | 110.0   | 107.0     | 106.0          | 101.0              | 93.0          |
| 162.JL70         | 115.9 | 137.0     | 108.0     | 109.0 | 100.0   | 103.0     | 106.0          | 104.0              | 95.0          |
| 102.3180         | 114.1 | 107.0     | 106.0     | 107.0 | 106.0   | 105.0     | 105.0          | 98.0               | 91.0          |
| 162.4L40         | 119.8 | 117.0     | 113.0     | 109.0 | 107.0   | 107.0     | 107.0          | 101.0              | 95.0          |
| 162.4L50         | 115.8 | 110.0     | 1-09.0    | 108.0 | - 106.0 | 106.0     | 106.0          | 101.0              | 93.0          |
| 162.4L60         | 116.9 | 138.0     | 110.0     | 111.0 | 108.0   | 103.0     | 107.0          | 103.0              | 95.0          |
| 162.0L70         | 114.8 | 104.0     | 106.0     | 100.0 | 106.0   | 107.0     | 107.0          | 105.0              | 96.0          |
| 162.41.80        | 112.5 | 105.0     | 103.0     | 105.0 | 105.0   | 105.0     | 104.0          | 98.0               | 91.0          |
| 62. 2L40         | 113.5 | 111.0     | 106.0     | 103.0 | 101.0   | 101.0     | 101.0          | 93.0               | 85 . 0        |
| 62. JL 50        | 110.8 | 105.0     | 105.0     | 103.0 | 101.0   | 101.0     | 100.0          | 93.0               | 84 . 0        |
| 62.JL60          | 112.3 | 104.0     | 106.0     | 107.0 | 103.0   | 102.0     | 102.0          | 95.0               | 47.0          |
| 62.JL70          | 110.2 | 1)1.0     | 103.0     | 104.0 | 101.0   | 102.0     | 101.0          | 97.0               | 36.0          |
| 62.5180          | 108.2 | 101.0     | 100.0     | 101.0 | 100.0   | 100.0     | 100.0          | 91.0               | 82.0          |
| 63.1L40          | 135.1 | 130.0     | 131.0     | 128.0 | 123.0   | 113.0     | 115.0          | 109.0              | 1 04 0        |
| 63.1L50          | 129.6 | 124.0     | 125.0     | 122.0 | 120.0   | 119.0     | 114.0          | 1 08 0             | 102.0         |
| 63.1160          | 127.1 | -119.0    | 121.0     | 121.0 | 119.0   | 113.0     | 114.0          | 109.0              | 102.0         |
| 63.1170          | 123.4 | 11+0      | 116.0     | 117.0 | 116.0   | 115.0     | 113.0          | 110.0              | 100.0         |
| 63.1L30          | 121.3 | 114.0     | 113.0     | 115.0 | 114.0   | 113.0     | 110.0          | 103.0              | 95 0          |
| 63.2L40          | 131.7 | 128.0     | 127.0     | 123.0 | 120.0   | 110.0     | 112.0          | 105.0              | 100 0         |
| 63.2150          | 126.7 | 122.0     | 121.0     | 119.0 | 117.0   | 115.0     | 112.0          | 1 05 0             |               |
| 63.2160          | 124.7 | 117.0     | 114.0     | 119.0 | 117.0   | 115.0     | 112 n          | 107 0              | 39.0          |
| 63.2L70          | 121.5 | 113.0     | 114.0     | 115.0 | 114-0   | 113.0     | 111.0          | 107.0              | 99.0          |
| 63.21.80         | 118.6 | 112.0     | 1 1 1 - 0 | 112.0 | 111.0   | 110.0     | 107 0          | 107.0              | 90.0          |
| 63.31.40         | 127.7 | 125.0     | 122.0     | 117.0 | 115.0   | 113.0     | 111.0          | 100.0              | 92.0          |
| 63.31.50         | 123.7 | 119.0     | 118.0     | 115.0 | 114.0   | 113.0     | 110.0          | 104.0              | 90 · U        |
| 63.31.60         | 122.0 | 114.0     | 115.0     | 116.0 | 114.0   | 113.0     | 111 0          | 104.0              | 97.00         |
| 63.31.70         | 118.9 | 110.0     | 111.0     | 113.0 | 111.0   | 111 0     | 100 0          |                    | 90.0          |
| 63.31.80         | 116.8 | . 1       |           | 110.0 | 109.0   | 103.0     | 100.0          | 109.0              | 90.0          |
| 63.140           | 123.2 | 121.0     | 117.0     | 111.0 | 109.0   | 107.0     | 106 0          | 100+0              | 92.0          |
| 63.41.50         | 118.1 | 114.0     | 112.0     | 110.0 | 107.0   | 105.0     | 105.0          | 100+0              | 94.0          |
| 63.41.60         | 118.0 | 111.0     | 112.0     | 112.0 | 109.0   | 108.0     | 105.0          | 77.U               | 92.0          |
| 63.4170          | 116.0 | 107-0     | 108-0     | 110.0 | 108.0   | 107.0     | 100.0          | 1020               | 72.00         |
| 63.41.80         | 115.2 | 108.0     | 106-0     | 108.0 | 10710   | 107.0     | 107.0          | 100.0              | 93.0          |
| 63. 140          | 116-6 | . 114.0   | 169-0     | 105-0 | 104-0   | 1.0/0     | 105 0          | СЭ 0<br>Т 0 0 + 0  | 93.0          |
| 63.71.50         | 114.6 | 109.0     | 108-0     | 106.0 | 104.0   | 105.0     | 106 0          | 30+0<br>100 0      | 92.00         |
| 63.1.60          | 115.4 | 107.0     | 108.0     | 110.0 | 106.0   | 102.0     | 106 0<br>10000 | 1 0 0 0<br>1 0 0 0 | 92.00         |
| 63. jL70         | 114.3 | 103.0     | 105.0     | 108.0 | 106-0   | 106-0     | 107.0          | 1070               | 43 · U        |
| 63. LAN          | 112.9 | 194.0     | 103-0     | 105.0 | 104.0   | 104.0     | 107 0          | T N2 • N           | 34 • 0        |
|                  | ***** | A 7 T C U | 10090     |       | 1040    | T 0 2 4 0 | T U T • U      | 99.U               | 93.0          |

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NOTE: THESE ARE FREE FIELD VALUES

D199



and the particular states of the

HM-AP-45 WITH EJECTORS EJECTORS • P<sub>00</sub>  $L / D_{p} = 1.16$ EJECTOR • Pv THROAT GAP = 0.4 PRIMARY • Fr ĎΡ A<sub>S</sub>∕A<sub>B</sub>=0.45 ٨s C<sub>Fg</sub> = (THRUST-DRAG) MEASURED IDEAL PRIMARY THRUST (MASS FLOW) MEASURED  $C_D =$ ١ - DIV / CONV., D<sub>E</sub> / D<sub>P</sub> = 1.0 1.0 - CYLINDRICAL, DE / DP=1.0 Agen - CYLINDRICAL, DE/DP= 1.2 ( <sup>8</sup> 0.9 ၂ DISCHARGE COEFFICIENT (CD 3.31 0.63 1.72 THRUST COEFFICIENT 0.86 0.8 0.7 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0 PRESSURE RATIO (FT/Pcc) PRESSURE RATIO  $(P_T / P_{\infty})$ 0.9 BASE PRESSURE RATIO (PB/PV) ABID / AB THRUST COEFFICIENT (C<sub>F9</sub>) PRIMARY ALONE 3.11 1.72 0.86 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0 VENTILATION PARAMETER (AS/AB) PRESSURE RATIO (PT / Poo.)

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### -12201-



1)202



### Description:

The HM-AP-55-C nozzle is a 37-tube, area.ratio 3.33 nozzle intended for the acquisition of acoustic and performance data at gas total temperatures up to 3000°F. The tubes were fabricated from columbium material and coated with Cr-Ti-Si to resist oxidation at high temperatures. The tubes were inserted into a water-cooled baseplate and were removable.

Number of Elements: 37 tubes coated with round convergent ends

Area Estio: 3.33

Flow Area: 13-2 square inches

Exit Cant Angle: O degrees

Length of Tubes: 5.29 inches (effective)

Tube Exit Diameter: 0.674 inches

Material: Cr-Ti-Si coated columblum (tubes)



### D203



1)204



(37 Tube Hexagonal Array, AR = 3.33)

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### Remarks

This nozzle was designed to extend the multitube parametric study in the high jet velocity and total temperature (  $\geq 5000^{\circ}$ F) regions common to afterburning turbojet engines. Tests were conducted at the HNTF, Reference D25, and the GE JENOTS facility, Reference D26. The acoustic data acquired in either case indicated that instrumentation and facility problems existed at the high gas temperatures.

Higher suppression values, about 2 PNdB, were reported in Reference <u>D26</u>. Differences in temperature profile may have been responsible.

Three high temperature nozzle configurations were intended for this series:

HM-AP-55-A (37 Tubes, AR 4.0) HM-AP-55-B (37 Tubes, AR 5.2) HM-AP-55-C (37 Tubes, AR 3.33)

1)206

Test Facility: MNTF Date: August 13, 1968 T<sub>amb</sub>: 67°F R. H.: 75%

**3**84

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| Run No.                                                                                                                                                                                            | $P_{\Psi}/P_{\omega}$                                                                                                                                                                        | $\underline{\mathbf{T}_{\mathbf{T}}}$                                                                                                                                          | VJ (Ideal)                                                                                                                                               | Nozzle                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| 222.1<br>222.2<br>222.3<br>222.4<br>222.5<br>223.1<br>223.2<br>223.3<br>223.4<br>223.5<br>224.3<br>224.4<br>224.5<br>224.6<br>224.5<br>224.6<br>224.7<br>225.1<br>225.2<br>225.3<br>225.4<br>225.5 | 1.82<br>2.22<br>2.63<br>3.04<br>3.44<br>1.81<br>2.24<br>2.64<br>3.03<br>3.44<br>1.81<br>2.23<br>2.63<br>3.04<br>1.82<br>2.23<br>3.44<br>1.82<br>2.63<br>3.44<br>1.82<br>2.63<br>3.04<br>3.44 | 1568°F<br>1562<br>1574<br>1539<br>1623<br>2612<br>2722<br>2706<br>2712<br>2680<br>2158<br>2134<br>2081<br>2090<br>2058<br>2621<br>2585<br>2582<br>2585<br>2582<br>2596<br>2707 | 1983 fps<br>2255<br>2463<br>2626<br>2768<br>2454<br>3110<br>3299<br>3435<br>2260<br>2570<br>2771<br>2942<br>3062<br>2460<br>2802<br>3044<br>3238<br>3390 | HM-AP-55C<br>H<br>HM-AP-55C<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H<br>H |
| 218.1<br>218.2<br>218.3<br>218.4<br>218.5<br>219.1<br>219.2<br>219.3<br>219.4<br>219.5<br>220.1<br>220.2                                                                                           | 1.84<br>2.22<br>2.63<br>3.03<br>3.43<br>1.82<br>2.23<br>2.63<br>3.04<br>3.44<br>1.82<br>2.23                                                                                                 | 2677°F<br>2753<br>2768<br>2762<br>2893<br>1681<br>1704<br>1676<br>1702<br>1641<br>2121<br>2133                                                                                 | 2477 fps<br>2847<br>3119<br>3304<br>3502<br>2026<br>2329<br>2575<br>2690<br>2768<br>2223<br>2550                                                         | 4.1 Inch Round Convergent Nozzle                                                             |

| 220.3 | 2.64 | 2089 | 2758 | 4.1 Inch Round Convergent Noz. |
|-------|------|------|------|--------------------------------|
| 220.4 | 3.05 | 2051 | 2912 | 11                             |
| 220.5 | 3.44 | 2044 | 3040 | "                              |
| 221.1 | 1.82 | 2679 | 2468 | "                              |
| 221.2 | 2.23 | 2665 | 2809 |                                |
| 21.3  | 2.62 | 2540 | 3044 | 11<br>11                       |
| 221.4 | 3.04 | 2515 | 3230 | 11                             |
| 221.5 | 3.44 | 2546 | 3347 | И                              |

# HM-AP-55-C NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2//25-FT

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|   | RUN NO.     | OASPL          | 500    | 1K             | 2K     | 4K           | -8K   | 16K            | 32K            | 64K           |
|---|-------------|----------------|--------|----------------|--------|--------------|-------|----------------|----------------|---------------|
|   | 218.1L40    | 126.8          | 120.0  | 121.0          | _122.0 | 118.1        | 113.0 | 109.0          | 101.0          | -95 J         |
| - | 218.1L50    | 127.4          | 117.0  | 122.0          | 122.0  | 120.0        | 117.0 | 113.0          | 108.0          | 99 <b>.</b> ) |
|   | 218.1L60    | 126.9          | 114.0  | 120.0          | 123.0  | 120.0        | 116,0 | 113.0          | 105.0          | 97.0          |
|   | 218.1170    | 129.7          | 109.0  | 112.0          | 115.0  | 115.0        | 113.0 | 109.0          | <u>103.0</u>   | 93 <b>.</b> 0 |
|   | 217.1180    | 110.3          | 107.0  | 109.0          | 112.0  | 113.0        | 111.0 | 107.0          | 100.0          | 89.3          |
|   | 218.2140    | 128.6          | 122.0  | 124.0          | 123.0  | 119.0        | 115.0 | 110.0          | 105.0          | 96.0          |
|   | 218.2L50    | 129.5          |        | 124.0          | 125.0  | 121.0        | 118.0 | 114.0          |                | 101.1         |
|   | 218 2120    | 127 0          | 110.0  |                | 1-10-0 | 110 0        | 117 0 | 117 O          | 108 0<br>TTT 0 | 104.0         |
|   | 210+2170    | 122.6          |        | 112.0          | 116.0  | 117.0        | 116.0 | 113.0          | 106.0          | 07.0          |
|   | 218.3140    | 130.4          | 125.0  | 125.0          | 125.0  | 120.0        | 115.0 | 111.0          | 103.0          | 94.0          |
|   | 21.8.31 5.0 | 13-1.8         | 1.22.0 | 127.0          | 127.0  | 123.0        | 120.0 | 110.0          | 112.0          | 104.0         |
| - | 218.3160    | 13.4           | 119.0  | 125.0          | 129.0  | 128.0        | 124.0 | 120.0          | 114.0          | 107.]         |
| l | 218.3170    | 120.6          | 113.0  | 117.0          | 121.0  | 121.0        | 119.0 | 116.0          | 110.0          | 103.0         |
|   | 218.3180    | 125.J          | 113.0  | 114.0          | 118.0  | 119.0        | 119.0 | 116.0          | 109.0          | 101. J        |
|   | 218.4149    | 132.5          | 127.0  | 128.0          | 127.0  | 121.0        | 117.0 | 113.0          | 105.0          | 100.0         |
|   | 218.4L50    | 133.4          | 124.0  | 129.0          | 128.0  | 124.0        | 122.0 | 118.0          | 114.0          | 105.0         |
|   | 218.4L60    | 135.4          | 120,0  | 128.0          | 131.0  | 130.0        | 125.0 | 122.0          | 115.0          | 109.0         |
|   | 218.4L70    | 128.0          | 114.0  | 118.0          | 122.0  | 123.0        | 121.0 | 117.0          | 111.0          | 104.0         |
|   | 218.4180    | 125.9          | 113.0  | 115.0          | 119.0  | 122.0        | 121.0 | 118.0          | 111.0          | 102.9         |
|   | 218.5140    | - 0.0          | -U.U   | -U.U           | -U.U   | -0.0         | -0.0  | -0.0           | 0.0-           | -0.0          |
|   | 218.5150    | 134.4          | 120.0  | 130.0          | 129.0  |              |       | 118.0          | 112.0          | 100.0         |
|   | 210.5L00    | 120 0          | 121.0  | 120.0          | 122.0  | 124 0        | 122.0 | 140 0          |                | 106 0         |
|   | 218.5180    | 128.3          | 115.0  | 116.0          | 120.0  | 124.0        | 123.0 | 110.0          | 114.0          | 105.0         |
|   | 219.1140    | 125.3          | 118.0  | 120.0          | 122.0  | 117.0        | 112.0 | 106.0          | 99.0           | 94.1          |
|   | 219.11.50   | 123.4          | 114.0  | 119.0          | 118.0  | 115.0        | 111.0 | 106.0          | 102.0          | 92.1          |
|   | 219.1L60    | 119.7          | 109.0  | 114.0          | 115.0  | 112.0        | 109.0 | 106.0          | 98.0           | 88.0          |
|   | 219.1L70    | 115.5          | 104.0  | 107.0          | 116.0  | 110.0        | 108.0 | 103.0          | 97.0           | 87.J          |
|   | 219.1L80    | 114.8          | 104.0  | 106.0          | 199.0  | 109.0        | 107.0 | 104.0          | 96.0           | 85.3          |
|   | 219.2L40    | 129.4          | 121.0  | 124.0          | 12:0   | <u>121.U</u> | 116.0 | 112.0          | 105.0          |               |
|   | 219.2150    | 123.6          | 117.0  | 123.0          | 124.0  | 121.0        | 118.0 | 113.0          | 109.0          | 100.0         |
|   | 219.2LbU    | 129.4          | 113.0  | 119.0          | 121.0  | 118.0        | 115.U | 113.0          | 105.0          | 9/.1          |
|   | 210 2180    | 1187           | 107.0  | 100.0          | 112.0  | 117.0        | 112.0 | 109.0          | 1020           | 01 0          |
|   | 219.3148    | 139.6          | 123.0  | 126.0          | 126.0  | 120.0        | 116.0 | 113.0          | 106.0          | 101.0         |
|   | 219.3150    | 130.6          | 119.0  | 125.0          | 126.0  | 123.0        | 120.0 | 116.0          | 113.0          | 104.0         |
|   | 219.3160    | 128.4          | 115.0  | 121.0          | 124.0  | 122.0        | 119.0 | 11.0           | 110.0          | 102.0         |
|   | 219.3L70    | 123.2          | 109.0  | 113.0          | 117.0  | 118.0        | 116.0 | 113.0          | 107.0          | 99.0          |
|   | 219.3180    | 122.2          | 109.0  | 111.0          | 115.0  | 117.Ù        | 116.0 | 113.0          | 105.0          | 96.0          |
|   | 219.4L40    | 132.7          | 125.0  | 127.0          | 127.0  | 126.0        | 120.0 | 115.0          | 109.0          | 105.0         |
|   | 219.4L50    | 133.3          | 122.0  | 127.0          | 128.0  | 127.0        | 123.0 | 119.0          | 116.0          | 107.0         |
|   | 219.4160    | 132.2          | 118.0  | 125.0          | 127.0  | 126.0        | 123.0 | 121.0          | 115.0          | 108.)         |
|   | 219.4L70    | 120.2          | 112.0  | 11/.9          | 120.0  | 121.0        | 119.0 | 115.0          | 109.0          | 101.0         |
|   | 219.4L80    | 125.2          | 112.0  | 115.0          | 118.0  | 120.0        | 119.0 | 115.0          | 108.0          | 99.0          |
|   | 213.5140    | 13341          | 127.0  | 120.0          | 120.0  | 107 0        | 110.0 | TT2.0          | 112.0          | <u>104.</u>   |
|   | 219.9L9U    | 13400<br>132 に | 123+0  | 129•U<br>126 D | 150.0  | 126.0        | 124+0 | 119•U<br>110 D | 112•U<br>117 D | 104 0         |
|   | CT201C01    | IJC • ···      | TT 200 | 120.0          | .150.0 | TCOOU        | TCCOU | TT200          | TT2+0          | T00.0         |

NOTE: THESE ARE FREE FIELD VALUES

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|                                  |          |                |                      |                      | -                |                  |                          |                |                  |
|----------------------------------|----------|----------------|----------------------|----------------------|------------------|------------------|--------------------------|----------------|------------------|
|                                  |          |                | HM-A                 | AP-55-C              | NOZZLE           | TEST DA          | TA                       |                |                  |
| RUN NO.                          | OASPL    | 500            | 1K                   | 2K                   | 4K               | 8K               | 16K                      | 32K            | 64K              |
| 219.5LZ0                         | 127.4.   | 114.0          | 119.0                | 121.0                | 121.0            | 120.0            | 115.0.                   | 110.0          | 103.             |
| 2.9.9100                         | 120.9    | 114.0          | 11/00                | 121.0                | 140 0            | 140.0            |                          | 110.0          | 101.             |
| 220,1150                         | 127.0    | 115.0          | 121.0                | 122.0                | 119.0            | 116.0            | 112.0                    | 103.0          | 97.0             |
| 220.1L60                         | 123.0    | 111.0          | 117.0                | 119.0                | 115.0            | 112.0            | 113.0                    | 102.0          | 94.0             |
| 220.1L70                         | 117.3    | 1.05.0         | 109.0                | 112.0                | 112.0            | 111.0            | 197.0                    | 101.0          | 91.0             |
| 220.11°0                         | 112.4    | 104.0          | 105.0                | 199.0                | 110.0            | 108.0            | 105.0                    | 97.0           | 87.0             |
| 220.2140                         | 1: 3.8   | 121.0          | 124.0                | 124.0                | 119.0            | 115.0            | 110.0                    | 102.0          | 97.0             |
| 220-21-20                        | 1 - 5-•9 | 118.0          | 124.0                | 124.0                | 121.0            | 118.0            | 113.0                    | 109.0          | <del>3</del> 9.9 |
| 220.2160                         | 1 0.0.5. |                | 120.0                | .122.0.              | 120.0            | (1160            | 113.0                    | 102.0.         | 97               |
| 223.2180                         | 118.9    | 100.0          | 113.0                | 112-6                | 113.0            | 114.0            | 110.0                    | 104.0          | 96.0             |
| 220.3140                         | 130.3    | 124.0          | 126.0                | 1 16.0               | 120.0            | 116.0            | 110.0                    | 102.0          | 100.0            |
| 220.3150                         | 131.4    | 121.0          | 126.0                | 127.0                | 123.0            | 120.0            | 115.0                    | 112.0          | 103.0            |
| 220.3160                         | 123.6    | 115.0          | 122.0                | 125.0                | 124.0            | 120.0            | 115.0                    | 109.0          | 102.0            |
| 220+3L70                         | 123.2    | 110.0          | 114.0                | 117.0                | 118.0            | 116.0            | 112.0                    | 106.0          | 98.0             |
| 220.3180                         | 122.1    | 110.0          | 111.0                | 115.0                | 117.0            | 1.6.0            | 112.0                    | 105.0          | 95.0             |
| 220 41 40                        | 177 7    | 127 0          | 127 0                | 120.0                | 121.0            | 11/0             | 111.0                    | 104.0          | 101.3            |
| 220.4160                         | 131.4    | 117.0          | 124.0                | 127.0                | 125.0            | 122.0            | 113.0                    | 114.0          | 105.0            |
| 220.4L70                         | 126.2    | 112.0          | 117.0                | 120.0                | 121.0            | 119.D            | 115-0                    | 109.0          | 102.0            |
| 220.4L80                         | 124.7    | 111.0          | 114 . U              | 118.0                | 119.0            | 118.0            | 116.0                    | 109.0          | 100.0            |
| 220.5140                         | 134.1    | 128.0          | 129.0                | 131.0                | 122.0            | 118.Û            | 113.0                    | 105.0          | 102.0            |
| 220.5L50                         | 24.3     | 124.0          | 129.0                | 130.0                | 126.0            | 122.0            | 115.0                    | 114:C          | 106.J            |
| 220.566                          | 127 1    | 119.0          | 120.0                | 126.0                | 127.0            | 123.3            | 120.9                    | 113.0          | 106.0            |
| 220,5180                         | 127.8    | 113.0          | 115 0                | 119 0                | 126+U<br>126-0   | 120.0            | 11r.U                    |                | 103.9            |
| 221.1L40                         | 125.8    | 120.0          | 121.0                | 122.0                | 118.0            | 113.0            | 103.0                    | 101.0          |                  |
| 221.11=0                         | 125.6    | 117.0          | 121.0                | 122.0                | 119.0            | 115.0            | 110.0                    | 106.0          | 97.9             |
| 221.160                          | 124.5    | 112.0          | 118.0                | 121.0                | 118.0            | 11.4.0           | 111.0                    | 103.0          | 95 J             |
| 221.1176                         | 119.1    | 107.0          | 111.0                | 117.0                | 113.0            | 112.0            | 100.0                    | 1.1.0          | 92.J             |
| 221.1180                         | 117.2    | 136.0          | 107.0                | 111.0                | 112.0            | 110.0            | 106.0                    | 98.0           | 87.0             |
| 221.2140                         | -0.0     | -0.0           | -0.0                 | -0.0<br>0.0          | -0.0             | ~0.0             | -0.0                     | ~0.0           | -0.0             |
| 221.2160                         | ± U.o U  |                | - <u>11 - 11 - 1</u> | ∽ <u>⊾∍⊔</u><br>~C.0 | لاملات.<br>۱۰.۱۰ | انملات<br>۲۰۵۰ م | _ للملا <u>ت</u><br>م. م | <u> 11-</u> 10 |                  |
| 221.2170                         | - Ŭ. Û   | -0.0           | -0.0                 | -0.0                 | -0.ŭ             | -0.0             | - ù . O                  | -0.0           | -0.0             |
| 221.2180                         | - 8.0    | -0.0           | -0.0                 | -8.0                 | -0.0             | -U.J             | -0.0                     | -0.0           | -0.0             |
| 221.3L40                         | 130.7    | 125.0          | 126.0                | i25.0                | 120.0            | 116.0            | 111.0                    | 104.0          | 99.0             |
| 221.3L50                         | 131.5    | 122.0          | 126.0                | 127.0                | 123.0            | 120.0            | 11'.0                    | 111.0          | 103.)            |
| 221,3L60_                        | _131.7   | _117_0_        | 124.1                | 127.0                | 126.0            | 122.0            | 120.0                    | 113.0          | 10021            |
| 221.3170                         | 107:1    |                | 11200                | 119:0                | 146 3            | 110.0            | 114.0                    | 109.0          | 102.3            |
| 221 · JENE<br>221 - 41 40        | 132.7    | 127.0          | 128-0                | 127.0                | 122.B            | 118.0            | 117 N                    | 105 U<br>106 0 | 99.9<br>100 1    |
| 221.4150                         | 133.3    | 124.0          | 129.0                | 128-0                | 124.0            | 121-0            | 117.0                    | 113-0          | 106.0            |
| 221.4166                         | 133.6    | 119.0          | 126.0                | 129.0                | 128.0            | 124.0            | 120.0                    | 113.0          | 107.0            |
| 221.4170                         | 127.0    | 113.0          | 117.0                | 121.0                | 122.0            | 120.0            | 115.0                    | 109.0          | 102.0            |
| 221.4L80                         | 125.0    | 112.0          | 114.0                | 117.0                | 120.0            | 119.0            | 116.0                    | 109.0          | 100.0            |
| 221.5L40                         | 133.5    | 128.0          | 129.0                | 127.0                | 123.0            | 119.0            | 115.0                    | 109.0          | 103.0            |
| <u> イイエ・コレフリ</u>                 | 136 O    | 120 0<br>120 0 | 107 n                | 124.0                | 120 0            | 1250             | 1 <u>19</u> 0            | 115.0          | 106.0            |
| 221 6160                         | 1        |                | 171411               | エンエッロ                | エビコ・ロ            | イビンチル            | لەكك⊥                    | 110,0          | T0.2°0           |
| 221.51.70                        | 128.5    | 114.0          | 119.0                | 122.0                | 123.0            | 122 0            | 110 0                    | 117 0          | 104 0            |
| 221.5L60<br>221.5L70<br>221.5L80 | 128.5    | 114.0<br>113.0 | 119.0<br>115.0       | 122.0                | 123.0<br>123.0   | 122.0<br>122.0   | 118.0<br>118.0           | 113.0<br>111.0 | 106.0            |

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D210

|   |                       |                  |                | HM-AI          | P-55-C                | NOZZLE                 | TEST DAT       | ΓA             |                       | -            |
|---|-----------------------|------------------|----------------|----------------|-----------------------|------------------------|----------------|----------------|-----------------------|--------------|
|   | RUN NO.               | OASPL            | 500-           | ١K             | 2К                    | 4K                     | 8K             | 16K            | 32K                   | 64K          |
|   | 222.1L40<br>222.1L50  | 112.6<br>112.5   | 102.0<br>100.0 | 100.0<br>99.0  | 39.0<br>39.0          | 102.0<br>102.0         | 109.0<br>109.0 | 106.0<br>106.0 | 101.0<br>102.0        | 92.J<br>91.J |
|   | 222.1L60              | 111.3            | 97.0           | 97.0           | 170.0                 | 104.0                  | 107.0          | 105.0          | 99.0                  | 89.0         |
|   | 222.1L70<br>222.1180  | 110.5            | 95.0<br>97.0   | 95.0<br>95.0   | 97.0<br>96.0          | 103.0                  | 106.0          | 105.0          | 99.0<br>99.0          | 91+0<br>89-1 |
|   | 222.2140              | 117.0            | 109.0          | 106.0          | 104.0                 | 105.0                  | 112.0          | 111.0          | 10.3.0                | 37.0         |
|   | 222.2L50              | 110.7            | 105.0          | 104.0          | 103.0                 | 106.0                  | 112.0          | 111.0          | 108.0                 | 97.0         |
| - | 222.2160              | 115.2            | 102.0          | 102.0          | 104.0                 | 107.0                  | 111-0          | 1-0-9.0        | 102.0                 | 94.0         |
|   | 222.2L70              | 113.5            | 100.0          | 100•0<br>99•0  | 100.0                 | 106.0                  | 108.0          | 107.0          | 102.U<br>103.0        | 94.0<br>94.0 |
|   | 222.3L40              | 119.2            | 114.0          | 112.0          | 108.0                 | 107.0                  | 112.0          | 111.0          | 104.0                 | 96.0         |
|   | 222.3150              | <u>117,8</u>     | 109.0          | 108.0          | 116.0                 | 107.0                  | 113.0          | 111.0          | 106.0                 | 94.0         |
|   | 222.31.70             | 115.3            | 103.0          | 106.0          | 10/.0                 |                        |                | 110.0          | 102.0                 | 93.9<br>94.0 |
|   | 222.3180              | 114.5            | 104.0          | 102.0          | 103.0                 | 1.05.0                 | 109.0          | 109.0          | 194.0                 | 94.0         |
|   | 222.4640              | 122.1            | 118.0          | 117.0          | 111.0                 | 108.0                  | 112.0          | 111.0          | 103.0                 | 96.0         |
|   | 222.4150              | 119.1            | 113.0          | 112.0          | 109.0                 | 108.0                  | 112.0          | 110.0          | 107.0                 | 95.j         |
|   | 222.4L60<br>222.4176  | 117.4<br>116.2   | 197.0          | 108.0          | 109.0                 | 109.0                  | 111.0          | 111.0          | 104.0                 | 95.J         |
|   | 222.4L80              | 110.2            | 106.0          | 105.0          | 105.6                 | 105.0                  | 110.0          | 109.0          | 104.0                 | 96.J         |
|   | 222.5140              | 125.3            | _121.eU        | 121.0          | 116.0                 | 111.1                  | 113.0          | 111.0          | 104.0_                | 9/.0         |
|   | 222.5150              | 121.7            | 116.0          | 116.0          | 113.0                 |                        | 113.0          | 112.0          | 109.0                 | 98°0         |
|   | 222.5170              | 119.5            | 109.0          | 107.0          | 106.0                 | 111.0<br>111.9         | 112.0<br>112.0 |                | 105.0                 | 96.0         |
|   | 222.5L80<br>223.11.40 | 117.3            | 108.0          | 107.0          | 107.0                 | 109.0                  | 111.0          | 111.0          | 106.0                 | 97.0         |
|   | 223.1L50              | 115.0            | 105.0          | 103.0          | 10.0                  | 104.0                  | 112.0          | 109.0          | 105.0                 | 95.0         |
|   | 223.1L60              | 114.2            | 103.0          | 102.0          | 192.0                 | 105.0                  | 110.0          | 108.0          | 102.0                 | 93.9         |
|   | 223.1L70<br>223.1L80  | 113.0<br>112.9   | 101.0<br>101.0 | 100.0<br>99.0  | 1]1.)<br>99.0         | 105.0<br><u>16</u> 3.0 | 139.0<br>109.0 | 10-•0<br>107•0 | 101.0<br>102.0        | 92.0<br>93.0 |
|   | 223.2L40<br>223.2L50  | $119.1 \\ 118.1$ | 115.0<br>111.0 | 112.0<br>109.0 | 107.0<br>10F.G        | $106.0 \\ 106.0$       | 112.0<br>113.0 | 109.0<br>110.0 | 102.0<br>107.0        | 93.0<br>96.J |
|   | 223.2160              | 115.3            | 107.0          | 106.0          | 106.0                 | 108.0                  | 112.0          | 110.0          | 103.0                 | _94.1        |
|   | 223.2L70              | 115.4            | 105.0          | 104.0          | 105.0                 | 109.0                  | 112.0          |                | 104.0                 | 96.0         |
|   | 223.3L40              | 124.2            | 120.0          | 119.0          | 113.0                 | 110.0                  | 115.0          | 112.0          | 105.0                 | 96.0         |
|   | 223.3150              | 120.5            | 115.0          | 113.0          | 110.0                 | 109.0                  | 114.0          | 111.0          | 107.0                 | 97.9         |
|   | 223.3L60<br>223.3L70  | 118.8            | 110.0<br>106.0 | 110.0<br>107.0 | 110.0<br><u>107.0</u> | 110.0<br>110.9         | 113.0<br>112.0 | 111.0          | 104.0<br><u>103.0</u> | 95.0         |
|   | 223.3L80<br>223.4L40  | 116.8<br>127.3   | 108.0<br>123.0 | 106.0<br>123.0 | 106.0<br>118.0        | 108.0<br>113.0         | 111.0<br>115.0 | 110.0<br>113.0 | 106.0                 | 97.0<br>96.0 |
|   | 223.4L50              | 123.4            | 118.9          | 118.0          | 114.0                 | 112.0                  | 115.0          | 112.0          | 107.0                 | 96.0         |
|   | 223.4L60              | 120.3            | 111.0          | 113.0          | 113.0                 | 112.0                  | 113.0          | 112.0          | 104.0                 | 95.0         |
|   | 223.4170              | 118.7            | 110.0          | 109.0          | 138.0                 | 112.0                  | 113.0          |                | 104•0<br>106.0        | 96.9         |
|   | 223.5L40              | 129.7            | 125.0          | 126.0          | 121.0                 | 116.0                  | 116.0          | 113.0          | 105.0                 | 97.0         |
|   | 223.5150              | 126.3            | 121.0          | 122.0          | 118.0                 | 114.0                  | 115.0          | 112 0          | 108.0                 | <b>98.</b> 0 |
|   | 223.5160              | 123.0            | 115.0          | 116.0          | 116.0                 | 115.0                  | 115.0          | 113.0          | 106.0                 | .98.0        |
|   | 223.5180              | 119.E            | 111.0          | 110.0          | 110.0                 | 111.0                  | ⊥⊥4•U<br>114•N | 112.0          | 107.0                 | 90.U         |
|   | 224.3140              | 116.0            | 106.0          | 103.0          | 101.0                 | 105.0                  | _112.0         | 110.0          | 104.0                 | 98.0         |
|   | 224.3L56              | 115.5            | 104.0          | 102.0          | 191.0                 | 105.0                  | 112.0          | 109.0          | 105.0                 | 95.0         |
|   |                       |                  | N              | OTE: THE       | SE ARE FR             | REE FIELD              | VALUES         |                |                       |              |

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|------------------|--------------|----------------|--------|--------------|--------------|------------------------------|--------|----------------|----------------|
|                  |              |                | HM-A   | P- 55-C      | NOZZLE       | TEST DA                      | ТА     |                |                |
| RUN NO.          | OASPL        | 500            | ١K     | 2K           | 4K           | 8K                           | 16K    | 32K            | 64K            |
| 224.3LF0         | 114.8        | 101.0          | 101.0  | 192.9        | 106.0        | 111.0                        | 109.0  | 102.0          | 93.0           |
| 224.3170         | 114.2        | 99.0           | 99.0   | 191.0        | 106.0        | 110.0                        | 108.0  | 104.0          | 96.0           |
| 224.3180         | 112.9        | 100.0          | 98.0   | 39.0         | 103.0        | 109.0                        | 107.0  | 103.0          | 94.9           |
| 224.4146         | 118.7        | 113.0          |        | 105.0        | 106.0        | 113.0                        | 111.0  | 105.0          | 97.0           |
| 221 4150         |              | 109.0          | 105 0  | 114.0        |              |                              | 111.0  | 105 0          | <u> 18 - 1</u> |
| 224.4100         | 115.5        | 112.1          | 102.0  | 133.0        | 107 0        | 111 0                        | 100.0  | 105.0          | 90.J           |
| 224.4680         | 115.6        | 104.0          | 102.0  | 132.0        | 105.0        | 111.0                        | 110.0  | 105.0          | 98.0           |
| 224.5140         | 122.0        | 117.0          | 116.0  | 111.0        | 109.0        | 114.0                        | 112.0  | 105.0          | 102.]          |
| 224.5150         | 119.1        | 112.0          | 111.0  | 108.0        | 108.0        | 113.0                        | 111.0  | 109.0          | 98.j           |
| 224.5L60         | 113.3        | 107.0          | 108.0  | 139.0        | 109.0        | 113.0                        | 112.0  | 106.0          | 98.0           |
| 224.5L7C         | 117.5        | 105.0          | 106.0  | 116.0        | 110-0        | 113.0                        | 110.0  | 106.0          | 99.0           |
| 224-0260         | 12/04        | 101-0<br>101-0 | 100 U  | 142+0        | 110+U        | 112.0                        | 112 0  | 105 O          | 99.0           |
| 224.6150         | 122.4        | 116.0          | 116.1  | 113.0        |              | 115.0                        | 113.0  | 103'U<br>103'U | 98.0           |
| 224.6160         | 120.1        | 110.0          | 112.0  | 112.0        | 112.0        | 114.0                        | 112.0  | 104.0          | 95.0           |
| 224.6L7C         | 11/          | 107.0          | 108.0  | 109.0        | 111.0        | 111.0                        | 109.0  | 103.0          | 94.0           |
| 224.6L80         | 110.+        | 198.0          | 107.0  | 197.0        | 108.0        | 111,0                        | 109.0  | 104.0          | 95.0           |
| 224.7L40         | 127.9        | 123.0          | 124.0  | 119.0        | 114.0        | 115.0                        | 114.0  | 105.0          | 102.J          |
| 224.7150         | 124.0-       | 118.0          | 118.0  | 115.0        | 113.0        | 110.0                        | 114.0. | -111.          | 101.3          |
| 224.7150         | 122.1        | 112.0          | 113.0  | 114.0        | 114.0        | 116.9                        | 115.0  | 107.0          | 99.9           |
| 224.7130         | 119.6        | 116.0          | 109.0  | 179.6        | 111.0        | 114.0                        | 113.0  | 107.0          | 99.0           |
| 225.1140         | 116.3        | 109.0          | 105.0  | 1)1.0        | 105.0        | 113.0                        | 110.0  | 104.0          | 96.0           |
| 225.1L50         | 115.5        | 106.0          | 103.0  | 192.0        | 105.0        | 113.0                        | 110.0  | 107.0          | 96.0           |
| 225.1L6 <u>0</u> | 115.1        | <u>10</u> 3.0  | 102.0  | 103.0        | <u>106.Ŭ</u> | 111.0                        | 109.0  | 103.0          | - 94. ]        |
| 225.1L70         | 114.2        | 102.0          | 100.0  | 1 32.0       | 107.0        | 110.0                        | 107.0  | 103.0          | 94.0           |
| 225.1180         | 114.1        | 112.1          | 144 O  | 106 D        | 102+0        | 117 O                        | 111 0  | 104.0          | 95.0           |
| 225+2140         | 112 L        | 111 0          | 108.0  | 1 16.0       | 106.0        | 114.0                        | 111.0  | 109.0          | 98.0           |
| 225.2160         | 117.7        | 106.0          | 106.0  | 196.6        | 108.0        | 113.0                        | 112.0  | 100.0          | 97.0           |
| 225.2L70         | 115 <u>.</u> | 104.0          | 103.0  | 135.0        | 109.0        | 112.0                        | 110.0_ | 105.0          | 980            |
| 225.2L80         | 117.0        | 105.0          | 103.0  | 103.0        | 107.0        | 112.0                        | 112.0  | 107,0          | 99.0           |
| 225.3L40         | 123.5        | 119.0          | 118.0  | 1:2.0        | 110.0        | 115.0                        | 113.0  | 106.0          | 99.0           |
| 225.3140         | 121.5        | 115.0          | 114.0  | 111.0        | 114 D        | 115.0                        | 113.0  | 107 0          | 100 1          |
| 225.360          | 118 5        | 109°3<br>102 0 | 107.0  | 198.0        | 111 0        | 147.0                        | 110.0  | 106.0          | 97.0           |
| 225.3180         | 118.2        | 108.0          | 106.0  | 106.0        | 110.0        | 113.0                        | 112.0  | 107.0          | 98.0           |
| 225.4L40         | 120.5        | 122.0          | 122.0  | 117.0        | 113.0        | 115.0                        | 113.0  | 107.0          | 102.0          |
| 225.4L50         | 123.9        | 118.0          | 118.0  | 114.0        | 112.0        | 116.0                        | 114.0  | 111.0          | 102.0          |
| 225.4L60         | 121.8        | 111.0          | 0 ء 11 | 113.0        | 113.0        | 116.0                        | 115.0  | 109.0          | 101.0          |
| 225.4L70         | 120.0        | 108.0          | 109.0  | 116.0        | 113.0        | 115.0                        | 112.0  | 108.9          | 100.0          |
| 225.418.0        | 119.7        | 110.0          | 109.0  | 109.0        |              | 114.0                        | 113.0  | 109.0<br>107 0 | 100.0          |
| 225 51 51 50     | 125 0        | <u>120 0</u>   | 121 0  | <u>117.0</u> |              | _ <u>العادية.</u><br>11 n.11 |        | 111_N          | 101.0          |
| 225.5160         | 123.9        | 114.0          | 116.0  | 116.0        | 116.0        | 117.0                        | 115.0  | 109.0          | 102.0          |
| 225.5170         | 121.3        | 111.0          | 112.0  | 113.0        | 115,0        | 116.0                        | 114,0  | 109.0          | 102.0          |
| 225.5L80         | 129.2        | 111.0          | 110.0  | 111.0        | 112.0        | 114.0                        | 113.0  | 109.0          | 101.7          |
|                  |              |                |        |              |              |                              |        |                | 1              |

NOTE: THESE ARE FREE FIELD VALUES

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HM-AP-57 NOZZLE

12 SPOKES, AR 1.86

NO PICTURE AVA!LABLE

Number of Elements: 12 Spokes Area Ratio: 1.86 Spoke Penetration: 75% Flow Area: 13.2 Square Inches Exit Cant Angle: 0 Degrees Ventilation Gutter Cant Angle: 77° Material: 321 CRES

Description:



D214





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## HM-AP-57 NOZZLE

### Remarks

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The data acquired in the HM-AP-57 Nozzle tests included ground reflection interference. The spectra was arbitrarily corrected for ground reflection interference and it was noted that perceived noise level suppression values improved by 1 to 2.5 PNdB. For instance at pressure ratio 3.0 and total temperature of  $1500^{\circ}$ F the free field suppression value was 8.0 while the ground reflection influenced value was 6.0. See Reference D27.

# HM-AP- 57 NOZZLE

Test Facility: Annex D (Cell #1) Nozzle and microphone height is 20 Inches

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Date: January 10, 1968

T<sub>amb</sub>: 38°F

R.H.: 73%

| Run No. | $\underline{P_{T}/P_{\infty}}$ | $\frac{\mathbf{T}_{\mathbf{T}}}{\mathbf{T}}$ | V <sub>J</sub> (Ideal) | Nozzle                           |
|---------|--------------------------------|----------------------------------------------|------------------------|----------------------------------|
| 2037    | 1.8                            | 1000°F                                       | 1659 fps               | нм-ар <b>-</b> 57                |
| 2049    | 1.8                            | 11                                           | 1659                   | 11                               |
| 2038    | 2.2                            | 11                                           | 1900                   | 11                               |
| 2050    | 2.2                            | 11                                           | 1900                   | U                                |
| 2039    | 2.6                            | 11                                           | 2073                   | "                                |
| 2051    | 2.6                            | 17                                           | 2073                   | 11                               |
| 2040    | 3.0                            | 11                                           | 2205                   | 17                               |
| 2052    | 3.0                            | 11                                           | 2205                   | 11                               |
| 2041    | 3.2                            | 11                                           | 2250                   | 11                               |
| 2053    | 3.2                            | 11                                           | 2250                   | 11                               |
| 2042    | 3.4                            | 11                                           | 2311                   | 11                               |
| 2054    | 3.4                            | 11                                           | 2311                   | n                                |
| 2043    | 1.8                            | 1500°F                                       | 1923                   | 11                               |
| 2055    | 1.8                            | 11                                           | 1923                   | 11                               |
| 2044    | 2.2                            | 11                                           | 2202                   | 11                               |
| 2056    | 2.2                            | 11                                           | 2202                   | 11                               |
| 2045    | 2.6                            | 11                                           | 2402                   | 17                               |
| 2057    | 2.6                            | 11                                           | 2402                   | п                                |
| 2046    | 3.0                            | 11                                           | 2555                   | 17                               |
| 2058    | 3.0                            | 11                                           | 2555                   | 11                               |
| 2047    | 3.2                            | 11                                           | 2620                   | 11                               |
| 2059    | 3.2                            | 11                                           | 2620                   | 11                               |
| 2048    | 3.4                            | 11                                           | 2678                   | 11                               |
| 2060    | 3.4                            | 17                                           | 2678                   | n                                |
|         |                                |                                              |                        |                                  |
| 2079    | 1.8                            | 1000°F                                       | 1659 fps               | 4.1 Inch Round Convergent Nozzle |
| 2067    | 1.8                            | 11                                           | 1659                   | "                                |
| 2080    | 2.2                            | 11                                           | 1900                   | 17                               |
| 2068    | 2.2                            | 1ĭ                                           | 1900                   | 11                               |
| 2081    | 2.6                            | 11                                           | 2073                   | 11                               |
| 2069    | 2.6                            | tj                                           | 2073                   | 11                               |
| 2082    | 3.0                            | 11                                           | 2205                   | 11                               |
| 2070    | 3.0                            | u                                            | 2205                   | 11                               |
|         | 5.0                            |                                              |                        |                                  |

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# HM-AP-57 NOZZLE

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| 2083 | 3.2 | 1000°F | 2250 | 4.1 Inch Round Convergent Nozzle |
|------|-----|--------|------|----------------------------------|
| 2071 | 3.2 | -11    | 2250 | 11                               |
| 2084 | 3.4 | 11     | 2311 | 11                               |
| 2072 | 3.4 | tt     | 2311 | 11                               |
| 2085 | 18  | 1500°F | 1923 | 11                               |
| 2073 | 1.8 | 11     | 1923 | 11                               |
| 2086 | 2.2 | 11     | 2202 | 11                               |
| 2074 | 2.2 | 11     | 2202 | 11                               |
| 2087 | 2.6 | 17     | 2402 | 11                               |
| 2075 | 2.6 | п      | 2402 | -11                              |
| 2088 | 3.0 | 11     | 2555 | 11                               |
| 2076 | 3.0 | 31     | 2555 | 11                               |
| 2089 | 3.2 | 12     | 2620 | 11                               |
| 2077 | 3.2 | 11     | 2620 | 11                               |
| 2090 | 3.4 | 11     | 2678 | 11                               |
| 2078 | 3.4 | 11     | 2678 | 11                               |

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# HM-AP-57 NOZZLE TEST DATA

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2/25 FT

|           | 01001   | 500    | ١К    | 2К     | ЛК      | 8K        | 16K     | 32K              | 64K                |
|-----------|---------|--------|-------|--------|---------|-----------|---------|------------------|--------------------|
| 2027 144  | UASEL   |        | 115   | 100.00 | 10042   | 1 ( ) - 7 | 101     | 10340            | 9540               |
| 2037 150  | 110+5   | 110.0  | 105-0 | 101-0  | 11140   | 11).0     | 107-0   | 103.0            | 95.0               |
| 2037 1 60 | 11/*6 . | 110.0  | 108-0 | 106+0  | 114.0   | (12.0     | 109=0   | 104.0            | 97.0               |
| 2037 1.70 | 117.7   | 108.0  | 105+0 | 104+0  | 114+0   | 111.0     | 100+0   | 104 0            | 97:0               |
| 2037 1.80 | 114.8   | 105.0  | 103.0 | 100.0  | 110.0   | 169.0     | 106.0   | 104.0            | 94.0               |
| 2149 L45  | 110+1   | 112.0  | 107.0 | 100-0  | 119.0   | 104.0     | 105.0   | 102.0            | 93.0               |
| 20.49 .55 | 116+7   | 111.   | 108+0 | 102+0  | 111.0   | 109+0     | 105.0   | 103.0            | 95.0               |
| 2044 Lt , | 117.2   | 111.0  | 10/.0 | 102.0  | 112.0   | -i10.0    | 107.0   | 103.0            | 96.0               |
| 2049 L65  | 116.9   | 110.0  | 106.0 | 101+0  | 112+0   | 110.0     | 107.0   | 103.0            | 96.0               |
| 2049 L75  | 113,5   | 106.0  | 107.0 | 98.0   | 104+0   | 101.0     | 105+0   | 101.0            | 94+0               |
| 2n38 [=40 | 119+3   | 114.0  | 109.0 | 102.0  | 111+0   | 113.0     | 111+0   | 10/+0            | 99.0               |
| 2038 LSO  | 150+5   | 115.   | 111-0 | 164+0  | 113.0   | 114+0     | 109+0_  | _10(:0           | _100.0_            |
| 2038 60   | 120+9   | 114+0  | 111+0 | 105+0  | 115+0   | 1)7+11    | 111+0   | 107+0            | 101+0              |
| 2038 L70  | -119+5  | 111.0  | 108.0 | 104.0  | 115+0   | 113.0     | 111+0   | 10/+0            | _101+0             |
| 2038 [40  | 116+4   | 144.4  | 104.0 | 102.0  | 111+0   | 111.0     | 109+0   | 105+0            | 98+0               |
| 2050 645  | 119+4   | 114.4  | 111+0 | 104+0  | 1-12+9  | 114.0     | 110+0   | 107+0            | 99.0               |
| 2050 155  | 120+3   | 114.0  | 111+0 | 105.0  | 114+0   | 114.0     | 110.0   | . 10 10          | 100+0              |
| 2050 145  | 150+4   | 114.0  | 109+0 | 100+0  | 112+0   | 115.0     | 114.0   | 107+0            | 101.0              |
| 2050 175  | 120.3   | 11640  | 104.0 | 102.0  | 112+0 _ | 11240     | 111+0   | . 107+ <u>0</u>  | 00+0               |
| 2039 140  | 193.3   | 10749  | 114.0 | 102.00 | 112+0   | 111+0     | 103+9   | 10240            | 90.0               |
| 2039 150  | 124.1   | 118.0  | 114-0 | 10840  | 115.0   | 117.0     | 112-0   | 107+0            | 100.0              |
| 2039 160  | 173.7   | 11/04  | 114.0 | 104.0  | 117+0   | 118-11    | 114.0   | 110200           |                    |
| 2039 170  | 121.4   | 114.9  | 110.0 | 105+0  | 117+0   | 115.0     | 11.1.0  | 107+0            | 104+0              |
| 2039 LHO  | 118.9   | 110.5  | 107.7 | 194.0  | 113.0   | 113.0     | 111.0   | 100.0            | 101.0              |
| 2051 645  | 155+6   | 119.9  | 114.0 | 107.0  | 115.0   | 115.0     | 110.0   | 109-0            | -0.                |
| 2051 LS5  | 122.7   | 11/.0  | 114.0 | 108.0  | 116+0   | 116.0     | 116.0   | 109.0            | 103.0              |
| 2051 LAO  | 123.4   | 117+9  | 114.0 | 100.0  | 117+0   | 117.0     | 114.0   | 109.0            | 104.0              |
| 2051 LAS  | 123.0   | 115:0  | 112.0 | 108.0  | 118+0   | 117.0     | 113.0   | 109.0            | 104.0              |
| 2051 L75  | 114+3   | 111+0  | 108+0 | 105+0  | 114+0   | 113.0     | 111+0   | 10/+0            | 101+0              |
| 2040 640  | 126.5   | 124.0  | 118+0 | 110.0  | 117.0   | 116.0     | 114+0   | 110+0            | 101.0              |
| 2040 650  | 150+0   | 155*0  | 117.0 | 110•v  | 118.0   | 117+0     | 114+0   | 110.0            | 104+0              |
| 2040 640  | 125.9   | 120.0  | 116+0 | 111+0  | 119.0   | 150.0     | 116+0   | 111+0            | 105+0              |
| 2040 1 80 | 123+8   | 1)0+0_ | 113+0 | _109+0 | _119+0_ |           | 115+0_  | _110:0_          | 105.0              |
| 2052 145  | 120+5   | 114.7  | 109+0 | 106.0  | 115+0   | 114+0     | 113.0   | 107.0            | 102+0              |
| 2052 155  | 125.6   | 121.0  | 117.0 | 11040  | 110.0   | 11/00     | 114.0   | 11010            | •0•<br>• 10t 70    |
| 052 L60   | 123.7   | 117.5  | 114.0 | 109.0  | 11440   | 117.0     |         | 109.0            | 104.0              |
| . 52 L65  | 124.9   | 118.0  | 115.0 | 110.0  | 120.0   | 118.0     | 119.0   | 110-0            | 105-0              |
| 2052 L75  | 121.6   | 114.0  | 111.0 | 107.0  | 116+0   | 115.0     | 113.0   | 110.0            | 103-0              |
| 5001 L40  | 124.4   | 126.0  | 151+0 | 112+0  | 118+0   | 117.0     | 114.0   | 110.0            | 101.0              |
| 2041 650  | 126+8   | 153.1  | 118.0 | 111+0  | 119+0   | 119+0     | 115.0   | 111+0            | 105.0              |
| 2041 [00  | 120.4   | 121.0  | 117+9 | 111+0  | 120+0   | 120+0     | 116+0   | 114+0            | 105.0              |
| 2041 190  | 124+1   | 121.0  | 114+0 | 104.0  | 120.0   | 118.0     | 112+0   | _ 111:0_         | 106.0              |
| 2053 145  | 126.8   | 124.0  | 11164 | 1)1.0  | 111.0   | 110+0     | 112+0   | 111+0            | 104+0              |
| 2053 155  | 126.6   | 124    | 11040 | 11100  | 110.0   | 117.0     | 110+0   | 111.0            | ~0 <i>•</i>        |
| 2053 640  | 125.3   | 119.0  | 116.0 | 11110  | 110+0   | 119.0     | 112+0   | 110+0            | 103.0              |
| 2053 645  | 125.6   | 121.0  | 115.0 | 109.0  | 120.0   | 118.0     | 11240   | 11140            | 105+0              |
| 2053 L75  | 122.5   | 115.0  | 111.0 | 108+0  | 117.0   | 110.0     | 119.0   | 10749            | 10200              |
| 2042 L40  | 130.5   | 128.0  | 124.0 | 114.0  | 120.0   | 118.0     | 114.0   | 111.0            | 104.0              |
| 2042 LSO  | 158+5 - | 125.0  | 150+0 | 113.0  | 120.0   | 119.0     | 115.0   | 111+0            | 105.0              |
| 2042 L60  | 127+6   | 123.0  |       | 113.0  | 151+0   | _150+0_   | 117.0   | 114+0            | 106.0              |
| 2042 170  | 152.9   | 119+4  | 115+0 | 111+0  | 121±0   | 119.U     | 116.0   | 11200            | 106.0              |
| 2042 680  | 153•0   | 115+9  | 112+0 | 109+0  | 117+0   | 11/+0     | 115.0   | 111+0            | 104+2              |
| 2054 645  | 128+7   | 126.0  | 151+0 | 11700  | 120.0   | 11/+0     | 115.0   | 111+0            | - <del>- U</del> • |
| 2024 633  | 15/+5   | 124.0  | 118+0 | 111=0  | 120=0   | 118.0     | 114+0 - | - 111 <u>-</u> 0 | -10400.            |
| 2054 1 45 | 1/0+3   | 121+0  | 117+0 | 111+0  | 150+0   | 119+0     | 110-0   | 111+0            | 100.0              |
| 2054 L75  | 120.3   | 116 0  | 113.4 | 100-0  | 121+0   | 114.0     | 110+0   | 111+0            | 100+0              |
| 2043 L40  | 117.3   | 112.0  | 107-0 | 10440  | 110-0   | 111 1     | 105     | 11400            | 10440              |
| 2043 LSO  | 118.5   | 113.0  | 109-0 | 102-0  | 11000   | +11+0     | 100(0   | 104+0            | 42.0               |
| 2043 L60  | 11942   | 113-3  | 108-0 | 104+0  | 115.0   | 112-0     | 100+0   | 10440            | 9/+0               |
| 2643 L70  | 118.1   | 110-0  | 106.0 | 102-0  | 116-0   | 313.0     | 110     | 10040            | 70+0<br>70+0       |
| 5043 Leù  | 115+2   | 107.0  | 103.0 | 100.0  | 110.0   | 104-0     | 10/**   | 104+6            | 9000               |
| 2055 645  | 11/.7   | 114.0  | 107+0 | 101.00 | 110+0   | 110.0     | 107-0   | 106=0            | · 06.0             |
| 2055 155  | 118+4   | 113.0  | 109+0 | 103.0  | 112+0   | 112.0     | 10700   | 104.0            | 9300               |
| 2055 120  | 119+0   | 113.0  | 108:0 | 104+0  | 113.0   | 113.0     | 109+0   | 104-0            | 48-0               |
| 2055 175  | 118+8   | 112.0  | 107=0 | 104.0  | 114+0   | 112.0     | -104+0  | 104+0 -          | - 98.0.            |
|           | 1]6+5   | 107+9  | 104+0 | 101+0  | 115+6   | 110.0     | 107+1   | 103.0            | 96.0               |

### NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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|                       |            | н                  | Μ                     | 57 NO3             | 771:5 7        |                     | тл               |                   |                 |
|-----------------------|------------|--------------------|-----------------------|--------------------|----------------|---------------------|------------------|-------------------|-----------------|
| RUN NO.               | OASPL S    | 11<br>500          | 1K                    | -37 -₩Q2<br>-2Ķ    | -∠-⊑_ ⊧<br>_4K | EST DA              | 16K              | 32K               | 64K             |
| 2044 L40-             | 121.7      | =8.0               | 112.0                 | 105.0 -            | 113.0          | 114.0               | 111+0            | 100.0             | -99.0           |
| SU44 FW0              | 12248      | 17.0               | 112+0                 | 107.0              | 116+0          | 117+0-              | 113.0 -          | 105.0             | 102.0           |
| 2044 L70              | -121+7 1   | 14                 | 109+0                 | 106+0              | 157+0          | 115.0               | 113.0            | 100.0             | 103.0           |
| 2055-145              | 119+1 1    | 13+1)              | 106+0                 | 103+0              | 11-3+0         | \$13+0              | -10+1            | 106+0             | 99.0            |
| 2055 L55              | 122+0 1    | 17+0               | 113.0                 | 102+0-             | 115+0          | 115.0               | 111+0            | 100+0<br>100+0    | 101-0           |
| 2056 689              | 122.6 1    | 17.0               | 11-3+0                | 208+0 -            | 116+0-         | 116.0               | 113.0            | 160.9             | 102-0-          |
| 2056 : 75             | -122.0 1   | 10.0               |                       | 107.0              | 118+0          | -110.0              | 112.0            | 107.0-            | 102.0           |
| 2045 140              | 126+2 -1   | 24.9               | 117.5 ·               | 10300-             | 110+0          | 110-0               | 115+0 -<br>TTA+0 | 109+0             | 97+U            |
| 2045-650              | 152.5 1    | 21.0               | 117.0                 | 110+0              | 117•0          | 110:0               | 113.0            | 110.0             | 103.0           |
| 2045 L40<br>2045 1-70 | 125.2 -1   | 20.0               | 175+0                 | 111+0              | 118+0          | 114+0               | 115+0            | 111:0             | 105+0           |
| 2045 640              | 121+1      | 15.0 -             | 109+0                 | 109+0              | 120+0          | 112+0               | 112+0            | 110+0             | 10900.<br>18019 |
| 2057 145              | 125.1 1    | 22.0               | 117+0 -               | 109.0              | 116-0          | 116.0               | 113.0            | 110.0             | =0.             |
| 2057 160              | 125.1 -1   | 21.0               | 116.0                 | 110.0              | 117.0          | 118.0               | 113-0            | :10 <u>.</u> 0    | 104.0.          |
| 2057 135              | 125+7 1    | 21+0<br>14+0       | 116+0<br>116+0        | 111+0              | 118+0          | 119.0               | 115+0            | 11000             | 105.0           |
| 2057 L75              | 122-5 1    | 16.0               | 111.0                 | 107+1              | 117+0          | 116.0               | 1.3•0            | 109.0             | 103.0           |
| 2046 150              | 129+3 1    | 28.1               | 155.0                 | 112:0              | 118+0          | 110.0               | 113.0            | 110-0             | 101.0-          |
| 2046-L40              | 128+1 1    | 25.0               | 120+0                 | 112.0              | 119.0          | 119.0               | 114+0-           | 110.0             | 104.0           |
| 2646 170              | 120.2      | 20.0               | 115-0                 | 111.0              | 121+0          | 11900               | 137+9 1          | 112.0             | 100+0<br>106+0  |
| 2046 LBO<br>2058 LAS  | 173.6 1    | 17.0               | 112+0                 | 109.0              | 18.0           | 117.0               | 114.0            | 111.0             | 103.0           |
| 2058 55               | 129+1 1    | 27.0               | 121+0                 | 112.0              | 119•0          | 117.0               | 114.0            | 111+0             | -0.             |
| 5048 L40              | 128.0      | 24.1)              | 110+0                 | 112+0              | 121+0          | 120+0               | 112+0            | 1140,             | 105+0_          |
| 2058 LAS              | 126.9      | 22.0               | :17+0                 | 112.0              | 151.0          | 119.0               | 10.0 _           | 111.0.            | 10000           |
| 2047 140              | 124+5 1    | 18.0               | 113.0                 | 109.0              | 120+0          | 11/.0               | 114+0 1          | 110.0             | 104+0           |
| 2047 L60              | -130+4 1   | 213.ú              | 122+0                 | 115+0 )<br>115+0 1 | 120+0          | 11/.0               | 14.0             |                   | 104.0           |
| 2047 LAO              | 128:7 1    | 25.0               | 19.0                  | 113.0              | 21+U           | 151*0               | 17.0             |                   |                 |
| 2047 L/0<br>2047 L80  | 12/+4 13   | 21.0               | 115+0                 | 112+0 1            | 23•0           | 150+0               | 17+0 1           | 12.0 1            | 07.0            |
| 2059 L45              | 131.1 1    | 29.0               | 112+0                 | 112.0              | 118+0          | 118.0               | 15.0             |                   | 04+0            |
| 2059 L55              | 128.91     | 26.0               | 120.0                 | 113.0 _            | 21.0_          | 117.0               | 15+0             | 12+0              | 05.0            |
| 2027 LAD<br>2059 LAS  | 128+5 12   | 25.0               | 119+0                 | 113.0 1            | 21+0           | 150.0               | 17.0 1           | 14+0 1            | 07.0            |
| 2059 275              | 125+1 1    | 19.0               | 110+0_<br>114+0       | 113.0              | 22+0           | 120+0               |                  |                   | 0.00            |
| 2048 L40              | 133.4 13   | 31.0               | 28.0                  | 117.0 1            | 21.0           | 115.0               | 15+0 ]           | 11+0 1            | 05+0            |
| 2048 L50<br>2048 L60  | 133.5 1    | 32.0 _ 3           | 25.0                  | 116.0 1            | 22.0           | 150.0               | 14.01            | 11:0]             | 00.0            |
| 2048 170              | -158+1- 12 | 23.0               | 18+0                  | 113•0 1            | 23+0           | 120+0 1             | 15+0 ]           | 12+0              | 08.0            |
| 2048 LAD              | 125+0 12   | 21.0 -             | 13.0                  | 109+0              | 18-0           | 11/00               | 15.0 -1          | 11.0              | 03.0            |
| 2050 155              | 132+5 13   | 30.0               | 27+0                  | 117•0 1            | 21.0           | 118.0 1             | 15.0 1           | 12+0 1            | 00.0            |
| 2060 LAO              | 130+0 12   | 27.0               | 20+0                  | 119+0 1<br>119+0 1 | 22+0           | 151-0 1             | 10+0 1           | 1340 - 1          | 07.40           |
| 2060 LAS              | 128.8 12   | 25.0               | 19+0                  | 114.0 _1           | 22.0           | 120.0               | 17.0             | 12.0 1            | 07.0            |
| 2000 173              | 126.0 17   | 20.0               | 15.0                  |                    | 21.0           | 119.0               | 15+0 1           | 14.0 1            | 05.0            |
| 2079 L50              | 124.3 12   | 26.0 ° 1<br>21.0 1 | 20+0                  | 114+0 1            | 15+0           | 107.0 1             | 01.0             | 95.0              | 95.0            |
| 2079 L60              | 120.0 11   | 6.0 1              | 13•0                  | 07+0 1             | 14+0           | 109.0               | 04+0             | 98.0              | 91.0            |
| 2079 LR0              | 118+7 11   | 11.0               | 09+0                  | 105+0 1            | 12.0           | 107.0 1             | 03.0             | 97.0              | 91.0            |
| 2047 645              | 125.2 12   | 2.0 1              | 21+0                  | 11+0 1             | 14+0           | 102+0 ]<br>107+0 ]  | 01+5             | 9540<br>9440      | 88.6            |
| 2057 155              | 155.4 11   | 9.0 1              | 17.0                  | 09.0 1             | 14.0           | 109.0 1             | 03.n             | 98.0              | -V.             |
| 2067 1.50             | 120.3 11   | 6.0 1              | 14+0 1                | 07+0 1             | 14+0           | 104.0 1             | Věen             | 91:0              | 91-0            |
| 2067 175              | 110+2 1)   | 19.0 1             | .j1+0 = 1<br>07+0 = 1 | 05+0 1             | 13=0<br>10=0-  | 108+01<br>108+01    | U. + ()          | .97+Ç             | 91+0<br>        |
| 2080 L40<br>2080 L50  | 130.2 15   | 5.1 1              | 26+0                  | 20.0 1             | 23.0           | 15.0 1              | 09+0 1           | 04+0 1            | 00+0            |
| 2040 L60              | 128.5 12   | 24.) <u>]</u><br>G | 24+0                  | 16.0 1             | 21.0           | 115.0 1             | 10.0 _ 1         | 04.0              | 99.0            |
| 2080 L70              | 120+8 11   | ≯ 4 î   ]          | 13+0 1                | 10+0 1             | 16+0           | 132.0 1             | 10+0 1<br>10+0 1 | 04±0<br>113±0     | 98.0            |
| 2080 L80              | 112.5      | 19.1 1             | 08.0                  | 07.0 1             | 13+0           | 104.0 1             | Ub+n ]           | 01+0              | 93.0            |
| 2058 145              | 129.5 12   | 25.0 1             | 25.0                  | 18.0 1             | 25.0           | 115.0 1             | (****0- 1        | 03.0 1            | 00.0            |
| 2068 160              | 124.4 11   | (4) 1<br>1940 1    | 18+0                  | 12.0 1             | 20+0<br>19+0   | 114.0- 1<br>114.0 1 | 07+0 1<br>10-0 1 | 0440              | 98+0<br>9810    |
| 2058 LAS              | 122+1 11   | 6+0 1              | 15.0 1                | 10+0 1             | 17•0           | 113+0 1             | 03+0 1           | 03+0              | 98.0            |
| 2068 175              | 118+9 11   | 2.0 1              | 10+0 1                | 08.0 1             | 14+0           | 111.0 1             | 04.5 1           | 02.0              | 94+0            |
| 2081 650              | 131.5 12   | (**** 1<br>25.0 1  | 27.0                  | 20.0 1             | 20+0           | 110.0 1             | 15+0 1           | .07+0 1<br>10+ύ 1 | 0.00            |
| 2081 L60              | 127.6 12   | 2.1 1              | 21+0                  | 16.0 1             | 55•0           | 110.0 1             | 14+0 1           | 09+0 1            | 0.0             |
| 4041 L70<br>2081-180  | 124+4 1]   | 2.0 . 1            | 15.0 ]                | 13.0               | 20.0           | 116+0 1             | 14.0]            | 08.01             | 03.0            |
|                       | • LI FO II | 1 000              | 1144 1                |                    | 1040-          | 41967 J             | 1                | VIAN              | 77 ( I)         |

# NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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|            |          | ······   |          |          |         |           |         |              |              |   |
|------------|----------|----------|----------|----------|---------|-----------|---------|--------------|--------------|---|
|            |          |          |          |          |         |           |         |              | -            |   |
|            |          |          |          |          | _       |           |         |              |              |   |
|            |          | -        | HM-AP    | -57 N    | 0771 5  | TEST      | ΠΛΤΛ    |              |              |   |
|            |          |          |          | <u>.</u> |         | 1-01-     | enin    |              |              |   |
| RUN-NO.    | OASPL    | 500      | ٦K       | 2K       | đK      | 8к        | 163     | 32K          | 64K          |   |
| 24/0       |          |          |          |          |         | •         |         | 02.0         | 0411         |   |
| 2069 145   | 132.2    | 128.0    | 128.0    | 156.1    | :27 · J | -1511-0   | 3-10+6  | 111.0        | 107.0        |   |
| 2059 155   | 12413    | 124.0    | . 124+0  | 118.0    | 123-0   | 119*0     | 1+4+0   | 109+0        |              |   |
| 2407 60    | 121+1    | 126+9    | 121+0    | 116+0    | 122.0   | 118=0     | 115.0   | 103.0        | 104.0        | r |
| 2007 65    | 122-2    | 110.0    | 1.17     | 11.3+0   | 151+2   | 118-0     | 1-19+0  | 109.0        | 103+0        |   |
| 2007 275   | 172-1    | 1-3447   | 11319    | 14195    | 118+0   | 1-1-5-5-9 | 113-0   | 10/+0        | 100.0        |   |
| 2082 150   | 1-34 1   | 1241     | 120.0    | 125+0    | 151+0   | 151-0     | 1-17+0  | 1-1-1+0      | 108.0        |   |
| 2042 140   | 130-2    | 124.0    | 12749    | 120.0    | 120.00  | 127.0     | 112.0   | 112+0        | 100+0        |   |
| 2082 170   | 127.2    | 119.1    | 118.0    | 11-7.0   | 127.10  | 120.0     | 11/+0   | 110-0        | 101.0        |   |
| 2083 2802  | 124-5    | 114.0    | 113.0    | 116.0    | 120.0   | 110-0     | 114.0   | 110.0        | 103.0        |   |
| 207 :15    | 1-14 . 4 | 129.0    | 130.0    | 125.0    | 128+1   | 123.0     | 110.0   | 11:1-0       | 109-0        |   |
| 2010 LS5   | 132.2    | 124.00   | 127.0    | 1.22.0   | 120.0   | 121.0     | 110.0   | 113.0        | -108-0       |   |
| 2020 1 40  | 130+5    | 124 . 1. | 123.0    | 119.0    | 122+4   | 151*0     | 111.0   | 112.0        | -107.0       |   |
| 2070 1.65  | 127+9    | 120.0    | 1-19+0   | 118.9    | 153+0   | 120.0     | 11/+0   | 111.0        | 107.0        |   |
| 20/0 175   | 125+7    | 114.2    | 115.n    | 135+0    | 151+0   | 237.11    | 110.0   | 111.0        | 104.0        |   |
| 2043 [40   | 137+4    | 130.1    | 135+0    | 195.6    | 158•0   | 176,0     | 12720   | 115+2        | 109.0        |   |
| 2043 140   | 13 • 0   | 158°a    | 130+0    | 150+0    | 128+1   | 154*1     | 119.0   | 115+0        | 110.0        |   |
| 2003 100   | 1.31+2   | 129 + 9  | 124+0    | 123+0    | 126.0   | 121+0     | 110+0   | 113+0        | 101.0        |   |
| 2083 180   | 128.2    | 120+9    | 119.0    | 119-0    | 123+0   | 151-0     | 11/20   | 114.0        | -107+9       |   |
| 2071 145   | 12045    | 11749    | 110+0    | 120+0    | 12240   | 11,20     | 112+0   | 111+0        | 105.0        |   |
| 2071 155   | 13041    | 130.0    | 131+0    | 120.4    | 129.1   | 123.0     | 114+0   | 114 10       | 110+9        |   |
| 2071 160   | 131.4    | 125.1    | 124.0    | 12       | 126.1   |           | 119.0   |              | -10240       |   |
| 2071 165   | 129.0    | 121.0    | 121.0    | 120.0    | 124-11  | 124.0     | 117.0   | 112-0        | 100.0        |   |
| 20/1 L75   | 126.7    | 111.0    | 116.0    | 115.0    | 122-1   | 120.0     | 116-0   | 111.0        | 105.0        |   |
| 2084 640   | 13/+3    | 130.0    | 133.0    | 132.11   | 127.0   | 122-0     | 118.0   | 112.0        | 109.0        |   |
| 2084 L50   | 135.4    | 129.1    | 131.0    | 126.0    | 129+0   | 124.0     | 120.0   | 115.0        | 110.0        |   |
| 2084 640   | 131+н -  | 125.0    | 125.0    | 153.0    | 125+0   | 172.0     | 119+0   | 114.0        | 108.0        |   |
| 2084 170   | 128+5    | 120.1    | 119+0    | 119#0    | 124.0   | 121,0     | 117.0   | 113.0        | 105.0        |   |
| 2034- [//0 | 126+6    | 116.0    | 116+0    | 119.0    | 155+0   | 119.0     | 116.0   | 111+0        | 105.9        |   |
| 2012 145   | 1,36+3   | 130.9    | 135.0    | 151+n    | 157+0   | 159.0     | 150+0   | 115.0        | 110.0        |   |
| 20/2 [55   | 133.9    | 159*0    | 158.0    | 154+0    | 158.0   | 153.0     | 117+0   | 114+0 _      | 109+0        |   |
| 2072 146   | 132+0    | 125.4    | 125.0    | 124.0    | 150+0   | 15310     | 119.0   | 114.0        | 109+0        |   |
| 2072 128   | 154+2    | 124.0    | 121+0    | 120.0    | 15420   | 155.0     | 110.0 - | -112:0-      | 06°0         |   |
| 2085 140   | 121.4    | 110+0    | 117+0    | 117+9    | 155+0   | 151*0     | 117+0   | 113.0        | 106+0        |   |
| 2085 1 50  | 12044    | 124+1    | 152+0    | 118.0    | 151+0   | 111.0     | 102.0   | AÀ 0         | 91.0         |   |
| 2985 1.40  | 124.2    | 120.0    | 123+0    | 114.0    | 118+0   | 111-0     | 100.0   | 97+0         | 95.0         |   |
| 2085 1 70  | 119.9    | 115.0    | 117+0    | 111+0    | 118+0   | 112.0     | 101.9   | 100+0        | 94+0         |   |
| 2045 LA0   | 110.7    | 110.9    | 108.0    | 100+0    | 115+0   | 107+0     | 100+7   | 99.0         | 93.0         |   |
| 2073 1.45  | 128+0    | 174.0    | 124.0    | 117.0    | 112.0   | 131.0     | 10440   | <b>Y0</b> •0 | 90.0         |   |
| 2073 L55   | 125+1    | 124.4    | 121.0    | 113.0    | 117.0   | 111.0     | 100-0   | 9700         | 97.0         |   |
| 2073 1.60  | 123.5    | 119.0    | 119+0    | 111.0    | 117+0   | 112.0     | 106+0   | 100.0        | 74#V<br>94.0 |   |
| 2073 L65   | 151+1    | 116.0    | 114.0    | 109.0    | 116+0   | 111.0     | 100.0   | 99.0         | 94.0         |   |
| 20/3 175   | 117+9    | 115.0    | 110.0    | 107.0    | 113.0   | 104.0     | 105.0   | 98.0         | 91.40        |   |
| 2006 140   | 132+4    | 17/.1    | 128.0    | 155*0    | 15/•0   | 117.0     | 114.0   | 109.0        | 105.0        |   |
| 2086 160   | 132+5    | 155*4    | 151+0    | 140+0    | 150+0   | 150.0     | 115+0 - | - 109=0 -    | 105.0        |   |
| 2056 170   | 125.3    | 153*0    | 155.0    | 116+0    | 153.0   | 117.0     | 113.0   | 100.0        | 101.0        |   |
| 2086 L80   | 119.7    | 110+0    | 110+0    | 112+0    | 119+0   | 115.0     | 111+0   | 105+0        | 99.0         |   |
| 2074 645   | 132.4    | 12644    | 337.0    | 109+0    | 115.0   | 112.0     | 108+0   | 103+0        | 96.0         |   |
| 2074 L55   | 129.9    | 125.0    | 125.0    | 12130    | 127+0   | 117.0     | 114+0   | 100.0        | 104.0        |   |
| 2074 LAO   | 128.0    | 123.0    | 122.0    | 116.0    | 122.0   | 117-0     | 113.0   | 107.0        | 195.0        |   |
| 2074 L65   | 125.3    | 150.0    | 118.0    | 113.0    | 120.0   | 116.0     | 111.0   | 105-0        | 100.0        |   |
| 2074 175   | 151+8    | 115.0    | 113.0    | 111+0    | 117.0   | 114.0     | 110.0   | 165.0        | 97.0         |   |
| 2007 140   | 133+3    | 126.1    | 150.0    | 123.0    | 126.0   | 119.0     | 115.0   | 1.0.0        | 107.0        |   |
| 2087 140   | 134+0    | , 5a * 3 | 156+0    | 153+0    | 159.0   | 155.0     | 118.0   | 112:0        | 105.0        |   |
| 2087 1 70  | 130-6    | 15221    | 124.0    | 119.0    | 152+0   | 121.0     | 116.0   | 112.0        | 100.0        |   |
| 2087 180   | 126+3    | 150+0    | 118+0 _  | -115.0 . | 151+0-  | 11800 -   | -112+0  |              | -104.0-      |   |
| 2075 145   | 155+6    | 114+0    | 113+0    | 113+0    | 118•0   | 116+u     | 113+0   | 106.0        | 101+0        |   |
| 2075 155   | 1 19 • 5 | 124+11   | 1.30 • 0 | 150.0    | 158+6   | 151*0     | 11/+0   | 112+0        | 108+0        |   |
| 2075 640   | 132+7    | 121.0    | 127+0    | 155.0    | 127+0   | 151+0     | 11/+0   | 112:0        | 10/+0        |   |
| 2015 665   | 13003    | 124+8    | 124+0    | 119+0    | 152+0   | 151+6     | 110+0   | 111:0        | 106.0        |   |
| 2075 E 75  | 124.0    | 117."    | 170+0    | 110.0    | 122.0   | 114.0     | 115.0   | 110+0        | 105.0        |   |
| SUNB LOD   | 134 . 6  | 130      | 130-4    | 126 4    | 120+0   | 110+0     | 112+0   | 109+0        | 102+0        |   |
| 5068 F20   | 135.8    | 130.0    | 130-0    | 124+0    | 12/+0   | 150.0     | 110+0   | 111+0        | 107.0        |   |
| 2068 660   | 133.0    | 127.0    | 126-0    | 122-0    | 120-0   | 123 "     | 141.0   | 112+0        | -110.0       |   |
| 2088 L70   | 128.4    | 122.1    | 120+0    | 118-0    | 123-0   | 120 0     | 117+0   | 11540        | 109+0        |   |
| SURB FRO   | 125.6    | 116.0    | 115.0    | 115.0    | 121.0   | 119_0     | 116.4   | 1150         | 104 4        |   |
| 20/6 1.45  | 135+6    | 130.0    | 131+0    | 125+0    | 129.0   | 123.0     | 118-4   | 11320        | 110 4        |   |
| 20/0 155   | 1.35+1 . | 129.0    | 158+0    | 124.0    | 130+0   | 124.0     | 150-0   |              | 111-4        |   |
| 2076 126   | 133+0    | 127.0    | 126+0    | 155.0    | 128+0   | 123.0     | 11910   | 114+0        | 109.0        |   |
| 2076 175   | 156+3    | 123.0    | 155+0    | 119.0    | 125.0   | 121.0     | 118.0   | 113.0        | 108.0        |   |
|            | 12/+1    | 114+0    | 117+0    | 117.0    | 155+0   | 150+0     | 117-0   | 112.0        | 105.0        |   |
|            |          |          |          |          |         |           |         |              |              |   |

# NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

| HM-AP-57 NOZZLE TEST DATA        |                         |                        |                         |                         |                         |                         |                         |                                 |                            |  |
|----------------------------------|-------------------------|------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|---------------------------------|----------------------------|--|
| RUN NO.                          | OASPL                   | 500                    | 1K                      | 2K                      | -4K                     | 8K                      | 16K                     | 32K                             | 64K                        |  |
| 2089-L40<br>2089 L50             | 135+4<br>136+8          | 131+0<br>-131+u.       | -132+0<br>-131+0        | 125.U<br>126.U          | 127+0<br>-131+0         | 150•0<br>151•0          | 122+n-                  | 112.0                           | 198.0<br><del>112</del> .0 |  |
| 2089-160<br>2089 170<br>2089 100 | 134•0<br>129•7-         | 155.0                  | 127+0                   | 123.0<br>119.0          | -129+0<br>125+0         | 124.0                   | 120+0                   | 116.0<br>11-3.0                 | 110+0                      |  |
| 2077 L45<br>2077 L55             | 136+4                   | 131.9<br>129.0         | -132+0<br>130+0         | 126+0                   | 129.0                   | 122.0                   | 119+0-                  | 114+0<br>117+0                  | 110+0<br>112+0             |  |
| 2077 LAO<br>2077 LAS             | )34+0<br>131+4          | 125.0                  | 127.0                   | 153+0                   | 129+0                   | 124.J<br>123.U          | 120+0<br>119+0          | 116+0                           | 110+0<br>                  |  |
| 2090 L40<br>2090 L50             | 137.0                   | 131                    | 133.0                   | 130.0                   | 127•0                   | 155.0                   | 128+0                   | 113+0                           | 109.0                      |  |
| 2(90 LKO<br>2040 170             | 134-3<br>130-3          | 125°1<br>153° <i>1</i> | 151.0                   | 124.0                   | 129+0                   | 153.0                   | 121.0                   | 11/+0                           | 111.0                      |  |
| 2018 L45-<br>2078 L55            | 137.3                   | 131.0                  | 133+0<br>131+0          | 130.0                   | 123+0<br>129+0<br>131+0 | 124.0                   | 112+0                   | 117 <u>0</u><br>115•0<br>-117•0 | 111.0                      |  |
| 2078 LAG<br>2078 LAS<br>2078 L75 | 134+4<br>131+8<br>129+0 | 128.4                  | 128+0<br>124+0<br>119+0 | 124+0<br>121+0<br>11850 | 12900<br>12700<br>1240  | 12:.4<br>123.0<br>126.0 | i21+0<br>119+0<br>119+0 | 11670<br>214+0<br>114+0         | 111.0<br>110.0<br>107.0    |  |

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# NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE



HM-AP-58-A NOZZLE

#### ( 42 TUBES, 6 CLUSTERS OF 7 TUBES EACH, AR 9.7)

#### Description:

The HH-AP-58-A nozzle is a  $\frac{1}{2}$ -tube array. ... are are c clusters of tubes with 7 tubes in each cluster. The center of each cluster is located at a 5.75 inch radius from the array center. The tube cluster: are equally spaced at 60 degree are intervals. Lach tube has a  $12-spok\epsilon$ nozzle termination.

Number 12 Llements: 42 tulid with. 12-spoke aczie type end.

Area Ratio. 7.1

rlow Area: 15 square inches

Exit Cast August 0 degrees

Length of Tubes: 7 inches

Tube lerminations: 12 spokes with  $A_{13} = 1.06$ 

15% spoke penetration

6.92 inches outside diameter

 $A_{\rm F} = 0.357$  square inches

u degrées cant ingle

 k\_rres ventilation gutter cant angle

Materia: 301 CHIE



NO PICTURE AVAILABLE

ALANCE STA

D225





### HM-AP-58-A NOZZLE

(42 Tubes, 6 Clusters of 7 Tubes Each)

#### Remarks

The HM-AP-58-A Nozzle indicated that 6 clusters of 7 tubes each will provide about 2 PNdB more suppression at pressure ratios > 3.C as compared to a 2-row annulus configuration of 42 tubes (HM-AP-59-A). See Reference D28.

# HM-AP-58-A NOZZLE

Test Facility: HNTF

Date: ca June 1969

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T<sub>amb</sub>: data not available

R.H.: data not available

| Run No. | $P_{T}/P_{\infty}$ | $\underline{\mathbf{T}}_{\underline{\mathbf{T}}}$ | VJ (Ideal) | Nozzle                           |
|---------|--------------------|---------------------------------------------------|------------|----------------------------------|
| 10.1    | 1.6                | 1500°F                                            | 1750 fps   | HM-AP-58-A                       |
| 10.2    | 2.2                | tt                                                | 2202       | 11                               |
| 10.3    | 2.6                | 13                                                | 2402       | 11                               |
| 10.4    | 3.0                | 11                                                | 2555       | tt                               |
| 10.5    | 3.4                | 1.                                                | 2678       | 11                               |
| 14.1    | 1.6                | 1500°F                                            | 1750 fps   | 4.1 Inch Round Convergent Nozzle |
| 14.2    | 2.2                | Ħ                                                 | 2202       | ii U                             |
| 14.3    | 2.6                | 11                                                | 2402       | 11                               |
| 24.4    | 3.0                | tt                                                | 2555       | n                                |
| 14.5    | 3.4                | 12                                                | 2678       | 11                               |

HM-AP-58-A NOZZLE TEST DATA OCTAVE BAND LEVEL - dB RE: 0.0002 DYNES/CM2//25 FT

| RUN NO     |              |                |       |              |                |              |              | . 0.00         | 102 D 1 | NES/           | ′ CM*//        | /25 F       | Τ                 |
|------------|--------------|----------------|-------|--------------|----------------|--------------|--------------|----------------|---------|----------------|----------------|-------------|-------------------|
| 10-1 L4g   | - U/<br>i 11 | 9325<br>10 7 1 | 500   | 1K           | 2              | К            | 4K           | 3              | к       | 16K            | 7              | лv          | 1.111             |
| 10-1 145   | 11           | (G R )         | .00,7 | 96.7         | ່ 9ະ           | .8           | 98.6         | 0.0            |         |                | 5.             | 21          | -04K              |
| 10-1 L5g   |              | 10.0 J         | 4.5   | 98.6         | 99             | .4 1         | 100.6        | 100            | 7       | 98.4           | 9:             | <b>3.</b> 6 | 97.9              |
| 10-1 155   | 11           | 27 4           | 04.9  | 97.5         | 99             | .6 1         | G1.3         | 101            |         | 191.7          | 108            | 2.0         | 95.0              |
| 10-1 1.60  | 41           | 2.1 1          | 57.8  | 97.1         | 155            | .4 1         | 112 8        | 101            | .9      | 162.4          | -101           | 1.1         | 97.9              |
| 15-1 165   | 11           | 2.0 1          | 15.8  | 109,7        | 59             | .0 1         | 12 1         | 14.74          | .3      | 104.9          | 164            | 1.3         | 100.9             |
| 10-1 170   | 4.4          | u.s 1          | 06.6  | 95.6         | 96             | .6           | 60.2         | 194            | .1      | 154.8          | 164            | 1.5         | 101.2             |
| 19-1 3     | 11<br>       | 1.0 1          | 13.4  | 94.9         | 96             | 3 1          | 00.C         | 123            | . 1     | 191.3          | 151            | .3          | 98.2              |
| 10-1 1.0   | 519          | 5.5 ji         | 12.9  | \$4.3        | 96             | 5 1          | 55.9<br>66 o | 15.5           | .0 1    | 54.3           | 104            | .2          | 59.6              |
| 10-1 105   | 11:          | 1.1 1          | 13.9  | 94.9         | 94             | 7            | 00.6         | 102.           | . 1     | 64.4           | 193            | .4          | 98.4              |
| 16-2 140   | 111          | 1.3 11         | i4.8  | 93.6         | 94             | <u> </u>     | 58.5<br>SS 6 | 102.           | .0 1    | G4.1           | 195            | .5          | 101 5             |
| 10-2 145   | 115          | 5.8 10         | 8.7   | 162.0        | 162            | 0 40         | 58.2         | 102.           | .G 1    | G4.S           | 105            | .6          | 101.0             |
| 16-2 150   | 110          | 5.3 10         | 6.7   | 103.2        | 164            | 4 JU<br>4 JU | 5.0          | 108.           | 6 1     | 07,6           | 108.           | .1          | 102.10<br>104 c   |
| 10-2 ,00   | 116          | .1 10          | 7.3   | 152.6        | 154.           | 7 1(         | 10.0         | 116.           | 1 19    | 59.3           | 198.           | 5           | 163 2             |
| 10-2 165   | 118          | .3 10          | 9.1   | 102.2        | 404.)<br>100 - | 9 10         | 6.9          | 109.           | 6 1!    | 39.3           | 197.           | 2 (         | 100.2             |
| 10-2 100   | 117          | .9 15          | 3.3   | 93.9         | 100.           | > 10         | 9.9          | 111.4          | S 11    | 1.0            | 110.           | 6 4         | 06.5              |
| 10-2 100   | 117          | .e 10          | 5.1   | 56.4         | 100.5          | / 15         | 9.4          | 111.           | 5 11    | 1.0            | 110            | т<br>п 4    | 00.0              |
| 10-2 [1]   | 116          | .9 100         | s.2   | 00 1         | - 4125 J.      | 16           | ອ.1          | 111.0          | 11      | 1.4            | 110            | 7 4         | 00.5              |
| 10-2 (1)   | 116,         | 1 104          | .5    | 98 6         | 102.0          | 10           | 7.2          | 110.3          | 5 ii    | 5.6            | 150            | · 1<br>7 (  | 110,12<br>124 - 2 |
| 10-2 [89   | 116.         | 1 105          | .9    | 97 0         | 100.0          | 100          | 5.6          | 109.6          | 5 11    | 5.6            | 100 0          | - 1<br>-    | 04.1              |
| 10-2 185   | 116.         | 7 106          | .4    | 97 J         | 100.0          | 164          | 1,7          | 108.1          | 10      | 9.7            | 11034          | , 19<br>19  | JJ.1              |
| 10-3 [46   | 118.         | 0 108          | .5 11 | 14 O         | 100.3          | 104          | 1.6          | 108.6          | 11      | 0.5            | 444 4          | 2 10        | 10.1              |
| 10-3 [45   | 118.         | 9 197          | .2 10 | 16 I         | 102.4          | 168          | .7           | 112.0          | 111     | ).6            | 110.0          | , 11<br>, 1 | 11,1              |
| 10-5 [50   | 116.0        | 6 107          | .1 11 | 5 7          | 107.0          | 119          | .3           | 113.3          | 112     | 2.1            | 110.7          | 10          | 15.9              |
| 10-3 [55   | 120.         | 5 109          | .ŭ 10 | 5 4          | 108.0          | 115          | .8 ;         | 113.3          | 112     | 2              | 10.1           | 10          | 4.2               |
| 10-5 [65   | 120.1        | ) 107          | 10    | 5 2          | 109.3          | 115          | .5           | 114.6          | 113     | .3             | 110,4          | 10          | 4.2               |
| 10-5 [65   | 120.5        | 5 105          | 2 10  | 20           | 3.101.8        | 115          | .3 ;         | 114,5          | 113     | 2              | 112.0          | 10          | 7.7               |
| 10-5 [/6   | 119.1        | 197.           | 3 10  | 4 7          | 107.2          | 112.         | .6 1         | 14.4           | 114     | ż              | 411.0<br>417 ÷ | 19          | 7.4               |
| 10-3 [75   | 118.4        | 163.           | 7 513 | 1.5          | 199.0          | 110          | .3 1         | 13.1           | 113     | n .            | 110.0          | 150         | 3.1               |
| 10-3 [55   | 118.2        | 104.           | 7 c   | 57           | 104.6          | 169.         | 8 1          | 12.5           | 112     | .8             | 112.9          | 100         | 5.6               |
| 10-5 185   | 118.1        | 195            | 5 ი.  |              | 102.6          | 107,         | 6 1          | 11.3           | 112     | .3             | 112 6          | 10:         | >.1               |
| 10-4 [46   | 121.9        | 107.           | <br>} | 7 4          | 102.4          | 197,         | 6 1          | 17.9           | 112     | 1 1            | 112.0          | 107         | .5                |
| 10-4 [45   | 122.1        | 107.0          | 5 10. | . 1          | 09.1           | 112.4        | < i j        | 16,4           | 115     | 6 1            | 16.0           | 157         | ·.9               |
| 10-4 (55   | i21,7        | 196.1          | 100   | 5 1          | ti9.9          | 117.1        | l 11         | 6.7            | 115.    | ž i            | 14.5           | 109         | •6                |
| 10-4 L55   | 123.6        | 1/16.1         | 107   |              | 10.7           | 113.4        | 1 11         | 6.6            | 115     | 7 1            | 14.0           | 106         | •9                |
| 10-4 66    | 122.7        | 164.9          | 107   | •0 1         | 12.1           | 115.6        | 5 11         | 5.5            | 117.4   | · 1            | 16.5           | 105,        | .6                |
| 10-4 165   | 122.8        | 103 1          | 100   | ·0 1         | 19.1           | 114.8        | 11           | 7.8            | 116 :   |                | 19.4           | 110,        | .3                |
| 10-4 170   | 151.0        | 194.1          | 104   | · [ 1[       | 59.2           | 114.8        | 11           | 7.3            | 116 0   | - 11           | 19.2           | 109.        | .8                |
| 10-4 L75   | 119.7        | 101 4          | 102   | . 1(         | 35.8           | 112.3        | 11           | 5.6            | 115 7   | 1 1 1<br>1 1 1 |                | 109.        | .7                |
| 10-4 L85 - | 119.4        | 162 7          | 104.  | 1 10         | 16.1           | 111.2        | 11:          | 4.3            | 11/ 3   | . 11           | 3.8            | 167.        | 9                 |
| 10-4 L85   | 119.4        | 160.3          | 100,  | 9 10         | 1.1            | 109.3        | <b>i</b> 13  | 3.0            | 112 7   |                | 1./            | 105.        | 3                 |
| 10-5 L40   | 121.8        | 167 7          | 100.  | 4 10         | 4.2            | 109.0        | 112          | 2.7            | 113,1   | 11             | 3.6            | 108.        | 1                 |
| 10-5 L45   | 122.5        | 101.1          | 109.  | 4 11         | 0.2            | 113.0        | 116          |                | 115.6   | 11             | 3.8            | 108,        | 6                 |
| 10-5 L50   | 121.9        | 100.8          | 110.  | 7 11         | i.4            | 113.6        | 117          | · •            | 115.8   | 11             | 3.6            | 98.6        | 5                 |
| 10-5 L55   | 123 7        | 100.4          | 115.  | 2 11:        | 1.7            | 113.7        | 116          | -1             | 116.5   | 113            | 5.1            | 105.6       | 3                 |
| 10-5 L63   | 122 7        | 100-2          | 109.0 | 5 113        | 3.4 1          | 115.9        | 110          | ••             | 115.7   | 111            | 1.1            | 104.7       | r                 |
| 0-5 L65    | 123 7        | 104.8          | 158.9 | 5 111        | 1.6 1          | 15.3         | 110          | •• ]           | 116.8   | 114            | .3             | 108.7       | ,                 |
| 0-5 L70    | 121 6        | 102.0          | 106.7 | ′ <u>111</u> | .2 1           | 16.4         | 110          | • · · · ·      | 16.9    | 112            | ;.7            | 107.4       |                   |
| 0-5 L75    | 120 6        | 102.5          | 104.3 | 108          | .5 1           | 13.6         | 110          | • • <u>1</u>   | 16.4    | 115            | .9             | 169.0       |                   |
| 0-5 L6G    | 120 4        | 109.5          | 103.6 | 108          | .1 1           | 12.9         | 446          | ະ <b>ປ</b> ີ 1 | 15.6    | 113            | .2 ;           | 106.9       |                   |
| G-5 L85    | 120.9        | 100.8          | 102.5 | 105          | .9 1           | 11.1         | 413.         | 0 1            | 14.9    | 111            | .7 1           | 104.7       |                   |
|            |              | 100.6          | 101.6 | 105          | .9 1           | 10_6         | 414.<br>(14  | o 1<br>7       | 14.8    | 113.           | .7 1           | 07.7        |                   |
|            |              |                |       |              | -              |              | 114          | 5 1            | 14.8    | 113            | .8 1           | 07.7        |                   |
|            |              |                |       |              |                |              |              |                |         |                |                | •           |                   |

# NOTE: THESE ARE FREE FIELD VALUES

D230-

|           |        |       | HM-AP- | - 58-A | NOŻZI      | E TES  |        |               |       |
|-----------|--------|-------|--------|--------|------------|--------|--------|---------------|-------|
| RUN:NO.   | OASPL  | 500   | ١K     | 2K     | 4K         | 8K     | -16K   | 32K           | 54K   |
| 14-1 140  | 125.0  | 118.6 | 129.5  | 118.8  | -1-1-5 . 6 | 111-6  | 195 6  | 166 8         | 02 0  |
| 14-1 145  | 126.3  | 121-2 | 122.1  | -119.6 | 115 3      | 111 -5 | 167.6- | 300 A         | 100.5 |
| 14-1 150  | 123.8  | i16.0 | 119.7  | 117.7  | 114.7      | 111 2  | 167.1  | 233.4<br>CO 5 | 66.0  |
| 14-1 655  | 123.3  | 114.2 | 117.9  | 117.9  | 115 5      | 112 6  | 100 3  | 102.5         | 97.6  |
| 14-1 L60  | 121.0  | 110.4 | 114.6  | 115.0  | 114.3      | 112.3  | 158.6  | 161 7         | 36.2  |
| 14-1 L65  | 129.8  | 115.5 | 112.8  | 114.5  | 115.1      | 113.6  | 168.7  | 103.2         | \$5.6 |
| 14-1 (70) | 118.3  | 158.3 | 115.0  | 111.5  | 112.3      | 111.1  | 167.3  | 102 3         | 93.6  |
| 14-1 175  | 117.5  | 105.4 | 108.2  | 119.5  | 111.2      | 169.9  | 156.4  | 60.3          | 91 9  |
| 14-1 L80  | 115.9  | 158.4 | 108.4  | 158.4  | 110.1      | 159.4  | 195.5  | 100.2         | 93.0  |
| 14-1 L85  | 116.7  | 167.1 | 157.4  | 159.4  | 110.5      | 116.1  | 156.5  | 151.7         | 94.6  |
| 14-2 L40  | 132.9  | 125.1 | 128.8  | 127.5  | 125.7      | 121.9  | 115 9  | 113.6         | 100 6 |
| 14-2 L45  | 134.5  | 127.8 | 129.2  | 128.2  | 126.4      | 122.6  | 110.1  | 116.2         | 110 7 |
| 14-2 650  | 132.5  | 122.1 | 126.8  | 127.4  | 125.4      | 121.6  | 118.2  | 112 0         | 157 4 |
| 14-2 L55  | 132.1  | 119.9 | 125.4  | 127.3  | 125.2      | 122.4  | 119.6  | 114 0         | 169 1 |
| 14-2 L60  | 129.4  | 115.9 | 121.9  | 123.9  | 123.0      | 121.3  | 118.2  | 112 5         | 167.6 |
| 14-2 L65  | 128.1  | 114.5 | 115.8  | 121.9  | 122.7      | 129.9  | 117.5  | 112 8         | 106 0 |
| 14-2 170  | 125.8  | 112.7 | 115.6  | 118.7  | 120.2      | 119.5  | 116.4  | 111.6         | 152.7 |
| 14-2 L75  | 124.4  | 115.0 | 114,9  | i17.5  | 118.8      | 116.1  | 115.2  | 158.8         | 161.1 |
| 14-2 L80  | 123.1  | 115.8 | 112.1  | 115.2  | 117.2      | 117.0  | 114.2  | 115.1         | 102.9 |
| 14-2 L85  | 123.7  | 111.3 | 112.4  | 115.8  | 117.7      | 118.0  | 115.0  | 116.7         | 103.4 |
| 14-3 L40  | 135.1  | 127.3 | 129.1  | 129.7  | 127.4      | 124.0  | 119.3  | 115.2         | 112.3 |
| 14-3 L45  | 136.9  | 139.2 | 131.6  | 139.6  | 128.4      | 125.0  | 121.2  | 116.4         | 113.1 |
| 14-3 L50  | 135.5  | 124.6 | 129.3  | 139.3  | 129.0      | 125.3  | 122.0  | 116.0         | 111.4 |
| 14-3 L55  | 135.1  | 121.7 | 127.5  | (39.2  | 125.7      | 126.1  | 123.8  | 118.3         | 113.6 |
| 14-3 63   | 132.5  | 118.3 | 124.5  | 126.9  | 126.4      | 124.6  | 121.8  | 116.5         | 112.0 |
| 14-3 L65  | 139.7  | 116.2 | 121.1  | 124.1  | 125.4      | 123.8  | 120.5  | 116.8         | 110.3 |
| 14-3 170  | 129.2  | 114.7 | 118.3  | 121.6  | 123.4      | 123.2  | 125.6  | 116.5         | 108.3 |
| 14-3 175  | 127.4  | 111.8 | 116.1  | 119.8  | 121.8      | 121.7  | 118.8  | 112.7         | 105.2 |
| 14-3 685  | 125.2  | 112.4 | 114.4  | 117.5  | 125.1      | 120.9  | 117.8  | 113.8         | 196.8 |
| 14-3 L85  | 128.9  | 113.0 | 114.3  | 117.7  | 121.5      | 121.7  | 118.7  | 114.9         | 108.2 |
| 14-4 [45  | 135,6  | 128.9 | 135.1  | 135.1  | 126.9      | 123.3  | 118.0  | 114.3         | 111.3 |
| 14-4 [45  | 137.6  | 131.4 | 132.7  | 131.4  | 128.5      | 124.8  | 125.7  | 115.4         | 113.1 |
| 14-4 [55  | 136.4  | 126.0 | 139.5  | 131.4  | 129.6      | 125.7  | 121.8  | 115.5         | 111.3 |
| 14-4 1.55 | 135.4  | 123.3 | 129.0  | 131.6  | 135.1      | 127.2  | 124.0  | 118.2         | 113.5 |
| 14-4 [60  | 133.4  | 119.4 | 125.9  | 128.1  | 127.4      | 125.0  | 121.3  | 115.2         | 116.3 |
| 14-4 65   | 132.3  | 118.9 | 123.1  | 126.1  | 127.2      | 125.0  | 120.9  | 116.2         | 109.4 |
| 14-4 [75  | 129.8  | 116.2 | 119.4  | 122.5  | 124.2      | 123.7  | 120.2  | 115.2         | 106.5 |
| 14-4 [/5  | 128.7. | 113.3 | 117.2  | 121.1  | 123.5      | 123.0  | 119.4  | 112.9         | 195.3 |
| 14-4 189  | 128.9  | 113.7 | 115.5  | 119.1  | 122.5      | 122.9  | 119.3  | 115.0         | 107.9 |
| 14-5 [49  | 138.1  | 131.5 | 132.6  | 132.2  | 129.3      | 126.1  | 121.6  | 118.8         | 115.6 |
| 14-5 [45  | 140.1  | 134.1 | 135.2  | 133.6  | 130.7      | 127.5  | 124.1  | 119.6         | 116.6 |
| 14-5 155  | 138.7  | 126.2 | 132.9  | 133.7  | 101.6      | 128.1  | 124.7  | 118.9         | 114,5 |
| 14-5 160  | 159.2  | 125.5 | 131.6  | 134.2  | 133.0      | 130.2  | 127.7  | 122.7         | 118.6 |
| 14-5 165  | 135.6  | 120.9 | 127.7  | 139.0  | 129.6      | 127.5  | 124.6  | 119.3         | 114.9 |
| 14-5 170  | 134.5  | 129.3 | 124.5  | 127.7  | 129.1      | 127.8  | 124.4  | 125.8         | 114.7 |
| 14-5 + 75 | 126.3  | 11/./ | 125.7  | 124.4  | 126.5      | 126.6  | 123.5  | 119.4         | 111.1 |
| 14_5 1 00 | 131.3  | 114.9 | 118.7  | 123.1  | 126.0      | 126.0  | 122.8  | 117.3         | 110.6 |
| 14-5 1 85 | 129.0  | 112.5 | 117.3  | 121.1  | 125.0      | 125.5  | 122.4  | 118.9         | 112.6 |
| 47-0 LUU  | 101.1  | 112.4 | 110.0  | 121.6  | 126,5      | 126.4  | 123.5  | 120.1         | 114.5 |

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# NOTE: THESE ARE FREE FIELD VALUES

D231

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#### HM-AP-59-A NOZZLE

### ( 42 TUBES, 12 LOBE SPGKE ENDS, ANNULAR ARRAY, AR.8.3)

#### Description:

The HM-AP-59-A nozzle is a 42-tube annulus array with 21 tubes in the outer row and 21 tubes in the inner row. The tube terminations are individual 12-spoke nozzles.

Number of Elements: 42 tubes with 12-spoke nozzle type ends

Area Ratio: 8.3

Tube Spacing (between inner and outer rows): 1.35 inches

Flow Area: 15 square inches

Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Terminations: 12 spokes with AR = 1.86

75% spoke penetration 0.92 inches outside diameter A<sub>F</sub> = 0.357 square inches 0 degrees exit cant angle 77 degrees ventilation gutter cant angle

Material: 321 CPES



NO PICTURE AVAILABLE

#### D232





D234

1.00

## HM-AP-59-A NOZZLE

(42 Tube Annulus Array, Two Rows of Tubes)

#### Remarks

The HM-AP-59-A Nozzle tests indicated that a two row annulus array of 42 tubes does not approach the degree of noise suppression that can be attained with a hexagonal array of 37 tubes (HM-AP-41). The annulus configuration had a peak suppression value of 11 PNdB while the hexagonal array had a peak value of 17 PNdB. See Reference D28.

# HM-AP-59-A NOZZLE

Test Facility: HNTF

Date:

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Tamb:

R.H.:

| Run No.                              | PT/P∞                           | $\underline{\mathrm{Tr}}$  | $V_{J}$ (Ideal)                          | Nozzle                                         |
|--------------------------------------|---------------------------------|----------------------------|------------------------------------------|------------------------------------------------|
| 25.1<br>25.2<br>25.3<br>25.4<br>25.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4 | 1500°F<br>"<br>"<br>"<br>" | 1750 fps<br>2202<br>2402<br>2555<br>2678 | HM-AP-59-A<br>"<br>"<br>"                      |
| 14.1<br>14.2<br>14.3<br>14.4<br>14.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4 | 1500°F<br>"<br>"<br>"<br>" | 1750<br>2202<br>2402<br>2555<br>2678     | 4.1 Inch Round Convergnt Nožzle<br>"<br>"<br>" |

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|                      | HM-AP-59-A NOZZLE TEST DATA |              |             |         |         |         |         |                    |              |
|----------------------|-----------------------------|--------------|-------------|---------|---------|---------|---------|--------------------|--------------|
|                      |                             | OCT          | TAVÉ BA     | ND LEV  | ℇ⅃~ⅆ₿   | RE: 0.0 | 002 DYN | ES/CM <sup>2</sup> | // 25 FT     |
| RUN NO.              | OASPL                       | 500          | 1K          | 2K      | 4K      | 8K      | 16K     | 32K                | 64K          |
| 25-1 140             | 108.2                       | 9.62         | 94.1        | 95.9    | 99.0    | 99.6    | 99.6    | 102.2              | 99.5         |
| 25-1 L45             | 107.7                       | 96.4         | 95.7        | 96.8    | 99.1    | 99.9    | 101.1   | 100.7              | 95,6         |
| 25-1-150             | 108.4                       | 96.5         | 95.6        | 98.0    | 100.4   | 165.9   | 101.6   | 100.8              | 97.1         |
| 25-1 L55             | 110.4                       | 100.5        | 95,0        | 99.0    | 101.9   | 193.7   | 103.5   | 102.6              | 98.5         |
| 25-1 (୧)             | 110.0                       | \$6.5        | 93.4        | 96.6    | 160.4   | 103.1   | 194.2   | 193.2              | 100.0        |
| 25-1 L65             | 113.4                       | 93.5         | 91.6        | 95.6-   | 100.6   | 104.1   | 109.2   | 108.8              | 101.6        |
| 25-1 170             | 109.6                       | 95.1         | 59.9        | 94.2    | \$9.2   | 101.9   | 104.6   | 153,7-             | 99.0         |
| 25-1 L75             | 107.6                       | <u>9</u> 3.2 | 89.3        | 93,6    | -98.7   | 101.2   | 102.5   | 100.3              | 95.7         |
| 25-1 L80             | 107.5                       | 94,4         | 89.7        | 92.4    | 97.5    | 99.6    | 102.2   | 102.0              | 95.9         |
| 25-1 L85             | 109.5                       | 95.2         | 88.6        | 93.0    | 97.8    | 151.6   | 165.8   | 104.5              | 100.3        |
| 25-2 L40             | 113.3                       | SD.4         | <b>98.7</b> | 101.5-  | 196.2   | 106.9   | 105.8   | 169.2              | 103.0        |
| 25-2 145             | 114,0                       | \$9.1        | 99.8        | 162.1   | 106.6   | 197.5   | 107.7   | 156.3              | 100.6        |
| 25-2 L59             | 113.6                       | 97.5         | 100.1       | 163.0   | 106.6   | 107.2   | 107.5   | 105.4              | 101.2        |
| 25-2 L55             | 116.4                       | S8.1         | \$9.5       | 104.4   | 108.6   | 115.4   | 119.6   | 158.8              | 104.5        |
| 25-2 L60             | 116.2                       | 96.1         | \$5.0       | 152.8   | 107.9   | 115.2   | 110.5   | 108.8              | 105.3        |
| 25-2 L65             | 119.3                       | \$4.1        | 55,3        | 161.5   | 107,3   | 110.8   | 115.3   | 114.2              | 106.6        |
| 25-2 170             | 115.1                       | 93.3         | 94.9        | 99.7    | 105.5   | 158.2   | 119.5   | 108.8              | 103.3        |
| 25-2 L75             | 113.3                       | 91.1         | 93.2        | 96.6    | 104.8   | 197.5   | 168.4   | 155.4              | 100.4        |
| 25-2 L80             | 113.9                       | 91.4         | 92.6        | \$7.3   | 193.6   | 105.8   | 108.9   | 108.8              | 103.0        |
| 25-2 L85             | 114.8                       | \$5.9        | 95.9        | 97.8    | 164.1   | 107.5   | 169.5   | 109.6              | 104.9        |
| 25-3 140             | 117.3                       | 103,4        | 102.2       | 164.6   | 169.3   | 111.4   | 115.2   | 116.1              | 106.2        |
| 25-3 (45             | 116.9                       | 102.5        | 163.0       | 104.4   | 109.2   | 111.0   | 110.9   | 108.9              | 102.4        |
| 25-3 L50             | 116.7                       | 101.2        | 103.3       | 165.3   | 169.3   | 110.7   | ii0.6   | 107.9              | 102.8        |
| 25-3 L55             | 118.1                       | 191.6        | 102.8       | 106.6   | 111.5   | 112.4   | 111.7   | 169.7              | <b>154.8</b> |
| 25-3 [6]             | 118.5                       | 95.2         | 151.2       | 195.1   | 110.2   | 115-5   | iič.(   | 115.7              | 106.6        |
| 20-3 L65             | 151.5                       | 97.2         | 99.6        | 163.6   | 169.9   | 113.6   | 117.3   | 115.5              | 107.5        |
| 25-3 [70             | 116.4                       | 96.4         | 98.1        | 102.0   | 107.8   | 110.3   | 111.5   | 169.1              | 163.1        |
| 25-5 L75             | 114.5                       | 94.1         | £6.3        | 155.6   | 136.6   | 109.1   | 109.5   | 106.1              | 100.5        |
| 25-3 160             | 114.4                       | 94.4         | 95.5        | 99.4    | 95,3    | 107.6   | 109.9   | 169.5              | 103.0        |
| 25 4 140             | 113.7                       | 94.G         | 95.4        | 99.6    | 105.3   | 108.6   | 99.9    | 169.0              | 103.7        |
| 25-4 [40             | 125.3                       | 166.6        | 104.6       | 106.5   | 111.6   | 114.5   | 113.6   | 113.4              | 169.0        |
| 25-4 [45             | 119.5                       | 195.6        | 105.5       | 106.6   | 111.1   | 114.2   | 113.8   | 115.7              | 103.2        |
| 25-4 [55             | 119,5                       | 194.2        | 165.9       | 107.4   | 111.5   | 114.0   | 113.8   | 115.6              | 105.2        |
| 25-4 (55             | 121.2                       | 104.8        | 105.1       | 169.4   | 113,4   | 115.7   | 115.1   | 112.8              | 107.8        |
| 25-4 [0]             | 121.1                       | 101.9        | 103.5       | 107.8   | 113.1   | 116.1   | 115.2   | 112.7              | 158.6        |
| 25-4 [05             | 124.2                       | 100.2        | 102.2       | 106.7   | 112.8   | 117.5   | 120.3   | 118.5              | 110.4        |
| 25-4.11              | 120.4                       | \$9.0        | 100.6       | 164,7   | 110.9   | 114.3   | \$15.7  | 113.4              | 107.7        |
| 25-4 [15             | 118.8                       | 96.9         | 99.2        | 194.0   | 115.3   | 113.6   | 113,9   | 115.1              | 104.5        |
| 25-4 180             | 126-1                       | -156.9       | -158.2-     | -112.4- | -116-4- |         | 4:3.8-  | -122.1-            | -115.6-      |
| 23-4 [63             | +===                        | 156,3        | -197.9-     | -112.4  | -118.1- | -121.6- | -123.8- |                    |              |
| 20-0 (^()<br>25 5 45 | 177.1                       | 200.0        | 107.3       | 197.9   | 112,7   | 113.4   | C.311   | 115.0              | 110.7        |
| 25 5 5 5 C           | <b>2.</b> 551               | 108.4        | 157.8       | 108.7   | 113.2   | 116.8   | 117.9   | 113.7.             | 106.5        |
| 25-5 155             | 121.9                       | 156.7        | 157.9       | 108.8   | 113.3   | 116.5   | 116.5   | 112.9              | 107.2        |
| 25-5 + 63            | 123.2                       | 107.5        | 197.5       | 111.1   | 114.9   | 117.9   | 117.4   | 114.7              | 109.4        |
| 25-5 165             | 123.4                       | 104.0        | 105.9       | 119.1   | 115.2   | 118.2   | 117.7   | 115.1              | 110.8        |
| 25_5 + 76            | 122.2                       | 102.5        | 104.3       | 198.4   | 114.6   | 119.5   | \$22.3  | 125.1              | 112.5        |
| 25_5 + 75            | 122.0                       | 101.2        | 102.9       | 156.8   | 113.0   | 116.9   | 118.1   | 115.2              | 109.1        |
| 25_5 100             | 122.0                       | <u>5</u> 2.9 | 101.5       | 105.7   | 112.2   | 115.8   | 116.2   | 112.1 -            | 106.2        |
| 25-5 1 65            | 120.6                       | 99.4         | 100.5       | 104.3   | 110.4   | 114.5   | 116.2   | 114.8              | 108.6        |
| FOR                  | 151.2                       | 20.6         | 100.0       | 104.6   | 110,6   | 114.9   | 115.3   | 115.5              | 109.9        |

NOTE: THESE ARE FREE FIELD VALUES

|     | HM-AP-59-A NOZZEE TEST DATA |                |       |        |        |               |         |       |          |       |   |
|-----|-----------------------------|----------------|-------|--------|--------|---------------|---------|-------|----------|-------|---|
| Ř   | UN NÔ.                      | OASPL          | 500   | 1K     | 2K.    | 4K            | -8K     | 16K   | 32K      | -64K  | - |
| 1   | 4-1 640                     | 125.0          | 118.6 | 125.5  | 118.6  | 115.6         | 11-1-,6 | 195.6 | 100.8    | 98.9  |   |
| 17  | 4-1 t45                     | 126.3          | 121.2 | 122.1  | 119.5  | 115.3         | 111.5-  | 197.9 | 195.4    | 100.5 |   |
| 1   | 4-1 150                     | 123.8          | 116.0 | 119.7  | 117.7  | 114.7         | 111.2   | 167.1 | S9.5     | 96.8  | : |
| 1-  | 4-1 L55                     | 123.3          | 114.2 | 117.9  | 117.9  | 145,5         | 112.8   | 109,3 | 102.5    | 97.6  |   |
| 1.  | 4-1 LEG                     | 121.0          | 115.4 | 114.6  | 115.0  | 114.3         | 112.3   | 108.6 | 151.7    | 96.2  | - |
| 1   | 4-1 L65                     | 120.8          | 115.6 | 112.8  | 114.5  | 115.1         | 113.0   | 108.7 | 103.2    | 95.6  |   |
| 1   | 4-1 670                     | 118.3          | 108.3 | 115.5  | 11-1.6 | 112.3         | 111.Ī   | 107.3 | 152.3    | 93.8  |   |
| 1.  | 2-1 175                     | 117.0          | 1.5.4 | 103.2  | 110.5  | 111.2         | 169.9   | 198.4 | 99.3     | 91.9  | - |
| 1.  | 4-1 187                     | 115.9          | 138.4 | 156.4  | 158.4  | 110.1         | 459.1   | 105.5 | 150.2    | 93.0  |   |
| 1   | 6-1 165                     | 116.7          | 157.1 | 157.4  | 169.4  | 110.5         | 116.1   | 196.5 | 101.7    | 94.6  |   |
| 1.  | 4÷2 L40                     | 132.9          | 125.1 | 125.8  | 127.5  | 125.7         | 121.9   | 116.9 | 113.6    | 159.8 | - |
| 1-  | 4-2 L45                     | 134.5          | 127.5 | 129.2  | 128.2  | 126.4         | 122.6   | 119.1 | 114.2    | 115.7 |   |
| 1.  | 4-2 655                     | 132.5          | 122.1 | 126.8  | 127.4  | 125.4         | 121.6   | 118.2 | 112.0    | 107-4 |   |
| 1.  | 4-2 L55                     | 132.1          | 119.9 | 125.4  | 127.3  | 125.2         | 122.4   | 119.6 | 114.0    | 109.0 | = |
| 1.  | 4-2 L60                     | 129.4          | 115.9 | 121.9  | 123.9  | 123,0         | 121.3   | 118.2 | 112.5    | 107.6 | - |
| 14  | 4-2 L65                     | 128.1          | 114.5 | 118.5  | 121.9  | 122.7         | 129,9   | 117.6 | 1-12.8   | 106,0 |   |
| 14  | 4-2 176                     | 125.8          | 112.7 | 115.6  | 118.7  | 150.5         | 119.5   | 116,4 | 111.6    | 102,7 |   |
| 14  | 4-2 L75                     | 124.4          | 110.0 | 114.0  | 117.5  | 118,8         | 118.1   | 115.2 | 138.8    | 161.1 |   |
| 14  | 4-2 L80                     | 123.1          | 115.6 | 112.1  | 115.2  | 117.2         | 117.0   | 114.2 | 110.1    | 152.9 |   |
| 14  | 4-2 L85                     | 123.7          | 111.3 | 112.4  | 115,8  | 117.7         | 118.9   | 115.9 | 115.7    | 103.4 |   |
| 14  | 4-3 140                     | 135.1          | 127.3 | 129.1  | 129.7  | 127.4         | 124.5   | 119.3 | 116.2    | 112.3 |   |
| 14  | 4-3 L45                     | 136.9          | 139.2 | 131.6  | 139.6  | 128.4         | 125.9   | 121.2 | 116.4    | 113.1 |   |
| 14  | 4-3 L50                     | 135.5          | 124.6 | 129.3  | 130.5  | 129.5         | 125.3   | 122.0 | 116.0    | 111.4 |   |
| 14  | 4-3 L55                     | 135.1          | 121.7 | 127.5  | 139.2  | 123.7         | 125.1   | 123.6 | 118.3    | 113.6 |   |
| 14  | 4-3 LGD                     | 132.5          | 118.3 | 124,5  | 126.9  | 126.4         | 124.6   | 121.6 | 116.5    | 112.0 |   |
| 14  | 4-3 L65                     | 130.7          | 116.2 | 121.1  | 124.1  | 125.4         | 123.8   | 120.5 | 116.8    | 110.3 |   |
| 14  | 1-3 L/G                     | 129.2          | 114,7 | 118.3  | 121.6  | 123.4         | 123.2   | 120.5 | 116.5    | 108.3 |   |
| 1-  | 1-3 L75                     | 127.4          | 111.8 | 116.1  | 119.8  | 121.5         | 121.7   | 118.6 | 112.7    | 195.2 |   |
| 14  | -3 LSG                      | 126.2          | 112.4 | 114.4  | 117.5  | 125.1         | 125.9   | 117.8 | 113.6    | 196.8 |   |
| 14  |                             | 126.9          | 113.6 | 114.3  | 117.7  | 121.5         | 121.7   | í18.7 | 114.9    | 108.2 |   |
| 12  |                             | 135.6-         | 128.9 | 130.1  | 135.1  | 126.9         | 123.3   | 118.0 | 114.3    | 111.3 |   |
| 14  | -4 L45                      | 137.6          | 131.4 | 132.7  | 131.4  | 128.5         | 124.8   | 125.7 | 115.4    | 113:1 |   |
| 14  | ·                           | 136.4          | 126.0 | 139.5  | 131,4  | 129.6         | 125.7   | 121.8 | 115.5    | 111.3 |   |
| 14  |                             | 136.4          | 123.3 | 129.0  | 131.6  | 135.1         | 127.2   | 124.0 | 118.2    | 113,5 |   |
| 14  | 1-4 L00                     | 133.4          | 119.4 | 125,9  | 128.1  | 127.4         | 125.0   | 121.3 | 115.2    | 119.3 |   |
| 14  |                             | 132.3          | 118.9 | 123.1  | 126.1  | 127.2         | 125.0   | 120.9 | 116.2    | 109.4 |   |
| 1.4 | -4 [7]                      | 129.8          | 116.2 | 119.4  | 122.5  | 124.2         | 123.7   | 120.2 | 115.2    | 156.5 |   |
| 14  |                             | 128.7.         | 113.3 | 117.2  | 121.1  | 123.5         | 123,0   | 119,4 | 112.9    | 195.3 |   |
| 14  | LOU                         | 128.0          | 113.7 | 115.5  | 119.1  | 122.5         | 122.9   | 119.3 | 115.0    | 107.9 |   |
| 1-  |                             | 126.9          | 114.3 | 115.3  | 119,7  | 123.7         | 123.7   | 129.4 | 116.2    | 109.5 |   |
| 14  | -5 [40                      | 133.1          | 131.5 | 132.6  | 132.2  | 129.3         | 126,1   | 121.6 | 118.8    | 115.6 |   |
| 14  | 15 150                      | 140.1          | 134.1 | 1.00.5 |        | 1 i i i i i i | 121.5   | 141.1 | فالمعاشة | 110.3 |   |
| 14  |                             | 138.7          | 125.2 | 132.9  | 133.7  | 131.6         | 128.1   | 124.7 | 118.9    | 114.5 |   |
| 1.4 | -5 (6)                      | 139.2          | 125.5 | 131.6  | 134.2  | 133.0         | 130.2   | 127.7 | 122:7    | 118.6 |   |
| 14  | -5   65                     | 137.0          | 129.9 | 12/11  | 139.0  | 129.6         | 127.5   | 124.6 | 119.3    | 114.9 |   |
| 14  | -5 1 70                     | 154.5          | 121.5 | 124.5  | 127.7  | 129.1         | 127.6   | 124.4 | 129.8    | 114.7 |   |
| 14  | -5 175                      | 17C.5<br>121 2 | 111.7 | 140.2  | 124.4  | 120,0         | 120.0   | 123.5 | 119.4    | 111.1 |   |
| 14  | -5 180                      | 131.5          | 117.3 | 110.1  | 121 4  | 126.0         | 170°0   | 162.6 | 117.5    | 119.6 | - |
|     |                             | 10010          | 117.2 | 111.2  | 161.1  | 152.0         | 152*2   | 122.4 | 118.9    | 112.6 |   |

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# NOTE: THESE ARE FREE FIELD VALUES

14 A.



#### HM-AP-59-B NOZZLE (42TUBES ANNULAR ARRAY, 2ROWS of TUBES, AR-8.3) Description:

The HM-AP-59B nozzle is a 42 tube annulus array with 21 tubes in the outer row and 21 tubes in the inner row. The tube terminations in the outer row are individual 12-spoke nozzles. The tubes in the inner row have round convergent ends.

Number of Elements: 42 Area Ratio: 8.3 Tube Spacing (between inner and outer rows): 1.35 Inches Flow Area: 15 Square Inches Exit Cant Angle: O Degrees Length of Tubes: 7 Inches

Tube Terminations:

- a. Outer Row of 11 Tubes 12 spokes with AR = 1.86 75% spoke penetration 0.92 inches outside diameter  $A_F = 0.357$  square inches 0 degree exit cant angle 77 degree ventilation gutter cant angle
- b. Inner Row of 11 Tubes 0.674 inch diameter flow exit 0.63 inch long convergent section

3

Material: 321 CRES





A LEASE STATES

\_\_\_\_\_J D241

### HM-AP-59-B NOZZLE

(42 Tube Annular Array, Two Rows of Tubes)

#### Remarks

111

This nozzle consisting of equal numbers of 12-lobe spokes and round convergent nozzle terminated tubes. The jet noise suppression characteristics are about 2 PNdB (or dB) less when compared to the case where all tubes had 12-lobe spoke ends (HM-AP-59-A Nozzle). Neither nozzle approached the degree of suppression attained by a 37 tube, 12-spoke ends, hexagon array (HM-AP-41). See Reference. D28.

# HM-AP-59-B NOZZLE

Test Facility: HNTF

Date:

NUMBER OF

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Tent.

5.2.:

| Run llo.                             | $P_{T}/P_{\bullet}$             | TI                         | $V_{J}$ (Ideal)                          | Nozzle                                           |
|--------------------------------------|---------------------------------|----------------------------|------------------------------------------|--------------------------------------------------|
| 26.1<br>26.2<br>26.3<br>26.4<br>26.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4 | 1500°r<br>"<br>"<br>"<br>" | 1750 fps<br>2202<br>2402<br>2555<br>2678 | HM-AP-59-B<br>"<br>"<br>"                        |
| 14.1<br>14.2<br>14.3<br>14.4<br>14.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4 | 1500°F<br>"<br>"<br>"      | 1770 fps<br>2202<br>2102<br>2595<br>2678 | 4.1 Inch Round Convergent Nozzle<br>""<br>"<br>" |

D243

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# HM-AP-59-B NOZZLE TEST DATA OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM<sup>2</sup>//25 FT

| RUN NO.   | OASPL | 500   | ١K    | 2K     | 4K     | 8K     | 16K    | 32K    | 64K   |
|-----------|-------|-------|-------|--------|--------|--------|--------|--------|-------|
| 26-1 140  | 169.2 | \$3.4 | 95.4  | 99.8   | 102.6  | 102.1  | 105.8  | 1012   | 95.9  |
| 26-1 645  | 119.4 | 92.9  | \$6.5 | 101.1  | 104.1  | 103.8  | 103.3  | 101.8  | \$5.7 |
| 26-1 L50  | 111.6 | 92.4  | \$6.7 | 152.6  | 106.2  | 105.4  | 154.7  | 155.6  | 95.8  |
| 26-1 L55  | 114.5 | 91.5  | 95.9  | 103.1  | 168.5  | 410.1  | 108.0  | 104.6  | \$9.1 |
| 26-1 160  | 115.9 | 93.7  | 93.9  | 101.5  | 108.0  | 111.8  | 110.2  | 105.8  | 123.7 |
| 26-1 L65  | 115.7 | 69.9  | 92.6  | 100.4  | 198.2  | 111.1  | 119.1  | 167.1  | 100.0 |
| 26-1 170  | 114.5 | 91.3  | 8.62  | 97.9   | 106.0  | 119.3  | 169.6  | 105.2  | \$8.5 |
| 26-1 175  | 113.5 | 87.4  | 69.63 | 97.0   | 105.1  | 108.9  | 109.1  | 103.8  | \$8.5 |
| 26-1 L80  | 112.4 | 88.1  | 88.7  | 95.3   | 102.9  | 107.6  | 107.5  | 104.8  | 97.5  |
| 26-2 L40  | 115.9 | 99.8  | 105.5 | 103.6  | 108.0  | 109.2  | 169.2  | 109.0  | 105.2 |
| 26-2 L45  | 116.8 | 5.82  | 101.2 | 104.7  | 169.1  | 110.6  | 311.3  | 109.0  | 102.1 |
| 26-2-150  | 118.1 | 98.3  | 101.9 | 106.6  | 110.7  | 112.3  | 113.1  | 108.7  | 102.6 |
| 26-2 L55  | 121.2 | 97.4  | 101.3 | 107.8  | 113.5  | 116.1  | 315.8  | 112.7  | 156.5 |
| 20-2 L60  | 122.5 | \$8.3 | 99.4  | 156.0  | \$12.9 | 116.1  | 117.6  | 113.7  | 108.4 |
| 20-2 L65  | 122.3 | 95.3  | 98.1  | 104.9  | 113.2  | 117.2  | 117.4  | 115.0  | 1.3.6 |
| 26-2 1.70 | 121.9 | 95.6  | 96.4  | 103.0  | 111.8  | 117.0  | 117.7  | 113.9  | 155.7 |
| 26-2 L75  | 120.7 | 92.8  | 94.6  | 101.8  | 110.6  | 115.6  | 116.8  | 111.9  | 104,9 |
| 26-2 L60  | 123.2 | 93.5  | 94.4  | 100.1  | 108.3  | 114.4  | 115.9  | 113.9  | 107.0 |
| 26-2 L8   | 123,3 | \$2.5 | 94.0  | 100.2  | 108.1  | 114.2  | 115.8  | 114,3  | 108.3 |
| 26-3 L40  | 118.5 | 192.8 | 103.0 | 105.6  | 115.2  | 112.4  | 112.1  | 111.5  | 105.9 |
| 26-3 L45  | 119.0 | 105.0 | 103.7 | 166.5  | 111.0  | 113.3  | 113.5  | 111.2  | 103.5 |
| 26-3 150  | 119.8 | 101.1 | 104.3 | 107.9  | 112.1  | 114.1  | 114.7  | 110.4  | 104.0 |
| 26-3 L55  | 122.5 | 160.0 | 103.9 | 109.9  | 115.1  | 117.0  | 117.0  | 114.2  | 107.9 |
| 26-3 LÊG  | 154.0 | 199.8 | 102.0 | 108.3  | 115.1  | 119.4  | 119.0  | 115.4  | 115.4 |
| 26-3 265  | 124.3 | 2.82  | 101.0 | 167,1  | 115,0  | 119.3  | 119.3  | 116.7  | 110.4 |
| 26-3 L70  | 123.9 | 98.4  | 99.2  | 165.1  | 113.7  | 115.9  | 119.9  | 115.8  | 157.9 |
| 26-3 L75  | 122.9 | 95.3  | 97.3  | 1.04.2 | 113.0  | 118.9  | 119.0  | 113.7  | 106.7 |
| 26-3 L60  | 122.5 | 95.8  | 96.8  | 152.4  | 110.8  | 116.0  | 118.2  | 116.0  | 169.2 |
| 26-3 L85  | 122.4 | 95.1  | 96.5  | 152.4  | 110.3  | 115.6  | 118.1  | 118.4  | 1.5.  |
| 26-4 L40  | 121.6 | 105.7 | 195.9 | 157.9  | 112.2  | 115.5  | 115.9  | 114.8  | 115.0 |
| 26-4 L45  | 122.1 | 164.7 | 165.3 | 158.6  | 113.0  | 116.3  | 117.2  | 114.5  | 106.6 |
| 26-4 150  | 122.4 | 193.7 | 106.9 | 169.7  | 114.1  | 116.6  | 127.7  | 112.9  | 196,7 |
| 2E-4 L55  | 124.8 | 102.4 | 196.3 | 111.7  | 116.4  | 119.3  | 119.7  | 116.6  | 110.5 |
| 26-4 160  | 125.9 | 102.8 | 194.5 | 110.2  | 116.8  | 121.2  | 121.0  | 117.2  | 112.6 |
| 26-4 LG5  | 126.2 | 103.4 | 103.4 | 198.9  | 116.6  | 121.2  | 121.4  | 118.7  | 112.8 |
| 26-4 L70  | 125.8 | 100.9 | 101.7 | 107.4  | 115.4  | 120.9  | 121.8  | 117.3  | 109.6 |
| 26-4 175  | 124.8 | 97.6  | \$9.7 | 166.1  | 114.9  | 119.8  | 121.0  | 115.5  | 108.6 |
| 26-4 LSO  | 123.6 | 98.1  | 99.3  | 104.4  | 112.1  | 116.1  | 119.4  | 116.6  | 109.6 |
| 26-4 185  | 155.0 | \$7.3 | 98.7  | 103.7  | \$10.8 | 116.6  | 117.8  | 114.8  | 108.1 |
| 26-5 L40  | 124.0 | 103.3 | 107.6 | 109.6  | 114.0  | 118.0  | 118.7  | 117.0  | 11Ž.6 |
| 26-5 L45  | 123.9 | 107.2 | 198.0 | 110.1  | 114.3  | 118.2  | 119.2  | 115.9  | 108.5 |
| 26-5 150  | 124.0 | 105.0 | 108.6 | 111.0  | 115.4  | \$18.6 | 119.5  | 114.2  | 109.2 |
| 26-5 L55  | 126.0 | 104.5 | 108.1 | 113.1  | 117    | :20.7  | 121.1  | 117.6  | 111.8 |
| 26-5 65   | 126.8 | 104.6 | 166.2 | 112.0  | 118.1  | 122.0  | 121.7  | 117.8  | 113.1 |
| 26-5 L65  | 127.0 | 162.2 | 105.2 | 110.9  | 117.8  | 122.2  | 121.9  | 119.1. | 113.2 |
| 26-5 L70  | 126.2 | 102,5 | 103.5 | 158.6  | 116,2  | 121.4  | 122.1  | 117.1  | 109.2 |
| 26-5 L75  | 125.2 | \$¥.5 | 101.5 | 107.7  | 115.9  | 120.4  | 121.2  | 115,1  | 108.1 |
| 26-5 185  | 124.j | 59.9  | 101.0 | 165.7  | 113.2  | \$19.5 | \$19.8 | 116.5  | 109.3 |
| 26-5 L65  | 123.3 | SS.A  | 100.4 | 105.0  | -111-9 | 118.2  | 119.1  | 115.9  | 109.1 |

### NOTE: THESE ARE FREE FIELD VALUES

| RUN NO.   | OASPL  | 500   | =1K   | 2K     | 4K     | 8K     | 16K    | 32K   | (   |
|-----------|--------|-------|-------|--------|--------|--------|--------|-------|-----|
| 14-1 145  | 125.0  | 118.6 | 120.5 | 118.8  | 115.6  | 111.6  | 105 6  | 109.8 |     |
| 14-1 : 45 | 126.3  | 121.2 | 122.1 | -119.0 | 115.3  | .111.5 | 167.6  | 100.4 | 11  |
| 14-1 150  | 123.8  | 146.9 | 119.7 | 117.7  | 114.7- | 111.2  | 197.1  | 99.5  | -   |
| 14-1 155  | 123.3  | 114.2 | 117.9 | 117.9  | 115.5  | 1.12.8 | 1/10.3 | 102.5 |     |
| 14-1 160  | 121.0  | 115.4 | 114.0 | 115.0  | 114.3  | -112.3 | 158 6  | 161.7 |     |
| 14-1 165  | 129.8  | 116.6 | 112.8 | 114.5  | 115.1  | 113.0  | 10.8.7 | 193.2 |     |
| 14-1 171  | 118.3  | 108.3 | 110.0 | 111.6  | 112.3  | 111.1  | 197.3  | 102.3 |     |
| 14-1 175  | 117.0  | 155.4 | 108.2 | 110.5  | 111.2  | 159.9  | 168.4  | 99.3  |     |
| 14-1 180  | 115.9  | 156.4 | 106.4 | 108.4  | 115.1  | 19.1   | 195.5  | 166.2 |     |
| 14-1 185  | 116.7  | 157.1 | 157.4 | 199.4  | 110.5  | 115.1  | 106.5  | 101.7 |     |
| 14-2 1:40 | 132.9  | 125.1 | 125.8 | 127.5  | 125.7  | 121.9  | .116.9 | 113.6 | 1   |
| 14-2 145  | 134.5  | 127.5 | 129.2 | 128.2  | 126.4  | 122.8  | -119.1 | 114.2 | 1   |
| 14-2 150  | 132.5  | 122.1 | 126.8 | 127.4  | 125.4  | 121.6  | 118.2  | 112.0 | 1   |
| 14-2 155  | 132.1  | 119.9 | 125.4 | 127.3  | 125.2  | 122.4  | 119.6  | 114.0 | 1   |
| 14-2 (60) | 129.4  | 115.9 | 121.9 | 123.9  | 123.0  | 121.3  | 118.2  | 112.5 | 1   |
| 14-2 165  | 128.1  | 114.5 | 118.6 | 121.9  | 122.7  | 129.9  | 117.0  | 112.8 | 1   |
| 14-2 170  | 125.8  | 112.7 | 115.6 | 118.7  | 120.2  | 119.5  | 116.4  | 111.6 | -1  |
| 14-2 175  | 124.4  | 116.0 | 114.0 | 11/.5  | 118.8  | 115.1  | 115.2  | 168.8 | 1   |
| 14-2 180  | 123.1  | 110.8 | 112.1 | 115.2  | 117.2  | 117.0  | 114.2  | 115.1 | 1   |
| 14-2 185  | 123.7  | 111.3 | 112.4 | 115.8  | 117.7  | 118.9  | 115.0  | 110.7 | 1   |
| 14-3-145  | 135.1  | 127.3 | 129.1 | 129.7  | 127.4  | 124.6  | 110 3  | 116.2 | •   |
| 14-3 145  | 136.9  | 139.2 | 131.6 | 135.6  | 125.4  | 125.0  | 121 2  | 116 4 | •   |
| 14-5 [45  | 135.5  | 124.6 | 129.3 | 130.3  | 120.1  | 125.3  | 122 15 | 116 6 | 1   |
| 14-3 155  | 135.1  | 121.7 | 127.5 | 135.2  | 125.7  | 125.1  | 123.6  | 118.3 | 1   |
| 14-3 160  | 132.5  | 118.3 | 124.5 | 126.9  | 126.4  | 124.6  | 121.6  | 116.5 | 1   |
| 14-3 165  | 135.7  | 116.2 | 121.1 | 124.1  | 125.4  | 123.8  | 129.5  | 116.8 | 1   |
| 14-3 176  | 129.2  | 114.7 | 118.3 | 121.6  | 123.4  | 123.2  | 120.6  | 115.5 | 1   |
| 14-3 175  | 127.4  | 111.8 | 116.1 | 119.8  | 121.6  | 121.7  | 118.6  | 112.7 | 1   |
| 14-3 180  | 126.2  | 112.4 | 114.4 | 117,5  | 120.1  | 125.9  | 117.8  | 113.6 | 1   |
| 14-3 1.85 | 128.9  | 113.0 | 114.3 | 117.7  | 121.0  | 121.7  | 118.7  | 114.9 | 1   |
| 14-4 140  | 135,6- | 128.9 | 130.1 | 135.1  | 126.9  | 123.3  | 118.0  | 114.3 | . 1 |
| 14-4 L45  | 137.6  | 131.4 | 132.7 | 131.4  | 128.5  | 124.8  | 125.7  | 115.4 | 1   |
| 14-4 L5G  | 136.4  | 126.0 | 139,5 | 131.4  | 129.6  | 125.7  | 121.8  | 115.5 | 1   |
| 14-4 L55  | 136.4  | 123.3 | 129.0 | 131.6  | 139.1  | 127.2  | 124.0  | 118.2 | 1   |
| 14-4 60   | 133.4  | 119.4 | 125.9 | 128.1  | 127.4  | 125.0  | 121.3  | 115.2 | 1   |
| 14-4 L65  | 132.3  | 118.9 | 123.1 | 126.1  | 127.2  | 125.6  | 120.9  | 116.2 | -   |
| 14-4 L70  | 129.6  | 116.2 | 119.4 | -22,5  | 124.2  | 123.7  | 120.2  | 115.2 | 1   |
| 14-4 L75  | 128.7. | 113.3 | 117.2 | 121.1  | 123.5  | 123.0  | 119.4  | 112.9 | 1   |
| 14-4 L80  | 128.0  | 113.7 | 115.5 | 119.1  | 122.5  | 122.9  | 119.3  | 115.6 | 1   |
| 14-4 L85  | 128.9  | 114.3 | 115.3 | 119.7  | 123.7  | 123.7  | 129.4  | 116.2 | 11  |
| 14-5 L40. | 138.1  | 131.5 | 132.6 | 132.2  | 129.3  | 125.1  | 121.6  | 118.6 | 1   |
| 14-5 145  | 140.1  | 134.1 | 135.2 | 133.6  | 130.7  | 127.5  | 124.1  | 119.8 | 1   |
| 14-5 L50  | 138.7  | 128.2 | 132.9 | 133.7  | 131.6  | 128.1  | 124.7  | 118.9 | 11  |
| 14-5 L55  | 139.2  | 125.5 | 131.6 | 134.2  | 133.5  | 130.2  | 127.7  | 122.7 | 11  |
| 14-5 LGJ  | 135.6  | 120.9 | 127.7 | 135.5  | 129.6  | 127.5  | 124.6  | 119.3 | 11  |
| 14-5 L65  | 134.5  | 125.3 | 124.5 | 127.7  | 129.1  | 127.8  | 124.4  | 125.8 | 11  |
| 14-5 L70  | 132.3  | 117.7 | 125.7 | 124.4  | 126.5  | 125.6  | 123.5  | 119.4 | 11  |
| 14-5 L75  | 131.3  | 114.9 | 118.7 | 123:1  | 126.0  | 126,0  | 122.8  | 117.3 | 11  |
| 14-5 L80  | 135.6  | 115.3 | 117.3 | 121.1  | 125.0  | 125.5  | 122.4  | 118.9 | 11  |
| 14-5 L85  | 131.7  | 115.7 | 116.6 | 121.6  | 126.5  | 126.4  | 123.5  | 120.1 | 11  |
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# NOTE: THESE ARE FREE FIELD VALUES



#### HM-AP-60 NOZZLE (24 SPOKES, AR 2.0)

#### Description:

The HM-AP-60 nozzle is a 24-spoke nozzle designed to install on a baseplate and be used in conjunction with various multi-tube arrangements. The HM-AP-60 nozzle was used as the central flow element in the HM-AP-61A suppressor nozzle configurations.

Number of Elements: 24 spokes

Area Ratio: 2.0

Spoke Penetration: 90%

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Ventilation Gutter Cant Angle: 20 degrees

Material: 321 CRES



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## HM-AP-60 NOZZLE

(24 Spokes, 2.0 Area Ratio)

#### Remarks

The second

The HM-AP-60 Nozzle was tested with and without an ejector. The tight fitting unlined ejector provided 2 to 6 dB suppression in the last five octave bands at PR = 3.0 and  $T_T = 1500^{\circ}F$ . This additional suppression was attained with considerable thrust loss. See Reference D28.

HM-AP-60 NOZZLE

Test Facility: HNTF Date: T<sub>amb</sub>:

R.H.:

| Run No. | $P_{T}/P_{\bullet}$ | $\frac{\mathbf{T}_{\mathbf{T}}}{\mathbf{T}}$ | $V_{J}$ (Ideal) | Nozzle                         |
|---------|---------------------|----------------------------------------------|-----------------|--------------------------------|
| 7.1     | 1.6                 | 1500°F                                       | 1750 fps        | нм-ар-60                       |
| 7.2     | 2.2                 | 11                                           | 2202            | 11                             |
| 7.3     | 2.6                 | 11                                           | 2402            | 11                             |
| 7.4     | 3.0                 | 11                                           | 2555            | 11                             |
| 7.5     | 3.4                 | 11                                           | 2678            | 11                             |
| 14.1    | 1.6                 | 1500°F                                       | 1750            | 4.1 Inch Round Convergent Noz. |
| 14.2    | 2.2                 | 17                                           | 2202            | 11                             |
| 14.3    | 2.6                 | 11                                           | 2402            | 11                             |
| 14.4    | 3.0                 | 11                                           | 2555            | 11                             |
| 14.5    | 3.4                 | 11                                           | 2678            | n                              |

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|                                                         |        | •      | <b>1M</b> ∆P- | -60 N(                                | )771 F | TEST D | ΛΤΛ    |        |        |
|---------------------------------------------------------|--------|--------|---------------|---------------------------------------|--------|--------|--------|--------|--------|
| OCTAVE BAND / EVEL and B REA 0 0002 DYNES / CM2// 25 ET |        |        |               |                                       |        |        |        |        |        |
| RUN NO.                                                 | OASPL  | 500    | 1K            | 2K                                    | 4K     | 8K     | 16K    | 32K    | 64K    |
| 7-1 L40                                                 | 116.6  | 113 5  | 100.6         | 163.2                                 | 162 1  | 106.0  | 106.5  | 163 6  | 07     |
| 7-1 L45                                                 | 116.7  | -111.7 | 116.6         | 1114 0                                | 103 4  | 168.6  | 168 3  | 153.0  | 07     |
| 7-1 150                                                 | 115.4  | 159.3  | 197.9         | 154.9                                 | 163.9  | 157.8  | 197.9  | 153.1  | 26     |
| 7-1 L55                                                 | 115.9  | 197.7  | 106.3         | 195.7                                 | 195.4  | 109.6  | 158.9  | 1715.7 | 99.1   |
| 7-1 LEG                                                 | 115.5  | 197.4  | 195.1         | 154.7                                 | 155.7  | 109.3  | 106.6  | 165.1  | 99.1   |
| 7-1 L65                                                 | 115.8  | 159.5  | 103.3         | 163.3                                 | 195.7  | 159.0  | 159.6  | 156.7  | 93.1   |
| 7-1 170                                                 | 116.6  | 111.1  | 192.9         | 103.3                                 | 106.2  | 109.9  | 110.2  | 107.4  | - 98.5 |
| 7-1 £75                                                 | 116.1  | 154.4  | 151.9         | 153.9                                 | 106.7  | 115.7  | .145.8 | 166.5  | 95.5   |
| 7-1 185                                                 | 115.8  | 154.5  | 155.7         | 102.2                                 | 105.5  | 115.2  | 115.5  | 158.6  | 166.5  |
| 7-1 L85                                                 | 116.1  | 105.3  | 166.4         | 152.4                                 | 105.5  | 115.6  | 110.8  | 158.2  | 161.0  |
| 7-2 L40                                                 | 124.9  | 120.6  | 120.3         | 115.1                                 | 110.6  | 111.9  | 111.8  | 115.5  | 195 /  |
| 7-2 L45                                                 | 125.0  | 119.8  | 125.4         | 116.2                                 | 111.9  | 112.9  | 113 3  | 119 7  | 163 4  |
| 7-2 L50                                                 | 123.3  | 116.7  | 118.1         | 115.7                                 | 112.4  | 112.6  | 112.7  | 158.2  | 152.6  |
| 7-2 L55                                                 | 122.8  | 114.0  | 115.5         | 115.5                                 | 113.6  | 114.9  | 114.5  | 111.4  | 105.1  |
| 7-2 L60                                                 | 121.6  | 112.1  | 112.9         | 113.0                                 | 113.5  | 114.7  | 113.9  | 115.4  | 1/15.2 |
| 7-2 L65                                                 | 122.1  | 119.7  | 111.5         | 112.5                                 | 114.3  | 115.8  | 115.4  | 112.8  | 163.4  |
| 7-2 L70                                                 | 121.7  | 113.8  | 109.5         | 110.9                                 | 112.7  | 115.2  | 115.1  | 112.1  | 193.2  |
| 7-2 L75                                                 | 125.1  | 157.1  | 108.6         | 116.0                                 | 111.6  | 114.2  | 114.4  | 159.8  | 152.1  |
| 7-2 L80                                                 | 120.1  | 197.7  | 196.8         | 108.6                                 | 115.7  | 113.7  | 114.6  | 112.0  | 155.6  |
| 7-2 L85                                                 | 121.0  | 197.4  | 196.2         | 196.7                                 | 111.2  | 114.9  | 115.8  | 113.2  | 106.5  |
| 7-3 640                                                 | 128.7  | 124.1  | 124.5         | 129.5                                 | 115.2  | 114.6  | 112.8  | 116.7  | 1/16 7 |
| 7-3 L45                                                 | 128.6  | 123.4  | 124.8         | 121.1                                 | 116.2  | 114.9  | 114.3  | 111.55 | 106 3  |
| 7-3 L50                                                 | 126.6  | 119.5  | 122.3         | 120.0                                 | 116.4  | 114.3  | 113.4  | 108.9  | 164 0  |
| 7-3 L55                                                 | 125.4  | 116.5  | 119.3         | 119.2                                 | 115.8  | 116.0  | 114.6  | 111.7  | 156.1  |
| 7_3 <u>[</u> 6j                                         | 123.9  | 113.6  | 116.4         | 116.5                                 | 116.5  | 116.2  | 115.1  | 111.7  | 196.6  |
| 7-3 L65                                                 | 124.5  | 112.9  | 114.0         | 115.5                                 | 116.7  | 117.7  | 117.7  | 115.2  | 106.4  |
| 7-3 L70                                                 | 123.8  | 115.4  | 412.1         | 113.6                                 | 115.6  | 117.6  | 116.7  | 113.6  | 105.1  |
| 7-3 L75                                                 | 122.5  | 159.1  | 119.8         | 113.5                                 | 114.8  | 116.5  | 116.4  | 112.0  | 154.8  |
| 7-3 L80                                                 | 122.0  | 109.6  | 109.8         | 111.4                                 | 113.2  | 115.6  | 116.3  | 113.5  | 197.0  |
| 7-3 L85                                                 | 121.9  | 159.1  | 108.9         | 111.4                                 | 113.5  | 115.7  | 115.5  | 113.0  | 156.4  |
| 7-4 L40 .                                               | 131.5  | 126.4  | 127.0         | 124.4                                 | 119.7  | 116.6  | 114.1  | 112.0  | 198.7  |
| 7-4 L45                                                 | 131.7  | 125.7  | 127.5         | 121.8                                 | 120.4  | 117.6  | 115.6  | 112.2  | 198.1  |
| 7-4 155                                                 | 135.1  | 122.5  | 125.5         | 124.2                                 | 129.7  | 117.6  | 1-15.4 | 115.5  | 195.9  |
| 7-4 L55                                                 | 128.9  | 119.2  | 122.9         | 123.7                                 | 121.1  | 118.8  | 110.2  | 112.9  | 197.6  |
| 7-4 60                                                  | 126.1  | 115.3  | 119.5         | 119.7                                 | 119.2  | 117.9  | 115.7  | 111.9  | 106.9  |
| 7-4 L65                                                 | 125.8  | 115.1  | 116.5         | 118.2                                 | 119.0  | 118.5  | 117.4  | 114.4  | 105.3  |
| 7-4 L7G                                                 | 125.2  | 116.8  | 114.1         | 116.0                                 | 117.3  | 118.6  | 117.7  | 114.3  | 105.9  |
| 7_4 L75                                                 | 123.6  | 115.7  | 112.9         | 115.2                                 | 116.3  | 117.4  | 116.9  | 112.3  | 195.4  |
| 7-4 185                                                 | 123.4  | 111.1  | 111.6         | 113.2                                 | 114.9  | 117.0  | 117.2  | 114.8  | 108.8  |
| 7-4 L85                                                 | 123.2  | 115.7  | 115.6         | 113,0                                 | 114.9  | 116.8  | 117.0  | 114.6  | 158.6  |
| 7-5 640                                                 | 133.7  | 128.0  | 129.1         | 127.3                                 | 123.1  | 119.6  | 115.1  | 112.6  | 109 8  |
| 7 5 145                                                 | 134.0  | 127.2  | 129.5         | 127.9                                 | 121.2  | 129.5  | 117.6  | 113.5  | 160.0  |
| 7-5 L5G                                                 | 132.8  | 123.9  | 123.0         | 127.4                                 | 124.2  | 120.8  | 117.7  | 112.5  | 10.6.5 |
| 7_5 L55                                                 | 131.7  | 120.5  | 125.3         | 126.7                                 | 124.5  | 121.9  | 118.6  | 115.0  | 169.0  |
| 7-5 [6]                                                 | 126.7  | 116.8  | 121.1         | 122.7                                 | 122.2  | 125.7  | 117.9  | 114_1  | 159.7  |
| 7-5 L65                                                 | 127.9. | 116.4  | 115.2         | 129.6                                 | 121.5  | 125.7  | 119.3  | 116.1  | 107.3  |
| 7-5 L75                                                 | 126.2  | 117.6  | 115.6         | 117.6                                 | 118.8  | 119.5  | 115.2  | 114.5  | 105.7  |
| 7-5 L75                                                 | 123.4  | 111.5  | 113.2         | 115.7                                 | 116.8  | 117.1  | 115.7  | 115.7  | 103 3  |
| 7-5 180                                                 | 123.5  | 112.1  | 113.1         | 114.5                                 | 115.7  | 117.1  | 115.3  | 113.8  | 167 4  |
|                                                         |        |        |               | · · · · · · · · · · · · · · · · · · · |        |        |        |        |        |

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NOTE: THESE ARE FREE FIELD VALUES

|                   |        | -<br>- <b>(</b> | <b>M-</b> AP- | 60 I <b>N</b> | DZZLE  | TEST D | ATA   |        |       |
|-------------------|--------|-----------------|---------------|---------------|--------|--------|-------|--------|-------|
| RUN NO.           | OASPL  | .500            | - 1K          | 2K            | 4K     | 8K     | 16K   | 32K    | 64K   |
| 14-1 645          | 125.0  | 118.6           | 129.5         | 118.8         | 115.6  | 111.6  | 195.6 | 109.8  | 98.9  |
| 14-1 L45          | 126.3  | 121.2           | 122.1         | 119.0         | 115.3  | 111.5  | 107.0 | 199.4  | 165.5 |
| 14-1 655          | 123.8  | 116.0           | 119.7         | 117.7         | 114.7  | 111.2  | 107.1 | 99.5   | 96.8  |
| 14-1 155          | 123.3  | 114.2           | 117.9         | 117.9         | 115.5  | 112.8  | 159.3 | 102.5  | 97.6  |
| 14-1 L60          | 121.0  | 110.4           | 114.6         | 115.0         | 114.3  | 112.3  | 198.6 | 151.7  | 96.2  |
| 14-1 L65          | 125.8  | 110.0           | 112.6         | 114.5         | 115.1- | 113.0  | 158.7 | 153.2  | 95.6  |
| 14-1 670          | 116.3  | 108.3           | 115.5         | 111.6         | 112.3  | 111.1  | 167.3 | 102.3  | 93.8  |
| 14-1 175          | 117.0  | 105.4           | 108.2         | 110.5         | 111.2  | 109.9  | 106.4 | 99.3   | 91.9  |
| 14-1 180          | 115.9  | 196.4           | 156.4         | 158.4         | 115.1  | 159.1  | 105.5 | 100.2  | 93.0  |
| 14-1 L85          | 116.7  | 107.1           | 157.4         | 109.4         | 110.5  | 115.1  | 106.5 | 161.7  | 94.6  |
| 14-2 145          | 132.9  | 125.1           | 125.8         | 127.5         | 125.7  | 121.9  | 116.9 | 113.6  | 109.8 |
| 14-2 L45          | 134.5  | 127.6           | 129.2         | 128.2         | 126.4  | 122.8  | 119.1 | 114.2  | 110.7 |
| 14-2 L50          | 132.5  | 122-1           | 126.8         | 127.4         | 125.4  | 121.6  | 118.2 | 112.0  | 107.4 |
| 14-2 L55          | 132.1  | 119.9           | 125.4         | 127.3         | 125.2  | 122.4  | 119.6 | 114.0- | 109.0 |
| 14-2 L60          | 129.4  | 115.9           | 121.9         | 123.9         | 123.0  | 121.3  | 118.2 | 112.5  | 107.6 |
| 14-2 L65          | 128.1  | 114.5           | 118.8         | 121.9         | 122.7  | 120.9  | 117.0 | 112.8  | 106.0 |
| 14-2 170          | 125.8  | 112.7           | 115.6         | 118.7         | 120.2  | 119.5  | 116.4 | 111.6  | 102.7 |
| 14-2 L75          | 124.4  | 115.5           | 114.0         | 117.5         | 118.8  | 118.1  | 115.2 | 198.8  | 101.1 |
| 14-2 L80          | 123.1  | 115.8           | 112.1         | 115.2         | 117.2  | 117.0  | 114.2 | 119.1  | 102.9 |
| 14-2 L\$5         | 123.7  | 111.3           | 112.4         | 115.8         | 117.7  | 118.9  | 115.0 | 119,7  | 103.4 |
| 14-3 L4G          | 135.1  | 127.3           | 129.1         | 129.7         | 127.4  | 124.0  | 119.3 | 116.2  | 112.3 |
| 14-3 L45          | 136.9  | 139.2           | 131.6         | 135.6         | 128.4  | 125.0  | 121.2 | 116.4  | 113.1 |
| 14-3 L50          | 135.5  | 124.6           | 129.3         | 139.3         | 129.0  | 125.3  | 122.5 | 116.0  | 111.4 |
| 14-3 L55          | 135.1  | 121.7           | 127.5         | 135.2         | 125.7  | 126.1  | 123.6 | 118.3  | 113.6 |
| 14-3 60           | 132.5  | 118.3           | 124.5         | 126.9         | 126.4  | 124,6  | 121.8 | 116.5  | 112.5 |
| 14-3 L65          | 135.7  | 116.2           | 121.1         | 124.1         | 125.4  | 123.8  | 129.5 | 116.8  | 115.3 |
| 14-3 L7G          | 129.2  | 114.7           | 118.3         | 121.6         | 123.4  | 123.2  | 129.6 | 116.5  | 158.3 |
| 14-3 L75          | 127.4  | 111.8           | 116.1         | 119.8         | 121.8  | 121.7  | 118.8 | 112.7  | 195.2 |
| 14-3 L80          | 126.2  | 112.4           | 114.4         | 117.5         | 129.1  | 125.9  | 117.8 | 113.6  | 196.8 |
| 14-3 L <b>8</b> 5 | 126.9  | 113.9           | 114.3         | 117.7         | 121.0  | 121.7  | 116.7 | 114.9  | 158.2 |
| 14-4 L49          | 135,6- | 128.9           | 139.1         | 139.1         | 126.9  | 123.3  | 118.9 | 114.3  | 111.3 |
| 14-4 L45          | 137.6  | 131.4           | 132.7         | 131.4         | 128.5  | 124.8  | 125.7 | 115.4  | 113.1 |
| 14-4 L30          | 136.4  | 126.0           | 139.5         | 131,4         | 129.6  | 125,7  | 121.8 | 115.5  | 111.3 |
| 14-4 L55          | 136.4  | 123.3           | 129.0         | 131.6         | 139.1  | 127.2  | 124.0 | 116.2  | 113.5 |
| 14-4 L60          | 133.4  | 119.4           | 125.9         | 128.1         | 127.4  | 125,0  | 121.3 | 115.2  | 110.3 |
| 14-4 L65          | 132.3  | 118.9           | 123.1         | 126.1         | 127.2  | 125.0  | 120.9 | 116.2  | 159.4 |
| 14-4 L75          | 129.6  | 116.2           | 119.4         | 122.5         | 124.2  | 123.7  | 120.2 | 115.2  | 106.5 |
| 14-4 L75          | 128.7. | 113.3           | 117.2         | 121.1         | 123.5  | 123.0  | 119.4 | 112.9  | 105.3 |
| 14-4 L <b>8</b> 5 | 128.0  | 113.7           | 115,5         | 119.1         | 122.5  | 122.9  | 119.3 | :15.6  | 107.9 |
| 14-4 L <b>85</b>  | 128.9  | 114.3           | 115,3         | 119.7         | 123.7  | 123.7  | 125.4 | 115.2  | 109.5 |
| 14-5 140          | 138.1  | 131.5           | 132.6         | 132.2         | 129.3  | 126.1  | 121.6 | 118.8  | 115.6 |
| 14-5 L <b>45</b>  | 140.1  | 134.1           | 135,2         | 133.6         | 130.7  | 127.5  | 124.1 | 119.8  | 116.6 |
| 14-5 E50          | 138.7  | 128.2           | 132.9         | 133.7         | 131.6  | 128.1  | 124.7 | 118.9  | 114.5 |
| 14-5 L55          | 139.2  | 125.5           | 131.6         | 134.2         | 133.0  | 135,2  | 121.7 | 122.7  | 118.6 |
| 14-5 LØO          | 135,6  | 120.9           | 127.7         | 130.0         | 129.6  | 127.5  | 124.6 | 119.3  | 114.9 |
| 14-5 L65          | 134.5  | 120.3           | 124.5         | 127.7         | 129.1  | 127.8  | 124.4 | 125.8  | 114.7 |
| 14-5 L70          | 132.3  | 117.7           | 125.7         | 124.4         | 126.5  | 126.6  | 123.5 | 119.4  | 111.1 |
| 14-5 175          | 131.3  | 114,9           | 118.7         | 123.1         | 126.0  | 129.0  | 122.8 | 117.3  | 115.6 |
| 14-5 L80          | 130.5  | 115.3           | 117.3         | 121.1         | 125.0  | ĭ25,5  | 122.4 | 118.9  | 112.6 |
| 14-5 L85          | 131.7  | 115.7           | 116,6         | 121.6         | 126.5  | 126,4  | 123.5 | 129.1  | 114.5 |

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### NOTE: THESE ARE FREE FIELD VALUES







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### HM-AP-61-A NOZZLE

(42 Tubes, 6 Clusters of 7 Tubes Each, and a 24 Spoke Nozzle in the Center)

#### Remarks

The HM-AP-61-A Nozzle is essentially the HM-AP-58-A Nozzle plus the HM-AP-60 Nozzle. About 2 PNdB better suppression was realized with this nozzle relative to the 42 tube annulus with 24-spoke central element (HM-AP-64-A), however there are spectrum similarities. See Ref. D28. The spectrum indicates contribution from all elements in the array. The jet turbulence of the outer groupings of the 42 tubes does not appear to mask the low frequency noise generated by the larger 24-spoke jet in the center.

# HM-AP-61-A NOZZLE

Test Facility: HNTF

Date:

Tamb:

R.H.:

| Run No.                              | P <sub>T</sub> /P <sub>∞</sub>  | $\underline{\mathbf{T}_{\mathbf{T}}}$ | V <sub>J</sub> (Ideal)                   | Nozżle                                         |
|--------------------------------------|---------------------------------|---------------------------------------|------------------------------------------|------------------------------------------------|
| 11.1<br>11.2<br>11.3<br>11.4<br>11.5 | 1.6<br>2.2<br>2.6<br>3.9<br>3.4 | 1500°F<br>"<br>"<br>"                 | 1750 fps<br>2202<br>2402<br>2555<br>2678 | HM-AP-61-A<br>"<br>"<br>"                      |
| 12.1<br>12.2<br>12.3<br>12.4<br>12.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4 | 1500°F<br>"<br>"<br>"                 | 1750 fps<br>2202<br>2402<br>2555<br>2678 | 6 Inch Round Convergent Nozzle<br>""<br>"<br>" |

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| HM-AP-61-A | NOZZLE TEST DATA |
|------------|------------------|
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OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM2// 25 FT

| RUN NO.  | OASPL       | 500    | 1K    | 2K    | 4K     | 8K      | 16K   | 32K   | 64K   |
|----------|-------------|--------|-------|-------|--------|---------|-------|-------|-------|
| 11-1 L4G | 108.8       | 105.3  | 1015  | 98.3- | 58.2   | 91.8    | 98.0  | 94.Z  | 93.5  |
| 11-1 L45 | 159.9       | 105.3  | 151.9 | 99.9  | 99.6   | 100.0   | 105.1 | 98.6  | \$3.3 |
| 11-1 L50 | 109.5       | 103.6  | 101.7 | 101.4 | 99.9   | 155.1   | 199.1 | 97.0  | 92.0  |
| 11-1 155 | 110.9       | 152.7  | 191.7 | 104.2 | 152.1  | 192.5   | 102.0 | 155.3 | 94.7  |
| 11-1 60  | 111.4       | 102.0  | 102.2 | 194.4 | 1:3.2  | 1/13.4  | 103.2 | 195.5 | 95.3  |
| 11-1 L65 | 112.3       | 100.7- | 165.8 | 164.6 | 154.8  | 195.5   | 104.9 | 152.9 | 96.3  |
| 11-1 175 | 112.0       | 199.2  | 98.6  | 101.3 | 1.53.9 | 156.8   | 105,4 | 102.4 | 95.5  |
| 11-1 L75 | 112.3       | 95.9   | 97.9  | 101.3 | 194.3  | 197.6   | 156.4 | 161.7 | S4.1  |
| 11-1 L80 | 111.9       | 97.1   | \$6.8 | 99.2  | 103.0  | 156.8   | 156.4 | 153.4 | S6.5  |
| 11-1 L85 | 115.2       | 96.1   | 96.6  | 99.3  | 192.7  | 107.1   | 108.9 | 154.5 | 51.4  |
| 11-2 (40 | 117.7       | -114.7 | 112.4 | 156.1 | 193.8  | 164.7   | 192.2 | 166.1 | 95.7  |
| 11-2 L45 | 118.4       | 114.2  | 113.0 | 108.2 | 105.9  | 197.1   | 106.2 | 103.9 | 98.2  |
| 11-2 L50 | 116.9       | 111.4  | 111.4 | 108.2 | 195.8  | 106.5   | 106.3 | 163.1 | 97.9  |
| 11-2 L55 | 117.1       | 109.7  | 159.5 | 109.5 | 197.8  | 108.5   | 107.9 | 106.2 | 100.9 |
| 11-2 L60 | 117.2       | 157.9  | 108.5 | 159.1 | 168.7  | 109.8   | 109.2 | 106.8 | 152.1 |
| 11-2 L65 | 117.9       | 106.3  | 196.2 | 109.2 | 115.6  | 115.9   | 119.8 | 108.4 | 102.2 |
| 11-2 L70 | 117.3       | 1.6.3  | 12-12 | 105.5 | 100.5  | 111.7   | 110.5 | 197.7 | 151.2 |
| 11-2 L75 | 117.6       | 102.2  | 103.3 | 106.5 | 159.7  | 112.4   | 111.9 | 197.8 | 199.7 |
| 11-2 L80 | 117.4       | 102.1  | 162.6 | 104.2 | 198.0  | 111.8   | 112.1 | 159.7 | 103.2 |
| 11-2 L85 | 117.4       | 101.1  | 101.6 | 194.6 | 197.8  | 111.9   | 112.2 | 169.7 | 103.6 |
| 11-3 L40 | 121.2       | 118.1  | 116.1 | 110.6 | 195.8  | 196.7   | 164.5 | 102.3 | 99.2  |
| 11-3 L45 | 121.7       | 117.5  | 116.5 | 112.8 | 197.9  | 169.0   | 108.0 | 105.6 | 160.4 |
| 11-3 L50 | 120.5       | 114.9  | 115.6 | 112.7 | 109.6  | 159.1   | 168.5 | 195.9 | 99.9  |
| 11-3 L55 | 119.8       | 112.3  | 113.3 | 112.7 | 169.9  | 115.6   | 150.6 | 157.7 | 102.5 |
| 11-3 LGG | 119.4       | 115.4  | 111.8 | 111.7 | 115.9  | 111.5   | 116.6 | 197.7 | 152.8 |
| 11-3 L65 | 119.5       | 169.3  | 169.0 | 111.5 | 112.1  | 112.4   | 111.5 | 159.2 | 102.9 |
| 11-3 175 | 118.8       | 169.0  | 106.9 | 109.4 | 111.3  | 115.8   | 111.2 | 198.4 | 152.1 |
| 11-3 175 | 118.4       | 104.8  | 105.7 | 108.2 | 115.9  | 113.1   | 112.1 | 197.6 | 199.2 |
| 11-3 660 | 118.0       | 1714.6 | 154.2 | 156.2 | 159.3  | 112.5 - | 112.1 | 169.6 | 193.3 |
| 11-3 L85 | 118.1       | 193.3  | 1:3.3 | 105.8 | 108.8  | 112.5   | 112.7 | 116.3 | 164.6 |
|          | 124.6       | 121.5  | 119.7 | 114.5 | 108.7  | 159.3   | 197.9 | 154.3 | 191.3 |
|          | 125.4       | 120.9  | 120.5 | 117.6 | 111.5  | 112.4   | 111.7 | 198.9 | 153.4 |
| 11-4 [3] | 123.4       | 117.3  | 118.7 | 116.9 | 111.3  | 115.9   | 159.8 | 155.7 | 199.9 |
| 11-4 155 | 122.5       | 114.6  | 116.4 | 116.6 | 112.8  | 112.5   | 115.8 | 198.5 | 153.3 |
|          | 121.3       | 112.3  | 114.4 | 114.3 | 113,9  | 113.9   | 111.7 | 198.8 | 104.1 |
| 11-4 205 | 121.3       | 111.7  | 111.4 | 113.5 | 113.8  | 114.2   | 113.1 | 115.6 | 154.4 |
| 11-9 (1) | 125.2       | 111.4  | 158.8 | 115.9 | 112.5  | 113.9   | 112.4 | 109.5 | 153.1 |
| 11-4 [75 | 119.7       | 156.7  | 157,6 | 110.1 | 112.2  | 114.0   | 113.2 | 169.1 | 152.2 |
| 11-4 669 | 119.8       | 156.8  | 166.3 | 167.9 | 119.8  | 114.0   | 113.8 | 111.7 | 105.5 |
| 11-4 65  | 119.9       | 105.9  | 195.5 | 157.9 | 115.7  | 114.0   | 114.2 | 112.1 | 156.9 |
| 11-5 175 | 121.2       | 124.0  | 122.4 | 11/.1 | 111.4  | 112.0   | 115.1 | 156.3 | 103.8 |
| 11-5 150 | 121.0       | 123.1  | 122.9 | 120.2 | 113.7  | 112.3   | 112.7 | 110.3 | 164.5 |
| 11-5 155 | 125.0       | 147 4  | 121.9 | 121.6 | 114.7  | 113.3   | 111.9 | 197.3 | 152.8 |
| 11-5 (6) | 102 6       | 111 7  | 119.9 | 120.9 | 115.3  | 115.0   | 112.9 | 115.5 | 194.7 |
| 11-5 165 | 122.0       | 114.1  | 111.3 | 11/.1 | 115.2  | 114.6   | 112.8 | 159.4 | 154.7 |
| 11-5 170 | 121 6       | 112.2  | 115.5 | 115.5 | 115.6  | 115.6   | 113.8 | 110.7 | 104.4 |
| 11-5 175 | 121.0       | 102 7  | 111.2 | 115.5 | 114.9  | 115.1   | 112.9 | 159.5 | 193.2 |
| 11-5 180 | 120 6       | 100.0  | 100 3 | 112.2 | 113.9  | 115.1   | 114.5 | 159.6 | 152.7 |
| 11-5 185 | 121.7       | 100.0  | 105.5 | 199.8 | 112.4  | 114.8   | 114.1 | 111.9 | 195.6 |
| ·· - 60. | ا والدينة ف | 10110  | 107.1 | 103.2 | 112.4  | 114.6   | 114.6 | 115.3 | 158.1 |

#### NOTE: THESE ARE FREE FIELD VALUES

| HALAD CLA NOTTLE TEST DATE |               |        |         |       |        |        |        |        |       |
|----------------------------|---------------|--------|---------|-------|--------|--------|--------|--------|-------|
|                            | _             |        | K-MI -0 |       | JELLE  |        | 14K    | 224    | 6 A.Y |
| RUN NO.                    | OASPL         | 500    | IK      | ZK    | 46     | ÖV.    | IOK    | JAK    | -04N  |
| 12-1 L40                   | 126.3         | 122.6  | 121.6   | 117.5 | 113.8  | 109.9  | 165.1  | 155.2  | 155.5 |
| 12-1 L43                   | 126.7         | 122.9  | 122.1   | 118.1 | 114.5  | 111.5  | 105.6  | 155.4  | 166.6 |
| 12-1 050                   | 124.8         | 119.9  | 129.5   | 117.0 | 114.0  | 115.3  | 125.2  | 99.1   | 57.8  |
| 12-1 L55                   | 123.5         | 117.7  | 118.8   | 117,5 | 114.9  | 111.9  | 197.1  | 151.8  | 98.1  |
| 12-1 L60                   | 122.3         | 1-15.3 | 117.2   | 115 8 | .114.9 | 111.5  | 136.7  | 159.7  | 96.5  |
| 12-1 L65                   | 121.1         | 113.7  | 114.7   | 114.9 | 114.9  | 115.9  | 157.5  | 191.9  | 95.2  |
| 12-1 L70                   | 119.8         | 113.5  | 112.4   | 113.1 | 112.5  | 115.6  | 1 76.0 | 109.4  | 94,3  |
| 12-1 L75                   | 118.9         | 169.5  | 111.5   | 113.5 | 112.5  | 119.4  | 1-10.3 | 59.1   | 92.3  |
| 12-1 L8G                   | 117.6         | 159.4  | 115.6   | 115.8 | 115.5  | 159.7  | 155.7  | 169.9  | 93.3  |
| 12-1 L85                   | 117.6         | 198.3  | 108.7   | 115.5 | .115.6 | 109.2  | 105.9  | 1991   | 95.1  |
| 12-2 640                   | 133.5         | 128.0  | 128.4   | 126.7 | 123.5  | 119.6  | 115.3  | 111.7  | 109.8 |
| 12-2 L45                   | 134.4         | 129.1  | 129.2   | 127.8 | 124.7  | 125.9  | 117.3  | 112.5  | 109.6 |
| 12-2 L50                   | 132.3         | 125.6  | 127.8   | 126.0 | 123.2  | 119.3  | 115.6  | 169.4  | 106.5 |
| 12-2 L55                   | 131.5         | 123.2  | 126.5   | 125.9 | 123.2  | 150.5  | 115.7  | 111.49 | 146.8 |
| 12-2 L60                   | 129 <b>.2</b> | 129.5  | 123.9   | 123.2 | 121.5  | 115.9  | 114.5  | 159.3  | 10.2  |
| 12-2 L65                   | 128.0         | 118.9  | 125.8   | 122.1 | 121.8  | 118.9  | 115.0  | 115.4  | 163.7 |
| 12-2 L70                   | 126.0         | 117.9  | 118.1   | 119.7 | 119.5  | in7.7  | 113.2  | 158.9  | 191-9 |
| 12-2 L75                   | 125.3         | 114.3  | 117.2   | 119.4 | 119.5  | 117.7  | 113.4  | 106.8  | 99.9  |
| 12-2 L80                   | 123.2         | 113.5  | 115.5   | 116.4 | 116.9  | 115.1  | :12.3  | 197.3  | 155.0 |
| 12-2 L85                   | 123.2         | 112.6  | 113.9   | 116.4 | 117.2  | 116.0  | 113.2  | 198.3  | 191.9 |
| 12-3 L45                   | 135.1         | 135.6  | 135.3   | 127.8 | 124.1  | 119.9  | 115.1  | 111.1  | 110.3 |
| 12-3 L45                   | 136.3         | 131.3  | 131.4   | 129.5 | 125.0  | 121.9  | 117.7  | 112.8  | 111.5 |
| -12-3 L50                  | 134.8         | 128.1  | 130.1   | 126.7 | 125.7  | 121.5  | 117.5  | 111.5  | 169.0 |
| 12-3 L55                   | 134.0         | 125.7  | 128.9   | 128.7 | 125.6  | 122.3  | 117.8  | 113.3  | 109.7 |
| 12-3 L60                   | 131.0         | 121.8  | 125.7   | 125.2 | 123.3  | 152.9  | 118.2  | 111.3  | 107.3 |
| 12-3 L65                   | 129.5         | 125.4  | 122.3   | 123.6 | 123.3  | 125,6  | 115.5  | 111.9  | 105.7 |
| 12-3 L70                   | 127.9         | 119.4  | 119.7   | 121.4 | 121.5  | 150.1  | 115.3  | 115.2  | 104.1 |
| 12-3 L75                   | 127.2         | 115.7  | 115.5   | 125.9 | 121.5  | 125.1  | 116.1  | 159.8  | 103.1 |
| 12-3 L80                   | 126.2         | 115.5  | 116.9   | 118.8 | 125.3  | 119.8  | 116.0  | 111.5  | 104.8 |
| 12-3 L85                   | 12ē.0         | 114.5  | 115.4   | 118.6 | 129.8  | 119.4  | 115.9  | 111.6  | 164.6 |
| 12-4 L45°                  | 136.9         | 132.6  | 132.0   | 129.2 | 126.1  | 122.4  | 118.2  | 114.7  | 113.1 |
| 12-4 L45                   | 138.3         | 133.4  | 133.3   | 131.2 | 127.9  | 124,4  | 129.7  | 116.2  | 113.6 |
| 12-4 L50                   | 136.9         | 129.9  | 132.2   | 135.9 | 128.0  | 124.5  | 120.8  | 115.3  | 111.9 |
| 12-4 L55                   | 136.2         | 126.9  | 136.6   | 135.9 | 128.5  | 125.7  | 121.7  | 117.9  | 113.8 |
| 12-4 160                   | 133.1         | 123.1  | 127.0   | i27.3 | 126.1  | 123,9  | 119.9  | 115.4  | 111.4 |
| 12-4 165                   | 131.9         | 121.9  | 124.0   | 125.8 | 125.8  | 123.6  | 120.0  | 116.1  | 110.2 |
| 12-4 L72                   | 130,5         | 125.6  | 121.1   | 123,6 | 124.5  | 123.7  | 119.3  | 114.9  | 168.9 |
| 12-4 L75                   | 135.2         | 117.3  | 120.0   | 123.3 | 124.9  | 123.7  | 125.1  | 114.5  | 197.8 |
| 12-4 L80                   | 129.1         | 117.0  | 118.5   | 121.2 | 123.5  | 123.0  | 119.7  | 116.9  | 159.9 |
| 12-4 L85                   | 129.1         | 116.0  | 117.0   | 121.2 | 124.2  | 122.7  | 119.8  | 116,1  | 159.8 |
| 12-5 L40                   | 138.4         | 134.9  | 133.7   | 130.2 | 127.4  | 124.4  | 129.4  | 117.1  | 115.3 |
| 12-5 L45                   | 339.8         | 151.8  | 135.5   | 132.5 | 160.4  | 14.3.5 | 12     | 115.3  | 115.7 |
| 12-5 L5G                   | 138.3         | 131.1  | 133.4   | 132.2 | 129.5  | 126.5  | 123.4  | 118.0  | 114.5 |
| 12-5 L55                   | 138.1         | 128.0  | 131.8   | 132.6 | 131.0  | 128.5  | 124.8  | 121.4  | 117.2 |
| 12-5 L60                   | 135.3         | 124.3  | 128.4   | 129.3 | 128.6  | 125.8  | 123.3  | 119.4  | 115.6 |
| 12-5 L65                   | 133.4         | 122.5  | 124.8   | 126.9 | 127.6  | 125.7  | 122.4  | 118.6  | 112.7 |
| 12-5 L70                   | 132.1         | 121.3  | 121.9   | 124.8 | 126.5  | 125.8  | 121.7  | 117.4  | 111.4 |
| 12-5 L75                   | 132.0         | 118.1  | 121.2   | 124.6 | 125.9  | 125.6  | 122.4  | 117.0  | 110.5 |
| 12-5 L80                   | 131.2         | 117.8  | 119.5   | 122.9 | 125.7  | 125.3  | 122.1  | 118.7  | 112.7 |
| 12-5 L <b>8</b> 5          | 131.4         | 117.1  | 117.7   | 123.4 | 126.3  | 125.2  | 122.7  | 119.3  | 113.1 |

## NOTE: THESE ARE FREE FIELD VALUES

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### HM-AP-64-A NOZZLE

(42 Tube Annulus, 2 Rows of Tubes, and 24-Spoke Nozzle in the Center)

#### Remarks

The HM-AP-64-A Nozzle is essentially the HM-AP-59-A Nozzle plus the HM-AP-60 Nozzle. The noise spectrum shows definite contribution by all elements. The low frequencies are dominated by the relatively large 24-spoke jet in the center of the array. The high frequency portion of the spectrum is largely attributed to the 42 annulus jets. See Reference D28.

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# HM-AP-64-A NOZZLE

Test Facility: HNTF

Date:

Tamb:

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k.H.:

| Run No.                              | $\underline{P_{T}}/\underline{P_{\infty}}$ | $\frac{T_T}{T}$        | $V_{J}$ (Ideal)                          | Nozzle                                             |
|--------------------------------------|--------------------------------------------|------------------------|------------------------------------------|----------------------------------------------------|
| 24.1<br>24.2<br>24.3<br>24.4<br>24.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4            | 1500°F'<br>"<br>"<br>" | 1750 fps<br>2202<br>2402<br>2555<br>2678 | HM-AP-64-A<br>"""""""""""""""""""""""""""""""""""" |
| 12.1<br>12.2<br>12.3<br>12.4<br>12.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4            | 1500°F<br>"<br>"<br>"  | 1750 fps<br>2202<br>2402<br>2555<br>2678 | ό Inch Round Convergent Noz.<br>"<br>"<br>"<br>"   |

## HM-AP-64-A NOZZLE TEST DATA OCTAVE BAND LEVEL-AB RE: 0.0002 DYNES/CM<sup>2</sup>// 25 FT,

| RUN NO.              | OASPL         | 500   | 1K             | 2X          | 4K     | 8K     | <b>16K</b> | 32K           | 64K   |
|----------------------|---------------|-------|----------------|-------------|--------|--------|------------|---------------|-------|
| 24-1 L40             | 112.0         | 199.8 | 103.0          | 99.5        | S9.3   | \$9.2  | 98.8       | 98.6          | \$5.4 |
| 24-1 L45             | 111.3         | 196.9 | + 103.2        | 100.2       | \$9.7° | 99.7   | 405.7      | 98.6          | 93.1  |
| 24-1 L50             | 119.8         | 106.9 | 192.7          | 100.9       | 9.92   | 99.8   | 1919       | 98.2          | 93.5  |
| 24-1 L55             | 113.0         | 109.4 | 102.8          | 103.5       | 151.9  | 192.2  | 103.4      | 101.4         | 9.6.2 |
| 24-1 L <b>f</b> j    | 112.7         | 165.6 | 152.2          | 104.5       | 103.4  | 153.9  | 105.6      | 103.1         | 98.1  |
| 24-1 L65             | 116.0         | 103.2 | 191.0          | 194.2       | 154.3  | 107.5  | 111.8      | 109 <b>.7</b> | 105.9 |
| 24-1 L70             | 113.5         | 164.6 | 99.9           | 102.4       | 103.2  | 106.2  | 108.3      | 105.2         | 98.6  |
| 24-1 L75             | 112.9         | 101.6 | 98.4           | 199.8       | 163.0  | 105.5  | 196.8      | 102.3         | 96.1  |
| 24-1-145             | 112.2         | 102.7 | 97.8           | \$9.3       | 102.3  | 164.1  | 107.2      | 105.1         | 98.0  |
| 24-1 L65             | 112.8         | 153.2 | 97.9           | <b>99.2</b> | 132.7  | 1(5).6 | 107.5      | 105.5         | \$9.2 |
| 24-2 140             | 120.5         | 117.6 | 114.7          | 119.5       | 105.9  | 106.3  | 195.7      | 105.9         | 102.4 |
| 24-2 145             | 119.8         | 115.9 | 114.4          | 115.5       | 156.4  | 106.5  | 107.0      | 105.2         | 99.5  |
| 24-2 L50             | 116.4         | 113.5 | 112.4          | 109.4       | 106.6  | 196.9  | 108.1      | 105.8         | 105.7 |
| 24-2 155             | 119.5         | 114.2 | 119.3          | 109.8       | 197.9  | 198.7  | 109.9      | 108.3         | 102.8 |
|                      | 118.0         | 159.3 | 158.2          | 109.2       | 158.2  | 109.3  | 111.3      | 169.4         | 104.5 |
| 24-2 103             | 121.5         | 197.9 | 196.6          | 159.2       | 109.4  | 112.5  | 117.2      | 115.2         | 106.6 |
| 24-2 110             | -118.5        | 157.8 | 105.0          | 197.8       | 105.7  | 111.5  | 113.5      | 115.2         | 103.8 |
| 24-2 140             | 110.4         | 194.9 | 103.2          | 105.9       | 157.4  | 115.1  | 111.2      | 196.6         | 100.3 |
| 24-2 185             | 117. <b>4</b> | 103.1 | 192.5          | 103.6       | 155.9  | 197.7  | 115.8      | 198.7         | 151.7 |
| 24-3 140             | 124.4         | 10212 | 102.0          | 104.0       | 150.8  | 109.8  | 112.0      | 109.9         | 153.6 |
| 24-3 145             | 124.1         | 121.9 | 116.5          | 114.9       | 108.6  | 109.1  | 108.3      | 108.4         | 154.7 |
| 24-3 150             | 125.1         | 119.0 | 117.9          | 115.4       | 198.9  | 158.9  | 109.0      | 106.5         | 191.2 |
| 24-3 1 55            | 121.4         | 112.9 | 112.2          | 115.9       | 198.7  | 198.2  | 108.6      | 105.8         | 166.6 |
| 24-3 160             | 110 0         | 444 3 | 115,5          | 116.0       | 110.3  | 119.6  | 111.0      | 109.2         | 103.8 |
| 24-3 L65             | 122 4         | 111.5 | 10.9           | 111.5       | 119.2  | 111.1  | 112.6      | 115.4         | 105.0 |
| 24-3 170             | 126 1         | 1/3 9 | 107.5          | 100 7       | 446.4  | 115.9  | 118.5      | 116.4         | 197.8 |
| 24-3 L75             | 118.1         | 156 7 | 105.5          | 105.1       | 110.1  | 112.0  | 114.0      | 111.8         | 195.5 |
| 24-3 L&D             | 118.7         | 106:6 | 154.7          | 106.3       | 166.2  | 110.6  | 112.0      | 108.0         | 192.3 |
| 24-3 L\$5            | 118.5         | 156.9 | 194.1          | 196.3       | 168.8  | 111.3  | 113.3      | 115.0         | 105.3 |
| 24-4 145             | 127.3         | 124.4 | 122.0          | 117.4       | 115.8  | 110.9  | 163 3      | 111.4         | 105.1 |
| 24-4 L45             | 126.6         | 122.5 | 121.7          | 119.3       | 112.1  | 111.2  | 116.9      | 157.0         | 103.2 |
| 24-4 150             | 124.8         | 119.4 | 119.8          | 118.5       | 112.5  | 110.9  | 115.4      | 166.9         | 162 4 |
| 24-4 155             | 123.5         | 118.7 | 116.7          | 116.6       | 113.0  | 112.5  | 111.4      | 158.6         | 163 3 |
| 24-4 165             | 121.6         | 114.0 | 114.3          | 114.2       | 112.5  | 112.2  | 112.6      | 169.6         | 154.6 |
| 24-4 L65             | 123.1         | 112.2 | 111.5          | 113.0       | 112.5  | 114.5  | 118.2      | 115.6         | 166.9 |
| 24-4 170             | 125.7         | 111.6 | 159.4          | 111.2       | 111.1  | 113.2  | 114.7      | 111.2         | 154.9 |
| 24-4 L75             | 118.5         | 198.3 | 107.3          | 169.4       | 119.0  | 111.9  | 112.4      | 107.3         | 191.1 |
| 24-4 LOG             | 118.7         | 108.2 | 156.7          | 107,7       | 159.5  | 119,6  | 113.4      | 111.1         | 194.3 |
| 24-4 L85             | 119.4         | 108.6 | 196.9          | 197.6       | 109.5  | 112.1  | 114.5      | 112.1         | 166.1 |
| 24-5 140             | 129.6         | 126.6 | 124.8          | 120.2       | 113.9  | 113.9  | 113.1      | 111.7         | 108.2 |
| 24-3 645             | 129.1         | 124.5 | 124.4          | 128:1       | 115.3  | 114.2  | 114.9      | 110.7         | 105.7 |
| 24-3 [30]            | 127.8         | 121.9 | 122.7          | 122.1       | 115.3  | 114.0  | 113.6      | 109.8         | 195.1 |
| 24-0 100             | 126.8         | 129.7 | 119.9          | 121.0       | 117.1  | 115.7  | 115.1      | 112.3         | 107.0 |
| 24-3 LUJ<br>24_5 (45 | 123.9         | 115.4 | 116.2          | 116.7       | 115.2  | 114.9  | 115.2      | 112.4         | 197.8 |
| 24_5 : 24            | 123.5         | 114.1 | 115.9          | 115.5       | 115.1  | 117.1  | 125.6      | 118.1         | 109.8 |
| 24-5 1 76            | 162.0         | 113.0 | 111.9          | 114.0       | 115.8  | 115.6  | 117.0      | 113.5         | 107.4 |
| 24-5 i an            | 120.4         | 110.2 | 19 <b>9</b> .7 | 111.5       | 112.1  | 113.6  | 114.0      | 106.7         | 152.7 |
| 24-5 144             | 150.4         | 110.0 | 198,7<br>407 A | 109,9       | 111.1  | 1:2,6  | 114.9      | 112.2         | 105.3 |
|                      | 16313         | 117.1 | T71.7 <b>2</b> | 102.2       | 112.0  | 113.8  | 115.2      | 113.1         | 106.9 |

NOTE: THESE ARE FREE FIELD VALUES

|           |        | n      |       | י ה-די |       |        |       |       |       |
|-----------|--------|--------|-------|--------|-------|--------|-------|-------|-------|
| RUN NO.   | OASPL  | 500    | 1K    | 2K     | 4K    | 8K     | 16K   | 32K   | 64K   |
| 12-1 640  | 126.3  | 122.6  | 121.6 | 117.5  | 113.8 | 159.9  | 195.1 | 199.2 | 159.5 |
| 12-1 L45  | 126.7  | 122.9  | 122.1 | 118.1  | 114.5 | 111.0  | 156.6 | 155.4 | 166.6 |
| 12-1 (50  | 124.8  | 119.9  | 129.5 | 117.9  | 114.0 | 115.3  | 153.2 | \$3.1 | \$7.8 |
| 12-1 L55  | 123.9  | 117.7  | 118.8 | 117.5  | 114.9 | 111.9  | 157.4 | 161.8 | 98.1  |
| 12-1 L60  | 122.3  | 115.3  | 117.2 | 115.8  | 114.6 | 111.5  | 168.7 | 166.7 | 96.5  |
| 12-1 LES  | 121.1  | 113.7  | 114.7 | 114.9  | 114.5 | 115.9  | 167.0 | 151.9 | 95.20 |
| 12-1 L70  | 119.8  | 113.5  | 112.4 | 113.1  | 112.5 | 115.6  | 163.0 | 155.4 | 94.3  |
| 12-1 175  | 118.9  | 109.5  | 111.5 | 113.5  | 112.5 | 110.4  | 166.3 | \$9.1 | 92.3  |
| 12-1 180  | 117.6  | 159.4  | 110.0 | 110.8  | 115.8 | 159.7  | 155.7 | 165.9 | 93.3  |
| 12-1 L85  | 117.5  | 108.3  | 198.7 | 115.5  | 119.6 | 159.2  | 105.9 | 155.7 | 93.1  |
| 12-2 L40  | 133.5  | 125.0  | 128.4 | 126.7  | 123,5 | 119.6  | 115.3 | 111.7 | 109.8 |
| 12-2 L45  | 134.4  | 129.1  | 129.2 | 127.8  | 124.7 | 120.9  | 117.3 | 112.5 | 109.8 |
| 12-2 150  | 132.3  | 125.6  | 127.8 | 126.0  | 123.2 | 119.3  | 115.6 | 159.4 | 156.5 |
| 12-2 L55  | 131.5  | 123.2  | 126.5 | 125.9  | 123.2 | 125.2  | 115.7 | 111.0 | 166.8 |
| 12-2 L60  | 129.2  | 125.5  | 123.9 | 123.2  | 121.5 | 118.9  | 114.5 | 159.3 | 195.2 |
| 12-2 L65  | 128.0  | 118.9  | 125.8 | 122.1  | 121.8 | 118.9  | 115.0 | 115.4 | 163.7 |
| 12-2 L/G  | 126.0  | 117.9  | 113.1 | 115.7  | 110.5 | 117.7  | 113.2 | 153.9 | 151.9 |
| 12-2 L75  | 125.3  | 114.3  | 117.2 | 119.4  | 119.5 | 117.7  | 113.4 | 156.8 | 99.9  |
| 12-2 1.80 | 123.2  | 113.5  | 115.0 | 116.4  | 116.9 | 115.1  | 112.3 | 157.3 | 109.0 |
| 12-2 1.85 | 123.2  | 112.6  | 113.9 | 116.4  | 117.2 | 116.5  | 113.2 | 168.3 | 161.6 |
| 12-3 1.45 | 135.1  | 135.6  | 135.3 | 127.8  | 124.1 | 119.9  | 115.1 | 111.1 | 119.3 |
| 12-3 1.45 | 136.3  | 131.3  | 131.4 | 129.5  | 125.5 | 121.9  | 117.7 | 112.8 | 111.0 |
| 12-3 155  | 134.6  | 125.1  | 139.1 | 125.7  | 125.7 | 121.5  | 117.5 | 111.5 | 159.5 |
| 12-3 155  | 134.5  | 125.7  | 128.9 | 128.7  | 125 6 | 122.3  | 117 8 | 113 3 | 159.7 |
| 12-3 150  | 131.0  | 121.8  | 125.7 | 125.2  | 123.3 | 129.8  | 115.2 | 111.3 | 167.3 |
| 12-3 165  | 129.5  | 125.4  | 122.3 | 123.6  | 123.3 | 125.6  | 115.5 | 111.9 | 195.7 |
| 12-3 175  | 127.9  | 119.4  | 119.7 | 121.4  | 121.6 | 120.1  | 115.3 | 110.2 | 164.1 |
| 12-3 175  | 127.2  | 115.7  | 118.5 | 125.9  | 121.5 | 125.1  | 116.1 | 199.8 | 163.1 |
| 12-3 189  | 125.2  | 115.5  | 116.9 | 118.8  | 120.3 | 119.8  | 116.0 | 111.5 | 154.8 |
| 12-3 185  | 128.0  | 114.5  | 115.4 | 118.5  | 125.8 | 119.4  | 115.6 | 111 6 | 154.6 |
| 12-4 145  | 136.9  | 132.6  | 132.0 | 129.2  | 126.1 | 122.4  | 118 2 | 116 7 | 113 1 |
| 12-4 1.45 | 138.3  | 133.4  | 133.3 | 131 2  | 127 0 | 124 4  | 120.7 | 116.2 | 113.1 |
| 12-4 155  | 136.9  | 129.9  | 132.2 | 136 0  | 128 6 | 12/ 5  | 120.0 | 110.2 | 113.0 |
| 12-4 155  | 136.2  | 125.9  | 136 6 | 136 0  | 120.0 | 125 7  | 121.0 | 117.5 | 111.9 |
| 12-4 169  | 133.1  | 123 1  | 127 6 | 107 3  | 126.1 | 103 0  | 121.1 | 111.0 | 113.0 |
| 12-4 155  | 131.9  | 121 9  | 124 6 | 125 8  | 125 8 | 123.5  | 115.5 | 110.4 | 111.4 |
| 12-4 175  | 130.5  | 126.6  | 121 1 | 123 6  | 124 5 | 103.0  | 110.3 | 444.5 | 110.4 |
| 12-4 175  | 130.2  | 117 3  | 120.0 | 123.0  | 124.5 | 103 1  | 112.2 | 114.9 | 155.9 |
| 12-4 185  | 129.1  | 117 15 | 110 5 | 121.2  | 103 5 | 123.0  | 120.1 | 114.5 | 100.9 |
| 12-4 1.85 | 129 1  | 116.6  | 110.0 | 121.2  | 123.3 | 100.0  | 119.7 | 110.0 | 109.9 |
| 12-5 1 40 | 132 4  | 134 6  | 133 7 | 130.0  | 124.6 | 1-24 4 | 113.0 | 110.1 | 109.6 |
| 12-5-145  | 12004  | 104.0  | 1.5.1 | 100.2  | 121.4 | 14.4   | 129.4 | 117.1 | 115.5 |
| 12-5 150  | 120.0  | 124.0  | 172.0 | 126.7  | 169.4 | 140.0  | 1     | 110.0 | 110.0 |
| 12-5 155  | 130.5  | 122 1  | 121 0 | 136.5  | 129.5 | 120.0  | 123.4 | 118.0 | 114.5 |
| 12-5 1 50 | 120.1  | 120.0  | 125 4 | 120 7  | 120 6 | 125.0  | 124.6 | 121.4 | 117.2 |
| 12-5 + 55 | 122.3  | 129.5  | 162.4 | 102 0  | 120.0 | 120.8  | 123.3 | 119.4 | 115.6 |
| 12-5 175  | 133,4  | 121 2  | 124.0 | 150.9  | 105 5 | 165.0  | 122.4 | 118.6 | 112./ |
| 12-5 175  | 120.1  | 112 1  | 121.9 | 164.8  | 120.5 | 162.8  | 121.7 | 11(.4 | 111.4 |
| 10-5 120  | 121.0. | 110.1  | 140 5 | 122.0  | 120.9 | 162.0  | 122.4 | 117.0 | 110.5 |
| 10-0 000  | 131.6  | 111.0  | 119.5 | 125.9  | 122.1 | 120.5  | 122.1 | 118.7 | 112.7 |

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#### NOTE: THESE ARE FREE FIELD VALUES







### HM-AP-65-A NOZZLE

(42 Tube Annulus, 2 Rows of Tubes, and RC Nozzle in the Center)

#### Remarks

The HM-AP-65-A Nozzle is essentially the HM-AP-59-A Nozzle configuration with a h.l inch diameter round convergent nozzle added. The noise characteristics of the HM-AP-65-A Nozzle was dominated by the 4.1 inch diameter round convergent nozzle in the center of the array. See Ref D28. The turbulent jets from the h2 tubes surrounding the relatively larger central jet did not effectively shield the noise generated by the central jet. The spectrum measured on the HM-AP-65-A indicated that the superposition theorem can not be used with a combination type nozzle. HM-AP-65-A NOZZLE

Test Facility: HNTF

Date:

**NAME** 

Tamb:

R.H.:

| Run No.                              | $P_{T}/P_{\infty}$              | $-\frac{T_T}{T}$      | V <sub>J</sub> (Ideal)                   | Nozzle                                      |
|--------------------------------------|---------------------------------|-----------------------|------------------------------------------|---------------------------------------------|
| 23.1<br>23.2<br>23.3<br>23.4<br>23.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4 | 1500°F<br>"<br>"<br>" | 1750 fps<br>2202<br>2402<br>2555<br>2678 | HM-AP-65-A<br>""<br>""                      |
| 12.1<br>12.2<br>12.3<br>12.4<br>12.5 | 1.6<br>2.2<br>2.6<br>3.0<br>3.4 | 1500°F<br>"<br>"<br>" | 1750 fps<br>2202<br>2402<br>2555<br>2678 | 6 Inch Round Convergent Noz.<br>"<br>"<br>" |

|           |       | •      |         |                |          |         |           |       |       |
|-----------|-------|--------|---------|----------------|----------|---------|-----------|-------|-------|
|           |       | ŀ      | -M-ΔP-  | -65 <u>-</u> Δ |          | E TEST  |           |       |       |
|           |       | •      |         | 0J-7           | NUZZL    |         |           |       |       |
|           | OCT.  | AVE BA | ND LEVE | L~dB           | RE: 0.00 | 02 DYNE | S/CM4//   | 25 FT |       |
| RUN NO.   | OASPL | 500    | ١ĸ      | 2K             | 4K       | 8K      | 16K       | 32K   | 64K   |
| 23-1 60   | 120.2 | 116.0  | 114.7   | 114.9          | 161.4    | 98.9    | 96.8      | 97.5  | 96.5  |
| 23-1 L45  | 120.2 | 115.4  | 115.3   | 115,2          | 192.3    | 98.6    | 98.4      | 96.5  | 95.2  |
| 23-1 650  | 119.4 | 113.2  | 115.1   | 114.6          | 193.7    | 99.8    | 99.6      | 96.8  | 94.5  |
| 23-1 L55  | 119.2 | 113.2  | 113.7   | 114.8          | 165.9    | 102.8   | 151.8     | \$9.1 | 95.6  |
| 23-1 60   | 117.3 | 108.8  | 111.7   | 112.3          | 157.4    | 166.6   | 1154.9    | 101.5 | 97.1  |
| 23-1 L65  | 116,8 | 106.8  | 198.6   | 169.7          | 157.3    | 157.7   | 109.7     | 107.0 | 98.6  |
| 23-1-170  | 114.2 | 195.6  | 106.5   | 197.1          | 105.9    | 155.7   | 105.6     | 102.1 | \$6.3 |
| 23-1 L75  | 112.5 | 193.5  | 164.1   | 105.4          | 165.1    | 164.7   | 163.8     | \$9.2 | 93.8  |
| 23-1 L80  | 111.7 | 103.9  | 102.7   | 103.6          | 163.5    | 152.9   | 103.6     | 151.1 | 94.7  |
| 23-1 L85  | 112.2 | 104.2  | 102.1   | 103.9          | 153.8    | 154.2   | 104.2     | 102.4 | 96.7  |
| 23-2 140  | 127.5 | 123.1  | 122.1   | 122.1          | 111.9    | 156.4   | 104.7     | 104.1 | 193.9 |
| 23-2 L45  | 128.1 | 122.4  | 122.8   | 123.7          | 114.1    | 197.8   | 106.8     | 193.8 | 101.9 |
| 23-2 150  | 127.4 | 119.8  | 122.6   | 123.5          | 115.4    | 198.9   | 197.8     | 104.6 | 151.2 |
| 23-2 155  | 127.1 | 119.0  | 120.9   | 123.8          | 116.3    | 111.2   | 110.1     | 156.6 | 102.2 |
| 23-2 [65  | 124.9 | 113.9  | 118.2   | 121.3          | 115.7    | 112.7   | 112.4     | 108.8 | 104.4 |
| 23-2 L65  | 123.8 | 111.3  | 114.2   | 117.3          | 114.6    | 115.0   | 117.4     | 114,2 | 105.5 |
| 23-2 L/G  | 121.5 | 110.0  | 111.8   | 114.9          | 112.7    | 113.3   | 113.5     | 109.6 | 193.1 |
| 23-2 1/5  | 116.9 | 107,3  | 109.2   | 111.7          | 111.3    | 112.1   | 111.6     | 106.4 | 165.3 |
| 23-2 L85  | 116.5 | 167,4  | 108.3   | 110.0          | 119.1    | 111.0   | 112.1     | 159.1 | 192.2 |
| 23-2 L85  | 119.5 | 107.3  | 197.4   | 115.1          | 110.7    | 112.1   | 112.4     | 110.0 | 103.7 |
| 23-3 [45  | 130.2 | 120.1  | 124.7   | 124.5          | 116,0    | 115.2   | 157.2     | 164.9 | 154.4 |
| 23-3 [45  | 130.9 | 123.4  | 120.0   | 120.3          | 118.5    | 112.6   | 159.1     | 154.4 | 103.9 |
| 23-3 [55] | 131.1 | 160.0  | 125.8   | 127.5          | 125.7    | 114.2   | 111.0     | 155.4 | 103.2 |
| 23-3 [00  | 128 1 | 116 5  | 124.9   | 127.0          | 121.1    | 116.1   | 113.0     | 198.4 | 164.1 |
| 23-3 [6]  | 126.7 | 110.5  | 129.7   | 125.9          | 119.8    | 116.5   | 114.6     | 115.1 | 105.5 |
| 23-3 170  | 123 3 | 112 2  | 114.0   | 121.5          | 118.2    | 117.9   | 119.4     | 115.5 | 106.5 |
| 23-3 175  | 121 1 | 100 3  | 111 3   | 110.9          | 115.0    | 115.9   | 115.4     | 115.8 | 104.3 |
| 23-3 (80  | 120.5 | 119.6  | 113 3   | 114.0          | 114.0    | 114.5   | 112.6     | 156.1 | 59.6  |
| 23-3 185  | 121.4 | 109.3  | 120.0   | 112 8          | 113.1    | 112.9   | 115.0     | 108.0 | 151.9 |
| 23-4 143  | 131.4 | 128 0  | 125.6   | 120.0          | 114.0    | 112.5   | 112.9     | 110.0 | 194.9 |
| 23-4 L45  | 132.5 | 127 1  | 122.0   | 123.3          | 115.5    | 113./   | 111.3     | 169.2 | 197.3 |
| 23-4 155  | 132.9 | 124 5  | 127.5   | 120 0          | 129.4    | 115.3   | 113.2     | 109.0 | 156,5 |
| 23-4 155  | 132.5 | 122.4  | 125 6   | 120.9          | 123.2    | 11/./   | 115,6     | 159.9 | 106.6 |
| 23-4 60   | 135.1 | 118.6  | 122.4   | 125.4          | 124.3    | 119./   | 116.9     | 112.5 | 157.9 |
| 23-4 L65  | 129.3 | 115.7  | 118.5   | · 122.0        | 120.0    | 119.3   | 117.8     | 113.7 | 159.3 |
| 23-4 L7j  | 126.7 | 114.1  | 115 6   | 110 5          | 120.0    | 121.1   | 123.0     | 119.6 | 111.3 |
| 23-4 175  | 124.5 | 115.9  | 113.1   | 117 4          | 110.9    | 125.2   | 119.6     | 115.3 | 109.3 |
| 23-4 180  | 124.7 | 111.6  | 112 6   | 115 5          | 110.9    | 119.4   | 117.1     | 111.2 | 195.5 |
| 23-4 L85  | 125.0 | 119.4  | 110 7   | 114 0          | 110.9    | 118.7   | 117.8     | 114.3 | 107.9 |
| 23-5 140  | 133.5 | 135 4  | 128 7   | 125 0          | 113-9    | 118.9   | 117.4     | 114.1 | 107.9 |
| 23-5 L45  | 134.7 | 129.7  | 120 8   | 120 0          | 120.0    | 110.4   | 114.1     | 111.9 | 110.0 |
| 23-5 L50  | 134.2 | 127.0  | 129.8   | 136 /          | 125 1    | 118.5   | 116.3     | 111.8 | 109.1 |
| 23-5 L55  | 135.1 | 124.5  | 128.1   | 131 3          | 127 6    | 122 3   | 118.1     | 113.0 | 159.5 |
| 23-5 [6]  | 131.9 | 119.7  | 124_1   | 127 8          | 124 0    | 123.3   | 125.3     | 115.8 | 111.3 |
| 23-5 L€5  | 135.9 | 117.2  | 119.8   | 124.3          | 122 0    | 103 0   | 134 3     | 110.4 | 111.1 |
| 23-5 170  | 128.5 | 115.9  | 117.3   | 121 3          | 121 0    | 155 2   | 124.3     | 129.8 | 112.4 |
| 23-5 L75  | 127.0 | 112.4  | 114.8   | 119.2          | 120.0    | 121 2   | 110 0     | 110.0 | 110.5 |
| 23-5 L8G  | 126.6 | 112.6  | 113.5   | 117.4          | 121.0    | 120.2   | 110 2     | 112.7 | 106.9 |
| 23-5 L85  | 128.0 | 112.0  | 112.2   | 117.2          | 123.8    | 121 4   | 120 4     | 115.4 | 109.1 |
|           |       |        |         |                |          | *****   | * * * * * | 110.9 | 111.0 |

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### NOTE: THESE ARE FREE FIELD VALUES

|                      |         | 1          |                 |        | N0771 |               |        |        | -            |
|----------------------|---------|------------|-----------------|--------|-------|---------------|--------|--------|--------------|
|                      | 04601   | - 1<br>500 | 7 <b>M-A</b> 7- | -63-A  | NUZZL | .E -1 E 5 I   | JAIA   | 0012   |              |
| KUN NU.              | UASPL   | 500        | IK              | .2K    | 4K    | 8K            | IOK    | 32K    | 64K          |
| 12-1 (45             | 126.3   | 122.6      | 121.6           | 117.5  | 113.8 | 159.9         | 195.1  | 199.2  | 199.5        |
| 12-1 [45             | 125.7   | 122.9      | 122.1           | 118.1  | 114.5 | 111.5         | 156,6  | 100.4  | 100.6        |
| 12-1-(5)             | 124.8   | 119.9      | 125.5           | 117.0  | 114.5 | 115.3         | 156.2  | 99.1   | 97.8         |
| 12-1-155             | 123.9   | 117.7      | 118.8           | 117.5  | 114.9 | 111.9         | 197.1  | 101.8  | 98.1         |
| 12-1 L6G             | 122.3   | 115.3      | 117.2           | 115.8  | 114.5 | 111.5         | 198.7  | 199.7  | 96.5         |
| 12-1 165             | 121.1   | 113.7      | 114.7           | 114.9  | 114-0 | 115.9-        | 107.0  | 161.9  | 95.2         |
| 12-1 170             | 119.8   | 113.5      | 112.4           | 113.1  | 112.5 | 115.6         | 156.0  | 199.4  | 94.3         |
| 12-1 175             | 118.9   | 159.5      | 111.5           | 113,9- | 112.5 | 119.4         | 106.3  | 99.1   | 92,3         |
| 12-1 185             | 117.6   | -159.4     | 119.9           | 110.6  | 110.8 | 109.7         | 165.7  | 100.9  | 93 <b>.3</b> |
| 12-1 L65             | 117.9   | 108.3      | 108.7           | 119,5  | 110.6 | 109.2         | 155.9  | 199.7  | 93.1         |
| 12-2 L40             | 133.5   | 128.0      | 128.4           | 126.7  | 123.5 | 119.6         | 115.3  | \$11.7 | 109.8        |
| 12-2 L45             | 134.4   | 123.1      | 129.2           | 127.8  | 124.7 | 120.9         | -117.3 | 112.5  | 169.8        |
| 12-2 L50             | 132.3   | 125.6      | 127.8           | 128.0  | 123.2 | 119.3         | 115.6  | 159.4  | 196.5        |
| 12-2 655             | 131.5   | 123.2      | 125.5           | 125.9  | 123.2 | 120.2         | 115.7  | 111.0  | 106.8        |
| 12-2 [60             | 129.2   | 120.5      | 123.9           | 123.2  | 121.5 | 118. <u>9</u> | 114.5  | 169.3  | 105.2        |
| 12-2 65              | 128.0   | 118.9      | 125.8           | 122.1  | 121.8 | 118.9         | 115.0  | 115.4  | 193.7        |
| 12-2 L7G             | 126.0   | 117.9      | 118.1           | \$19.7 | 119.5 | 117.7         | 113.2  | 158.9  | 101.9        |
| 12-2 L75             | 125.3   | 114.3      | 117.2           | 119.4  | 119.5 | 117.7         | :13.4  | 106.8  | 99.9         |
| 12-2 L\$0            | 123.2   | 113.5      | 115.0           | 116.4  | 116.9 | 116.1         | 112.3  | 107.3  | 100.0        |
| 12-2 L85             | 123.2   | 112.6      | 113.9           | 116.4  | 117.2 | 116.0         | 113.2  | 108.3  | 101.0        |
| 12-3 140             | 135.1   | 139.6      | 135.3           | 127.6  | 124.1 | 119.9         | 115.1  | 111.1  | 110.3        |
| 12-3 L45             | 136.3   | 131.3      | 131.4           | 129.5  | 126.0 | 121.9         | 117.7  | 112.8  | 111.5        |
| 12-3 650             | 134.8   | 126.1      | 130.1           | 125.7  | 125.7 | 121.5         | 117.5  | 111.5  | 159.0        |
| 12-3 L55             | 134.0   | 125.7      | 128.9           | 128.7  | 125.6 | 122.3         | 117.8  | 113.3  | 169.7        |
| 12-3 160             | 131.0   | 121.8      | 125.7           | 125.2  | 123.3 | 125.8         | 116.2  | 111.3  | 107.3        |
| 12-3 L65             | 129.5   | 125.4      | 122.3           | 123.6  | 123.3 | 125.6         | 115.5  | 111.9  | 165.7        |
| 12-3 L70             | 127.9   | 119.4      | 119.7           | 121.4  | 121.6 | 120.1         | 115.3  | 115.2  | 104.1        |
| 12-3 L75             | 127.2   | 115,7      | 118.5           | 120.9  | 121.5 | 120.1         | 116.1  | 109.8  | 103.1        |
| 12-3 L80             | 126.2   | 115.5      | 116.9           | 118.8  | 125.3 | 119.8         | 116.0  | 111.5  | 164.8        |
| 12-3 L85             | 126.0   | 114.5      | 115.4           | 118.5  | 120.8 | 119.4         | 116.0  | 111.6  | 154.6        |
| 12-4 140             | 136.9   | 132.6      | 132.0           | 129.2  | 126.1 | 122.4         | 118.2  | 114.7  | 113.1        |
| 12-4 L45             | 138.3   | 133.4      | 133.3           | 131.2  | 127.9 | 124.4         | 125.7  | 116.2  | 113.6        |
| 12-4 L50             | 136.9   | 129.9      | 132.2           | 135.9  | 126.0 | 124.5         | 120.8  | 115.3  | 111.9        |
| 12-4 L55             | 136.2   | 125.9      | 139.6           | 136.9  | 128.5 | 125.7         | 121.7  | 117.9  | 113.8        |
| 12-4 60              | 133.1   | 123.1      | 127.0           | 127.3  | 126.1 | 123.9         | 119.9  | 115,4  | 311.4        |
| 12-4 L65             | 131.9   | 121.9      | 124.0           | 125.8  | 125.8 | 123.6         | 125.0  | 116.1  | 110.2        |
| 12-4 L75             | 135.5   | 120.6      | 121.1           | 123.6  | 124.5 | 123.7         | 119.3  | 114.9  | 168.9        |
| 12-4 L75             | 135.2   | 117.3      | 120.0           | 123.3  | 124.9 | 123.7         | 125.1  | 114.5  | 197.8        |
| 12-4 L8Ú             | 129.1   | 117.0      | 118.5           | 121.2  | 123.5 | 123.0         | 119.7  | 116.0  | 109.9        |
| 12-4 L\$5            | 129.1   | 116.0      | 117.0           | 121.2  | 124.2 | 122.7         | 119.8  | 116.1  | 109.8        |
| 12-5 L40             | 138.4   | 134.5      | 133.7           | 139.2  | 127.4 | 124.4         | 125.4  | 117.1  | 115.3        |
| 12-5 L45             | 139.8   | 134.8      | 135.0           | 132.5  | 129.4 | 125.3         | 122.8  | 118.6  | 115.7        |
| 12-5 L50             | 138.3   | 131.1      | 133.4           | 132.2  | 129.5 | 126.5         | 123.4  | .118.0 | 114.5        |
| 12-5 L55             | 136.1   | 128.0      | 131.8           | 132.6  | 131.0 | 126.5         | 124.8  | 121.4  | 117.2        |
| 12-5 L60             | 135.3   | 124.3      | 125.4           | 129.3  | 128.6 | 126.6         | 123.3  | 119.4  | 115.6        |
| 12-5 L <b>65</b>     | 133.4   | 122.5      | 124.8           | 126.9  | 127.5 | 125.7         | 122.4  | 118.6  | 112.7        |
| 12-5 L70             | 132.1   | 121.3      | 121.9           | 124.8  | 126.5 | 125.8         | 121.7  | 117.4  | 111.4        |
| 10 F . 35            | 132.0   | 118.1      | 121.2           | 124.6  | 126.9 | 125.6         | 122.4  | 117.6  | 110.5        |
| 12~5 [15             |         |            |                 |        |       |               |        |        |              |
| 12-5 L75<br>12-5 L80 | 131.2 * | 117.8      | 119.5           | 122.9  | 125,7 | 125.3         | 122.1  | 118.7  | 112.7        |

NOTE: THESE ARE FREE FIELD VALUES



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#### HM-AP-78 NOZZLE

#### 16 SPOKES AND 208 TUBES, AR 3.1

Description:

Number of Elements: 16 spokes and 16 clusters of tubes

Area Ratic: 3.1

- Spoke Penetration: 8 spokes at 68.5%, 4 spokes at 92.5%, and 4 spokes at 97.5%
- Tube Arrangements: 8 clusters of tubes (15 tubes each); 8 clusters of tubes (11 tubes each)

Flow Area: 28 square inches

Exit Cant Angle: 0 degrees

Material: 321 CRES





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### HM-AP-78 NOZZLE

(16 Spokes and 16 Clusters of Tubes)

#### Remarks:

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This nozzle is a 1/8th scale representation of a GE4 engine design concept (NSC-30). Although a peak sideline suppression value of 15.5 PNdB was attained, the static thrust loss was excessive, e.g., 25%thrust loss at PR = 3.4.

Original measured data has been lost. See Reference D29 for information concerning spectrum levels.





OCTAVE PASS BANDS IN HERTZ RE: 0.0002 DYNES/CM<sup>2</sup>// 200 FT POLAR ARC 140 130 125 OVERALL SPL~dB RC OCTAVE BAND LEVEL~dB 120 50 115 30<sup>0</sup> 40<sup>0</sup> 50<sup>0</sup> 60<sup>0</sup> 70<sup>0</sup> -80<sup>0</sup> 900 ANGLE TO THE JET AXIS~DEGREES TOTAL TEMPERATURE (T 8) : 1500° F NOZZLE EXIT AREA (A 8): 12.6 FT2 70 5 2 5 1 Ż 5 1 100 1000 10000 FREQUENCY IN HERTZ HM-AP-85-1 NOZZLE PRESSURE RATIO: 1.8 (126 TUBE HEXAGON ARRAY) TOTAL TEMPERATURE: 1500° F AR 3.33 JET VELOCITY (IDEAL): 1923 FPS SCALE FACTOR: 8:1 NOZZLE EXIT AREA (A8): 12.6 FT2 OCTAVE PASS BANDS IN HERTZ OCTAVE PASS BANDS IN HERTZ 140 140 RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 08 06 001 011 051 08 RE: 0.0002 DYNES/CM<sup>2</sup>//200 FT POLAR ARC 00 00 01 01 021 021 ςσ OCTAVE BAND LEVEL~dB OCTAVE BAND LEVEL~dB 50. 50 70 **≢**70•∃ 100 90 tititut 80 70 70 5 5 1 10000 1 100 2 5 1 2 Ś Ż 5 Ż. 5 1000 100 10000 1000 FREQUENCY IN HERTZ FREQUENCY IN HERTZ PRESSURE RATIO: 2.2 "PRESSURE RATIO: 3.0 TOTAL TEMPERATURE: 1500° F TOTAL TEMPERATURE: 1500° F JET VELOCITY (IDEAL): 2555 FPS JET VELOCITY (IDEAL): 2202 FPS NOZZLE EXIT APEA (A.): 12.6 FT2 NOZZLE-EXIT AREA (A8): 12:6 FT2 FREE FIELD VALUES

#### HM-AP-15-1 NOZZLE

(126 Tube Hexagon Array, AR 3.33)

#### Remarks:

The effective tube length was varied by blocking secondary air entrainment with a peripheral wall around the tube array. The blocker lengths tested were 4, 6, 7 and 9 inches. This resulted in effective tube lengths of 7 inches (no blocking), 3 inches, 1 inch, 0 inches and -2 inches. Although thrust loss was significantly affected by effective tube length, there was little noticeable change in jet noise levels until the blockers extended beyond the nozzle exit plane (Ref. D30). A tube length of -2 inches resulted in a sharp decrease in thrust and noise.

Acoustic test data taken with the HM-AP-85-1 (126 tube, AR 3.33) nozzle during September 1968 was compared to data acquired in February and March of 1969. (Ref. D31). Acoustic data agreed within  $\pm$  1.5 PNdB. There was very little difference noted in acoustic data obtained with convergent tube ends or straight (non-convergent) tube ends.

Ref. D32 relates the 126 tube nozzle PNL suppression with nozzle area ratio. Three area ratios were considered: 2.8, 3.33 and 5.2. Optimum area ratio at gas conditions of PR = 3.0 and  $T_T = 1500^{\circ}$ F would occur at an area ratio of about 3.6 (14.8 PNdB suppression). The noise spectrum has a low frequency peak that is sensitive to pressure ratio and a high frequency peak that tends to agree with jet relationships (Strouhal number) prior to jet coalescence. The high frequency component of the spectrum peaks at a Strouhal number of 0.25, using the tube exit diameter as the dimension function. The low frequency part of the spectrum decreases in magnitude as area ratio increases.

Installation of a tight fitting ejector on the 126 tube, AR 3.33 nozzle improved PNL suppression by 1 to 2 PNdB, however, thrust loss increased (Ref. 034). The cylindrical ejector was 11 inches long and 12 inches in diameter. The effective primary nozzle diameter to ejector throat diameter ratio was 0.92. Addition of the ejector reduced the high frequency

noise levels, especially at the lower angles relative to the jet axis. Reference D35 discusses tests performed with various sizes of hardwall ejectors. The following ejectors were installed on the HM-AP-85-1 nozzle:

- (1) 11 inches long, 12 inches diameter
- (2) 16 inches long, 12 inches dimmeter
- (3) 11 inches long, 13 inches diameter

The longer ejector installation resulted in a l 1.5 PNdB reduction in PNL suppression relative to the shorter ejectors. Maximum 1500 foot sideline suppression attained was 15.8 PNdB with the ll inch long by 13 inch diameter ejector configuration.

Elliptically shaped tubes did not noticeably change the noise characteristics. See Reference D33.

MM-AP-85-1 NOZZLE

Test Facility: HNTF Date: April 7, 1969 T<sub>amb</sub>: 54°F R.H.: 53%

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| Run No. | $P_{T}/P_{\bullet}$ | $\frac{T_{T}}{T}$   | $V_{J}$ (Ideal) | Nozzle     |
|---------|---------------------|---------------------|-----------------|------------|
| 84.1    | 1.8                 | 1500 <sup>0</sup> ř | 1923 fps        | HM-AP-85-1 |
| 84.2    | 2.2                 | 11                  | 2202            | n          |
| 84.3    | 2.6                 | 11                  | 2402            | 11         |
| 84.4    | 3.0                 | 11                  | 2555            | 11         |
| 84.5    | 3.4                 | 11                  | 2678            | 11         |
| 84.6    | 1.8                 | 1000°F              | 1659            | 11         |
| 84.7    | 2.2                 | **                  | 1900            | "          |
| 84.8    | 2.6                 | 11                  | 2073            | 11         |
| 84.9    | 3.0                 | 18                  | 2205            | 11         |
| 84.10   | 3.4                 | 11                  | 2311            | 11         |
| 84.11   | 1.8                 | 500°F               | 1345            | **         |
| 84.12   | 2.2                 | 11                  | 1541            | 11         |
| 84.13   | 2.6                 | 11                  | 1681            | 11         |
| 84.14   | 3.0                 | 11                  | 1788            | 11         |
| 84.15   | 3.4                 | 13                  | 1850            | 11         |
|         |                     |                     |                 |            |

|         |                   | ł                         | M_AP_35_1              |                                |
|---------|-------------------|---------------------------|------------------------|--------------------------------|
| Run NO. | P <sub>T</sub> /P | $\mathrm{T}_{\mathrm{T}}$ | V <sub>J</sub> (Ideal) | Nozzle                         |
| 85.1    | 1.8               | 1500°F                    | 1923 fps               | 6 Inch Round Convergent Nozzle |
| 85.2    | 2.2               | 11                        | 2202                   | . 11                           |
| 85.3    | 2.6               | 11                        | 2402                   | 11                             |
| 85.4    | 3.0               | IJ                        | 2555                   | n                              |
| 85.5    | 3.4               | Ħ                         | 2678                   | 11                             |
| 85.6    | 1.8               | 1000°F                    | 1659                   | 11                             |
| 85.7    | 2.2               | 11                        | 1900                   | n                              |
| 85.8    | 2.6               | 11                        | 2073                   | IJ                             |
| 85.9    | 3.0               | tt-                       | 2205                   | IJ                             |
| 85.10   | 3.4               | 11                        | 2311                   | 11                             |
| 85.11   | 1.8               | 500°F                     | 1345                   | н                              |
| 85.12   | 2.2               | 11                        | 1541                   | n                              |
| 85.13   | 2.6               | 11                        | 1681                   | 11                             |
| 85.14   | 3.0               | 11                        | 1788                   | 11                             |
| 85.15   | 3.4               | 11                        | 1850                   | 11                             |

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#### HM-AP-86-1 NOZZLE





#### Description:

The HM-AP-86-1 nozzle is a 330 tube hexagonal array with equal spacing between tubes. The tubes have round convergent ends and are inserted into a baseplate. The baseplate attaches to a diffusing plenum which provides the transition from the gas supply line to the baseplate.

Number of Elements: 330 tubes with round convergent ends Area Ratio: 4.0 Flow Area: 28.3 square inches Exit Cant Angle: 0 degrees Length of Tubes: 7 inches

Material: 321 CRES



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# HM-AP-M-1 NOZZLE

(330 Tube Hexagonal Array, AR 4.0)

#### Remarks

Measured acoustic data for the HM-AP-86-1 nozzle has been lost. Most of the information on this nozzle was derived from Reference D36. Several ejectors were tested with this nozzle. Hexagonal unlined ejectors with lengths of 5, 12.9 and 25.8 inches attained up to 1 PNdB, 4 PNdB and 5 PNdB respectively at low pressure ratios, e.g. PR = 1.6,  $T_T = 1000^{\circ}F$ . At pressure ratios of 3.0 and 3.4 the unlined ejectors provided 1 PNdB or less additional suppression. The same ejectors with one-inch thick fiberglass installed on the inner walls significantly improved suppression values. The lined 5-inch ejector improved suppression by 1 PNdB relative to the unlined case. The 12.9"lined ejector improved suppression by 2 - 3 PNdB. The 25.8 inch ejector improved suppression by 5 - 6.5 PNdB. The ejector throat dimension in all cases was 11.8 inches. Maximum PNL suppression of 20.5 PNdB was realized by the HM-AP-86-1 nozzle with lined 25.8 inch long ejector at pressure ratios of 2.2 and 3.0 with  $T_T = 1500^{\circ}F$ .



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HM-AP-86-2 NOZZLE ( 330 TUBE HEXAGONAL ARRAY, AR 5.2 ) Description: The HM-AP-86-2 nozzle is a 330 tube hexagonal array with equal spacing between tubes. The tubes have round convergent ends and are inserted into a baseplate. The baseplate attaches to a diffusing plenum which provides the transition from the gas supply line to the baseplate. Number of Elements: 330 tubes with round convergent ends Area Ratio: 5.2 NO PICTURE AVAILABLE Flow Area: 28.3 square inches Exit Cant Angle: 0 degrees Length of Tubes: 7 inches Material: 321 CRES 3 PNL SUPPRESSION PNdB // 1500 FT SIDELINE 22 20 18 PNL SUPPRESSION (PNdB) 16 THRUST LOSS (%) 14 2 12 10 8 (•] ~2 0 1800 2000 2200 2400 2690 2800 2 3 1400 1600 1 PRESSURE RATIO (P./P.) JET VELOCITY (IDEAL) ~ FPS

> NOZZLE EXIT AREA (Ag): 12.6 FT<sup>2</sup> FREE FIELD VALUES

△---- △ 1500° F

⊙----⊙ 1000° F



# HH-AP-86-2

(330 Hube Hexagonal Array, AR 5.2)

#### <u>Remarks</u>

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Measured acoustic data for the HM-AF-86-2 nozzle has been lost. Extrapoleted PNL values are included in Reference D36.



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(12 Spoke and Center Plug, AR 2.9)

# Remarks

Acoustic characteristics were reported in Reference D37.

NAE-4A

Facility: Annex D (Cell #1) Nozzle and Microphone Heights are 20 Inches Date: Tamb: R.H.:  $P_{T}/P$  $\underline{\mathbf{T}_{T}}$  $V_{J}$  (Ideal) Run No. Nozzle 2.2 K 170 1100°F 1960 fps MAE 4A 2.6 11 H 171 tí 2130 Ħ 11 H 172 2280 3.0 н 164 1100°F 2.2 1960 fps 3.08-In. Round Convergent Nozzle\* H 165 11 2.6 2130 11 н 166 11 3.0 2280 \*1/8th scale C-6 Measured acoustic data is recorded in Reference D2.

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# NOZZLE TEST DATA

OCTAVE BAND LEVEL-W RE: 0.0002 DYNES / CM2// 25 FT

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| <b>XAE-4</b> |     |       |       |       |          |       |             |       |       |       |  |
|--------------|-----|-------|-------|-------|----------|-------|-------------|-------|-------|-------|--|
| RUN          | NQ. | OASPL | 500   | 1K    | <b>.</b> | 4K    | <b>8K</b> - | -16K  | 32K   | 64K   |  |
| <b>H16</b> 4 | L30 | A25.9 | 117.6 | 120.3 | 117.5    | 121.2 | 114.7       | 108.3 | 104.2 | 98.7  |  |
| <b>H164</b>  | L40 | 123.9 | 115.9 | 118.8 | 115.6    | 119.0 | 110.6       | 100.8 | 93.2  | 94.1  |  |
| 4164         | L50 | 124.9 | 115.0 | 118.4 | XÌ6.7    | 120.4 | 114.2       | 113.1 | 106.3 | 99.8  |  |
| <b>B</b> 164 | £60 | 120.3 | 108.0 | 111.9 | 111.5    | 116.5 | 112.7       | 107.4 | 102.0 | 96.2  |  |
| H164         | L70 | 114.2 | 102.5 | 105.5 | 105.8    | 110.1 | 107.0       | 102.5 | 95.0  | 86.0  |  |
| H165         | L30 | 125.5 | 118.3 | 119.7 | 117.8    | 120.2 | 114.0       | 106.8 | 102.4 | 97.4  |  |
| H165         | L4Ú | 126.5 | 118.2 | 121.3 | 118.0    | 122.0 | 113.9       | 104.5 | 95.8  | 94.3  |  |
| K165         | L50 | 128-8 | 117.7 | 121.5 | 120.2    | 125.0 | 119.4       | 115.6 | 111.6 | 107.8 |  |
| H165         | L60 | 123.2 | 110.6 | 114.5 | 114.2    | 119.6 | 115.4       | 110.8 | 105.8 | 99.1  |  |
| H165         | L70 | 118.1 | 105.3 | 108.2 | 109.1    | 114.1 | 111.5       | 106.8 | 100.2 | 94.3  |  |
| H166         | L30 | 128.9 | 121.5 | 121.8 | 123.8    | 122.2 | 117.5       | 110.2 | 107.0 | 106.0 |  |
| <u>H166</u>  | L40 | 130.1 | 121.1 | 124.5 | 123.1    | 125.2 | 118.2       | 109.2 | 103.3 | 104.2 |  |
| H156         | L50 | 131.9 | 120.1 | 124.8 | 124.1    | 127.3 | 122.4       | 119.3 | 115.5 | 111.0 |  |
| H166         | L60 | 127.0 | 113.0 | 117.8 | 119.3    | 123.4 | 118.7       | 114.3 | 109.6 | 102.9 |  |
| H166         | L70 | 122.2 | 108.1 | 112.2 | 114.4    | 118.2 | 115.5       | 110.6 | 103.8 | 96.3  |  |
| ¥170         | L30 | 114.9 | 111.5 | 106.7 | 102.1    | 106.1 | 104.8       | 102.9 | 100.9 | 93.2  |  |
| 1170         | L40 | 112.8 | 108.3 | 106.8 | 100.6    | 105.7 | 102.7       | 97.7  | 90.9  | 84.8  |  |
| H170         | L50 | 116.7 | 108.2 | 197.5 | 104.4    | 110.5 | 109.5       | 108.5 | 106.2 | 98.6  |  |
| H170         | L60 | 115.8 | 103.3 | 103.3 | 102.4    | 111.9 | 110.0       | 106.2 | 103.2 | 96.0  |  |
| H⊥70         | L70 | 111.5 | 100.2 | 99.4  | 98.6     | 105.8 | 107.1       | 102.6 | 97.0  | 88.5  |  |
| H171         | L30 | 119.7 | 116.9 | 111.8 | 107.3    | 109.5 | 108.l       | 106.3 | 103.9 | 98.5  |  |
| H171         | L40 | 117.2 | 113.3 | 111.9 | 105.1    | 108.7 | 105.7       | 100.7 | 95.1  | 94.2  |  |
| H171         | L50 | 120.2 | 112.5 | 111.9 | 107.6    | 113.6 | 112.6       | 111.8 | 108.7 | 102.5 |  |
| H171         | L60 | 118.6 | 107.1 | 107.2 | 105.7    | 114.7 | 112.3       | 109.2 | 105.3 | 99.4  |  |
| H171         | L70 | 113.0 | 102.7 | 102.4 | 101.3    | 107.8 | 109.3       | 105.4 | 99.4  | 90.6  |  |
| H172         | L30 | 123.2 | 120.7 | 115.6 | 110.9    | 113.3 | 110.6       | 108.7 | 105.3 | 99.4  |  |
| H172         | L40 | 120.8 | 117.0 | J15.7 | 108.3    | 111.9 | 108.3       | 103.5 | 96.3  | 94.4  |  |
| H172         | L50 | 122.8 | 115.8 | 114.8 | 110.7    | 116.1 | 114.9       | 114.0 | 110.4 | 104.1 |  |
| H172         | L60 | 120.6 | 109.9 | 110.3 | 108.3    | 116.3 | 114.2       | 111.3 | 107.0 | 101.0 |  |
| H172         | L70 | 115.6 | 106.4 | 104.8 | 103.7    | 110.1 | 110.4       | 106.9 | 100.5 | 91.7  |  |

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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MAE-203-3

(20 Spokes, AR 2.2)

#### Remarks

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The MAE 203-3 nozzle was fabricated for the 707 airplane jet noise suppression program. The nozzle was retested for the SST program. Jet noise characteristics were reported in Reference D37. MAE-203-3

Facility: Annex D (Cell #1) Nozzle and microphone heights are 20 inches.

Date:

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Tamb:

R. H.:

| Run No.                 | $\frac{PT/P}{PT}$ | $\underline{\mathbf{T}_{T}}$ | $V_{J}$ (Ideal)          | Nozzle                                  |
|-------------------------|-------------------|------------------------------|--------------------------|-----------------------------------------|
| н 276<br>н 277<br>н 278 | 2.2<br>2.6<br>3.0 | 1100°F<br>"                  | 1960 fps<br>2130<br>2280 | MAE 203-3<br>"                          |
| н 284<br>н 285<br>н 286 | 2.2<br>2.6<br>3.0 | 1100°F<br>"                  | 1960 fps<br>2130<br>2280 | 3.08 Inch Round Convergent Noszle*<br>" |

\* 1/3th scale

Measured acoustic data is recorded in Reference D2.

# NOZZLE TEST DATA

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OCTAVE BAND LEVEL- AB RE: 0.0002 DYNES/CM2//25 FT

| MAE-200-3       |       |         |       |         |       |            |       |       |              |        |  |
|-----------------|-------|---------|-------|---------|-------|------------|-------|-------|--------------|--------|--|
| RUN NO.         | OASPL | 500     | 1K ·  | *       | 4K    | ₿ <b>K</b> | 16K   | 32K   | -64K         |        |  |
| H276 L30        | 117.2 | 113.5   | 111.5 | 108.5   | 106.5 | 102.5      | 101.5 | 100.0 | 92.5         | ţ      |  |
| H276 L40        | 115.4 | 109.5   | 107.5 | 106.5   | 104.5 | 107.5      | 105.5 | 104.5 | 97.5         | ÷      |  |
| H276 L50        | 118.3 | 111.0   | 110.5 | 0. بُ11 | 110.0 | 107.5      | 106.5 | 104.0 | 98.5         | ,      |  |
| H276 L60        | 111.7 | 102.5   | 102.0 | 106.ũ   | 105.0 | 103.0      | 101.5 | 98.5  | 94.0         |        |  |
| H276-L70        | 109.7 | 99.5    | 99.0  | 103.0   | 103.0 | 102.5      | 101.0 | 98.0  | 89.0         |        |  |
| H277 L30        | 120.8 | 116.5   | 115.5 | 113.0   | 110.5 | 105.5      | 104.0 | 102.0 | 94.5         | 1      |  |
| H277 L40        | 118.3 | 118.0   | 111.0 | 110.5   | 198.0 | 109.0      | 107.0 | 106.0 | 99.5         | ł      |  |
| H277 L50        | 121.8 | 114.5   | 113.5 | 117.0   | 114.5 | 110.0      | 108.0 | 106.0 | 100.5        | ţ      |  |
| <b>H277 L60</b> | 114.7 | 105.5   | 105.0 | 110.0   | 108.0 | 105.0      | 103.0 | 100.5 | 96.0         |        |  |
| H277 L70        | 112.3 | 102.0-  | 102.0 | 106.5   | 105.5 | 105.0      | 102.5 | 99.5  | 91.0         | ţ      |  |
| H278 L30        | 124.1 | 119.0   | 118.5 | 117.5   | 115.5 | 110.0      | 106.0 | 103.5 | 98.0         | ŧ<br>1 |  |
| H278 L40        | 121.2 | 115.5   | 114.0 | 114.5   | 111.5 | 111.5      | 109.0 | 107.5 | 102.5        |        |  |
| H278 L50        | 124.9 | 117.0   | 116.5 | 120.5   | 118.0 | 113.5      | 110.0 | 107.5 | 103.5        |        |  |
| H278 L60        | 117.2 | 107.5   | 107.5 | 112.5   | 111.0 | 107.5      | 104.5 | 102.5 | 97.0         | r<br>1 |  |
| H278 L70        | 114.8 | 104.0   | 104.0 | 109.0   | 108.5 | 107.5      | 104.5 | 101.5 | 93.0         |        |  |
| H284 L30        | 125.4 | 116.7   | 120.3 | 117.4   | 120.1 | 114.7      | 107.5 | 103.3 | 97.2         | 1      |  |
| H284 L40        | 125.3 | 115.3   | 119.7 | 116.4   | 121.0 | 115.3      | 109.2 | 104.0 | 98.2         |        |  |
| H284 L50        | 125.4 | 114.4   | 120.0 | 117.6   | 120.7 | 114.8      | 110.8 | 104.4 | 98.0         |        |  |
| H284 L60        | 121.2 | 109.3   | 113.9 | 112.0   | 117.7 | 112.7      | 106.7 | 101.1 | 95.8         |        |  |
| H284 L70        | 115.2 | 103.0   | 105.9 | 105.9   | 110.5 | 109.3      | 104.3 | 98.5  | 89.7         |        |  |
| H285 L30        | 128.3 | 119.7   | 123.6 | 121.0   | 121.5 | 118.0      | 111.5 | 107.2 | 100.7        |        |  |
| H285 L40        | 127.8 | 118.0   | 121.8 | 119.4   | 123.1 | 118.4      | 112.6 | 108.0 | 101.9        |        |  |
| H285 L50        | 128.7 | . 117.0 | 122.8 | 121.1   | 123.9 | 119.3      | 114.7 | 109.4 | 103.4        |        |  |
| H285 L60        | 122.6 | 110.9   | 115.4 | 113.9   | 118.8 | 113.9      | 108.5 | 103.3 | 98. <u>1</u> | ,      |  |
| H285 L70        | 117.6 | 104.8   | 108.3 | 107.5   | 113.1 | 111.6      | 107.7 | 102.0 | 93.9         |        |  |
| H286 L30        | 131.6 | 122.4   | 125.2 | 127.0   | 124.5 | 120.6      | 113.9 | 110.5 | 106.5        |        |  |
| H286 L40        | 131.1 | 120.8   | 124.9 | 123.7   | 126.3 | 121.6      | 115.6 | 111.7 | 107.7        |        |  |
| H286 L50        | 132.3 | 120.5   | 126.2 | 126.1   | 126.8 | 1,22.7     | 118.5 | 113.8 | 109.5        |        |  |
| H286 L60        | 126.3 | 113.4   | 118.3 | 118.6   | 122.7 | 117.1      | 112.1 | 107.0 | 102.3        |        |  |
| 1286 T.70       | 122 3 | 108 2   | 112 4 | 115 7   | 116 9 | 115.9      | 112.4 | 106.5 | 99.4         |        |  |

NOTE: THIS DATA MCLUDES GROUND REFLECTION INTERFERENCE



MPP 130-20 NOZZLE

(16 SPOKES, AR 2.25)

Description

Number of Elements: 16 spokes Area Ratio: 2.25 Spoke Penetration:~ 70% Flow Area: 5.814 square inches Exit Cant Angle: 20° (outwards)

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## MPP--130--20

(16 Spokes, AR 2.25)

### Remarks

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The MPP 130-20 nozzle was fabricated for the 707 airplane jet noise suppression program. The nozzle was retested for the SST program. Jet noise characteristics were reported in Reference D37.

MPP-130-30 Facility: Annex D (Cell #1) Nozzle and Microphone Heights are 20 Inches Date: Tamb: R.H.:  $T_{T}$  $v_{J}$  (Ideal)  $P_T/P$ Run No. Nozzle н 176 2.2 1100°F 1960 fps MPP 130-20 H 177 11 2130 11-2.6 11 " . H 178 3.0 2280 3.08-In. Round Convergent Nozzle\* H 164 2.2 1100°F 1960 fps H 165 2.6 11 2130 H 166 11 2280 11 3.0

\* 1/8th scale C-6

Measured acoustic data is recorded in Reference D2.

# NOZZLE TEST DATA

OCTÁVE BAND-LEVEL - B. RE: 0.0002 DYNES/CM2//25 FT

| RUN NO.  | OASPL | <b>300</b> - | 1K    | ŻK    | 4K    | 8K    | 16K   | 32K   | 64K   |
|----------|-------|--------------|-------|-------|-------|-------|-------|-------|-------|
| H176 L30 | 117.4 | 114.4        | 110.3 | 108.9 | 105.1 | 106.1 | 105.1 | 102.0 | 94-0  |
| H176 L40 | 115.3 | 111.6        | 110.3 | 102.4 | 105.0 | 103.7 | 100:5 | 92.8  | 85.6  |
| H176 L50 | 117.3 | 110.5        | 109.6 | 105.4 | 109.4 | 109.2 | 109.1 | 106.2 | 96.3  |
| H176 L60 | 115.3 | 105.1        | 105.4 | 103.8 | 109.9 | 109:0 | 106.7 | 103.1 | 96.0  |
| H176 L70 | 112.9 | 102.1        | 102.1 | 100.5 | 106.8 | 107.6 | 105.8 | 98.6  | 89.5  |
| H177 130 | 121.7 | 118.5        | 115.ó | 108.5 | 109.3 | 111.1 | 108.7 | 105.0 | 99.1  |
| H177 L40 | 119.9 | 115.8        | 115.4 | 106.9 | 109.2 | 108.8 | 105.2 | 98.8  | 95.0  |
| H177 L50 | 121.3 | 114.0        | 113.9 | 109.1 | 113.5 | 113.0 | 112.8 | 109.7 | 103.5 |
| H177 L60 | 118.8 | 108.8        | 109.1 | 107.2 | 113.6 | 112.4 | 110.0 | 106.1 | 100.2 |
| H177 L70 | 114.7 | 104.6        | 104.4 | 102.8 | 108.7 | 109.5 | 106.5 | 100.6 | 91.2  |
| N178 L30 | 124.1 | 120.8        | 118.5 | 111.6 | 111.9 | 113.4 | 109.9 | 105.7 | 99.6  |
| H178 140 | 120.6 | 116.6        | 116.4 | 108.1 | 109.3 | 108.6 | 103.3 | 96.5  | 94.7  |
| H178 L50 | 123.3 | 116.7        | 116.1 | 111.2 | 115.9 | 115,1 | 114.5 | 110.9 | 104.6 |
| H178 L60 | 120.5 | 111.0        | 111.2 | 108.7 | 115.4 | 114.0 | 111.3 | 107.3 | 101.0 |
| H178 L70 | 116.3 | 106.0        | 105.8 | 104.4 | 110.5 | 111.1 | 107.8 | 102.0 | 92.8  |
| H164 L30 | 125.9 | 117.6        | 120.3 | 117.5 | 121.2 | 114.7 | 108.3 | 104.2 | 98.7  |
| H164 L40 | 123.9 | 115.9        | 118.8 | 115.6 | 119.0 | 110.6 | 100.8 | 93.2  | 94.1  |
| H164 L50 | 124.9 | 115.0        | 118.4 | 116.7 | 120.4 | 114.2 | 113.1 | 106.3 | 99.8  |
| H164 L60 | 120.3 | 108.0        | 111.9 | 111.5 | 116.5 | 112.7 | 107.4 | 102.0 | 96.2  |
| H164 L70 | 114.2 | 102.5        | 105.5 | 105.8 | 110.1 | 107.0 | 102.5 | 95.0  | 86.0  |
| H165 L30 | 125.5 | 118.3        | 119.7 | 117.8 | 120.2 | 114.0 | 106.8 | 102.4 | 97.4  |
| H165 L40 | 126.5 | 118.2        | 121.3 | 118.0 | 122.0 | 113.9 | 104.5 | 95.8  | 94.3  |
| H165 L5C | 128.8 | 117.7        | 121.5 | 120,2 | 125.0 | 119.4 | 115.6 | 111.6 | 107.8 |
| H165 L60 | 123.2 | 110.6        | 114.5 | 114.2 | 119.6 | 115.4 | 110.8 | 105.8 | 99.1  |
| H165 L70 | 118.1 | 105.3        | 108.2 | 109.1 | 114.1 | 111.5 | 106.8 | 100.2 | 94.3  |
| H166 L30 | 128.9 | 121.5        | 121.8 | 123.8 | 122.2 | 117.5 | 110.2 | 107.0 | 105.0 |
| H166 L40 | 130.1 | 121.1        | 124.5 | 123.1 | 125.2 | 118.2 | 109.2 | 103.3 | 104.2 |
| H166 L50 | 131.8 | 120.1        | 124.8 | 124.1 | 127,3 | 122.4 | 119.3 | 115.5 | 111.0 |
| H166 L60 | 127.0 | 113.0        | 117.8 | 119.3 | 123.4 | 118.7 | 114.3 | 109.6 | 102.9 |
| H166 170 | 122.2 | 108.3        | 112.2 | 114.4 | 118.2 | 115.5 | 410.6 | 103.8 | 96 3  |

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE



### MAE 53-18 NOZZLE

## ( 24 SPOKE AND CENTER PLUG, AR 2.1)



#### Description:

Number of Elements: 24 spokes and conical center plug Area Ratio: 2.1

Spoke Penetration: ~ 80%, terminatine at center plug

Flow Area: 5.94 square inches Exit Cant Angle: 18° outward Ventilation Cant Angle: 18°



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# MAE-SA- N

(24 Spokes and Center Plug, AR 2.1)

#### Remarks

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The MAE 53-18 nozzle was fabricated for the 707 airplane jet noise suppression program. The nozzle was retested for the SST program. Jet noise characteristics were reported in Reference D37. Tests with the MAE 53-18 nozzle with the center plug removed yielded about the same PNL suppression values. With the plug removed an increase in low frequency noise (octave bands 1 and 2) was noted, e.g., 8 dB increase at 50° relative to the jet axis, PR = 3.0 and  $T_{\rm TP} = \pm 100^{\circ}$ F. MAE-53-18

Facility: Annex D (Cell #1) Nozzle and Microphone Heights are 20 Inches

Date:

 $T_{amb}$ :

R.H.:

| <u>Run No</u> .         | PT/P              | $\underline{\mathbf{T}}_{\mathbf{T}}$ | $V_{J}$ (Ideal)          | Nozzle                                 |
|-------------------------|-------------------|---------------------------------------|--------------------------|----------------------------------------|
| н 281<br>н 282<br>н 283 | 2.2<br>2.6<br>3.0 | 1100°F<br>"                           | 1960 fps<br>2130<br>2280 | MAE 53-18<br>"                         |
| н 284<br>: 285<br>н 286 | 2.2<br>2.6<br>3.0 | 1100°F<br>"                           | 1960 fps<br>2130<br>2280 | 3.08-In. Round Convergent Nozzle*<br>" |

\*1/8th scale C-6

Measured acoustic data is recorded in Reference D2.

# NOZZLE TEST DATA

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# OCTAVE BAND LEVEL-AB RE: 0.002 DYNES/CH2//25 FT

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| RUN NO. | OASPL | 500   | ıк    | 2K    | 4K_   |       | 16Ķ   | 32K   | 64K   |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| H281L30 | 113.0 | 110.3 | 107.1 | 99.0- | 101.0 | 99.9  | 98.6  | 96.6  | 89.0  |
| H281L40 | 112.3 | 108.2 | 107.2 | 99.0  | 102.3 | 100.9 | 99.8  | 97.0  | 90.5  |
| H281L50 | 113.6 | 107.7 | 107.8 | 102.0 | 105.3 | 103.5 | 102.8 | 100.6 | 94.7  |
| H281L60 | 111.0 | 103.0 | 103.9 | 99.8  | 105×3 | 102.7 | 100.6 | 97.6  | 92.7  |
| H281L70 | 110.4 | 100.5 | 101.3 | 97.8  | 104.0 | 103.6 | 103.2 | 99.3  | 92.2  |
| H282L30 | 117.5 | 115.1 | 110.9 | 104.8 | 105.5 | 103.6 | 101.3 | 98.6  | 90.5  |
| H282L40 | 116.4 | 112.5 | 111.7 | 103.1 | 106.0 | 103.0 | 102.1 | 99.5  | 91.9  |
| H282L50 | 117.4 | 111.7 | 112.8 | 106.5 | 108.5 | 106.0 | 105.9 | 102.5 | 95 8  |
| H282L60 | 113.8 | 106.4 | 107.4 | 103.0 | 108.4 | 104.3 | 101.2 | 99.5  | 94.0  |
| H282L70 | 112.2 | 103.0 | 103.7 | 100.5 | 105.6 | 105.6 | 104.3 | 100.2 | 92.5  |
| H283L30 | 122.9 | 119.2 | 118.0 | 111.4 | 113.8 | 108.0 | 103.7 | 100.5 | 95.3  |
| H283L40 | 121.6 | 116.8 | 117.4 | 109.1 | 113.2 | 108.5 | 105.5 | 102.3 | 97.0  |
| H283L50 | 122.3 | 115.9 | 117.6 | 111.7 | 115.3 | 110.6 | 109.4 | 105.8 | 100.2 |
| H283L60 | 117.0 | 109.5 | 111.0 | 106.7 | 111.8 | 107.0 | 103.2 | 100.6 | 95.8  |
| H283L70 | 114.2 | 105.3 | 106.7 | 103.8 | 108.1 | 107.4 | 104.4 | 100.6 | 93.6  |
| H284L30 | 125.4 | 116.7 | 120.3 | 117.4 | 120.1 | 114.7 | 107.5 | 103.3 | 97.2  |
| H284L40 | 125.3 | 115.3 | 119.7 | 116.4 | 321.0 | 115.3 | 109.2 | 104.0 | 98.2  |
| H284L50 | 125.4 | 114.4 | 120.0 | 117.6 | 120.7 | 114.8 | 110.8 | 104.4 | 98.0  |
| H284L60 | 121.2 | 108.3 | 113.9 | 112.0 | 117.7 | 112.7 | 106.7 | 101.1 | 95.8  |
| H284L70 | 115.2 | 103.0 | 105.9 | 105.9 | 110.5 | 109.3 | 104.3 | 98.5  | 89.7  |
| H295L30 | 128.3 | 119.7 | 123.6 | 121.0 | 121.5 | 118.0 | 111.5 | 107.2 | 100.7 |
| H285L40 | 127.8 | 118.0 | 121.8 | 119.4 | 123.1 | 115.4 | 112.6 | 108.0 | 101.9 |
| H285L50 | 128.7 | 117.0 | 122.8 | 121.1 | 123.9 | 119.3 | 114.7 | 109.4 | 103.4 |
| H285L60 | 122.6 | 110.9 | 115.4 | 113.9 | 118.8 | 113.9 | 108.5 | 103.3 | 98.1  |
| H285L70 | 117.6 | 104.8 | 108.3 | 107.5 | 113.1 | 111.6 | 107.7 | 102.0 | 93.9  |
| H286L30 | 131.6 | 122.4 | 125.2 | 127.0 | 124.5 | 120.6 | 113.9 | 110.6 | 106.5 |
| H286L40 | 131.1 | 120.8 | 124.9 | 123.7 | 126.3 | 121.6 | J15.6 | 111.7 | 107.7 |
| H286L50 | 132.3 | 120.8 | 126.2 | 126.1 | 126.8 | 122.7 | 118.5 | 113.8 | 109.5 |
| H286L60 | 126.3 | 113.4 | 118.3 | 118.6 | 122.7 | 117.1 | 112.1 | 107.0 | 102.3 |
| H286L70 | 122.3 | 108.2 | 112.4 | 115.7 | 116.9 | 115.9 | 112.4 | 106.5 | 99.4  |

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE


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#PP-152

Facility: Annex D (Cell #1) Nozzle and Microphone Height are 20 Inches

Date: February 8, 1968

Tamb: 51°F

R.H.: 69%

| <u>Run No</u> .                              | $\frac{P_{T}/P}{P}$                     | $\frac{T_{T}}{T}$          | $v_{J}$ (Ideal)                                  | Nozzle                                              |
|----------------------------------------------|-----------------------------------------|----------------------------|--------------------------------------------------|-----------------------------------------------------|
| 2288<br>2289<br>2290<br>2291<br>2292<br>2293 | 1.8<br>2.0<br>2.2<br>2.48<br>3.0<br>3.4 | 1000°F<br>"<br>"<br>"<br>" | 1659 fps<br>1790<br>1900<br>2030<br>2205<br>2311 | MPP 152<br>"<br>"<br>"<br>. "<br>"                  |
| 2306<br>2307<br>2308<br>2309<br>2310<br>2311 | 1.8<br>2.0<br>2.2<br>2.48<br>3.0<br>3.4 | 1000°F<br>"<br>"<br>"<br>" | 1659 fps<br>1790<br>1900<br>2030<br>2205<br>2311 | 3.08 Inch Round Convergent<br>"<br>"<br>"<br>"<br>" |

D332

197 : 152 ·

(21 Tubes, AR 2.4)

### Remarks

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The MPP 152 nozzle was fabricated for the 707 airplane jet noise suppression program. It is similar to the 21 tube suppressor nozzle that was eventually installed on the JT-3/C-6 trubojet engines. The nozzle was retested for the SST program. Jet noise characteristics were reported in References D37 and D38.

### NOZZLE TEST DATA

OCTAVE BAND LEVEL- RE: 0.0002 DYNES / CH2// 25 FT

HPP-152

| ·F       | RUN-NO.     | OASP'         | 500     | 1K     | 2K     | <b>4K</b> | 8K-    | 16K    | 32K    | 64K     |
|----------|-------------|---------------|---------|--------|--------|-----------|--------|--------|--------|---------|
|          | 2288 L40'   | 109.1         | 102.0   | 99.0   | 91.0   | 102.0     | 103.Ö  | 102:0  | 96.0   | 69.0    |
|          | 2255-L50    | 109.9         | 101.0   | 98.0   | 92.0   | 103.0     | 105.0  | 103.0  | 97.0   | 90.0    |
|          | *2288 L60 . | 109.5         | 96.0    | 95.0   | 92.0   | 102.0     | 106.0  | 102.0  | 98.0   | 92.0    |
|          | .2288 L70   | 109.0         | 93.0    | 92.0   | 89.0   | 103.0     | 104.0  | 103.0  | 95.0   | 92.0    |
|          | 2288 L80    | 106.7         | 91.0    | 90.0   | 89-0   | 97.0      | 102.0  | 102.0  | 98.0   | 90+0    |
|          | 2289-L40    | 111.0         | -104.0  | -102.0 | 94.0   | 104-0     | 104.0- | 104.0  | 98.0   | 92.0    |
|          | 2289 L50    | . 111.7 -     | 104.0   | 101.0  | 94.0   | 105.0     | 106.0  | 104.0  | 99.0   | 92.0    |
|          | 2289 L60    | 111.1         | 97.0    | 97.0   | 94.0   | 105.0     | 106.0  | 105.0  | 100.0  | 93.0    |
|          | 2289 L70    | 109.1         | 94.C    | 94.0   | 90.0.  | 103.0     | 104.0  | 103.0  | 99.0   | 93.0    |
| •        | 2289 L80-   | 106.9         | 92.0    | 92.0   | 90.0   | 101.0     | 101.0  | 101.0  | 98.0   | 91.0    |
|          | 2290 L40    | 112.8         | 106.0   | 105.0  | 96.0   | 105.0     | 106.0  | 105.0  | -100.0 | 94.0    |
|          | 2290 -L50-  | 113.6         | 104.0   | 103.0  | 97.0   | 107.0     | -108.0 | 107.9  | 101.0  | -94.0   |
|          | 2290 L60    | 113.3         | 100.0   | 99.0   | 96.0-  | 108.0-    | 108.0  | 107.0- | -101.0 | -95.0   |
|          | 2290 470    | 310,8         | 96.0    | 56.0   | 92.0   | 105.0     | 106.0  | 104.0  | -101.0 | 94.9    |
|          | 90 L80      | 109.2         | -94,0   | 94.0   | 93.0   | 104.0     | 103.0  | 103.0  | 100.0  | 93.0    |
|          | 91 -L40     | 112.4         | 104.0   | 108.0- | 99.0   | 108.0     | 108.0  | 107.0  | 102.0  | 95.0    |
| -        | 1-L20       | 112.0         | 107.0   | 100.0  | 100.0  | 109.0     | 109.0  | 109.0  | 103.0  | 97.0    |
|          | 1 100       | 117.4         | 07.0-   | 102.0  | 90.0   | 110.0     | -107.0 | 108.0  | 103.0  | 97.0    |
| -        |             | 112.7         | 77+0    | .90.0  | 97.0   | 107.0     | 107.0  | 100.0  | 102.0  | 92+0    |
|          | 2 91 100    | 11013         | 70.0    | 40.0   |        | 102.0     | 104+0  | 104.0  | 101.0  | 94.0    |
|          | 2292 L40    | 119.2         | 113.0   | 114.0- | 104+0  | 111.0     | 111.0  | -109.0 | 103.0  | -00 0   |
| нала — М | .2292 L50   | 118.3         | 110.0   | -111.0 | 104.0  | 110.0     | 112.0  | 111.0  | -105.0 | 98.0    |
|          | 2292 L60    | 117.9         | -102.0  | 105.0  | 102.0  | 113.0     | 112.0  | 111.0  | 100.0  | 9940    |
|          | 2292 LIU    | 114.0         | 101.0   | 101+0  | .91.0  | 110.0     | 104.0  | 108.0  | 105.0  | 70+0    |
|          | 2292 LOU    | 112+1         | 78.0    | 70.0   | 7110   | 107.0     | 100.0  | 107.0  | 104.0  | 70.0    |
|          | 2293 L40    | 120.9         | 115.0   | 116.0  | 107.0  | 113.0     | 112.0  | 109.0  | 104.0  | 98.0    |
|          | 2293 L50    | 120.7         | 112.0   | 11420  | 107.0  | 114.0     | 114.0  | -112.0 | 107.0  | 100.0   |
|          | 2293 L60    | 119.0         | 107.0   | 108.0  | .104.0 | 114.0     | 113.0  | 112.0  | 100.0  | 100.0   |
|          | 2293 L70    | 110.5         | 102.0   | 103.0  | 100+0  | 100 0     | 111.0  | 109.0  | 10240  | 9940    |
|          | 2293 L80    | 119.3         | 100.0 - | 100.0  | 44.0   | 109.0     | 100.0  | 108.0  | -105.0 | 70.0    |
|          | 2306 140    | 119.0         | 112.0   | 115.0  | 112.0  | 111.0     | 104.0  | 98.0   | 90.0   | 85.0    |
| -        | 2306 150    | 118.7         | 112.0   | 115.0  | 106.0  | 112.0     | 107.0  | -102.0 | • 94.0 | 86.0    |
|          | 2306 600    | 117.7         | 101.0   | 103.0  | 104.0  | 10.0      | 106.0  | 101.0  | 94.0   | 00.0    |
| -        | 2306 190    | 100.0         | 101.0   | 102.0  | 100.0  | 105.0     | 102.0  | 100+0  | 73.0   | -03+0   |
|          | 2307 140    | 100.5         | 114 0   | 117 0  | 112.0  | 118.0     | 100.0  | 103.0  | 96.0   | 90.0    |
|          | 2307 150    | 122+6         | 114.0   | 117.0  | 109.0  | 117.0     | 111.0  | 104.0  | 97.0   | 90.0    |
|          | 2307 160    | 117.7         | 109.0   | 110.0  | 106.0  | 114.0     | 109.0  | 105.0  | 97.0   | 90.0    |
|          | 2307 170    | 114.7         | 104-0   | 104.0  | 101.0  | 111.0     | 107.0  | 103.0  | 96.0   | 88.0    |
|          | 2307 L80    | <u>j</u> 11.3 | 100.0   | 101.0  | 100.0  | 108.0     | 104.0  | 101.0  | 94.0   | 86.0    |
|          | 2308 L40    | 123.8         | 115.0   | 118.0  | 114.0  | 120.0     | 111.0  | 106.0  | 99.0   | 93.0    |
|          | 2308 L50    | 123.5         | 117.0   | 118.0  | 110.0  | 119.0     | 112.0  | 106.0  | 100.0  | 93.0    |
|          | 2308 L60    | 120.5         | 110.0   | 113.0  | 109.0  | 117.0     | 112.0  | 108.0  | 102.0  | 94.0    |
|          | 2308 L70    | 115.6         | 104.0   | 105.0  | 103.0  | 112.0     | 109.0  | 106.0  | 99.0   | 91.0    |
|          | 2308 L80    | 112.7         | 107.0   | 102.0  | 102.0  | 1.9∉0     | 106.0  | 103.0  | 97.0   | 91.88   |
|          | 23ng L40    | 126.3         | 11740   | 120.0  | 116.0  | 123.8     | 114.0  | 109.0  | 102.0  | 29.5    |
| _        | 2309 L50    | 124.9         | 119.0   | 117.5  | 113.0  | 121-0     | 114.0  | 108.9  | 102.0  | 95.0    |
|          | 2309 L60    | 122.1         | 114-0   | 114.0- | 110.0  | 118.0     | 114.0  | 110.0  | 105.0  | 97.0    |
|          | 2309 L70    | 117.7         | 107.0   | 107.0  | 105.0  | 114.0     | 111.0  | -108.0 | 102.0  | 94.0    |
|          | 2309 L80    | 114.7         | 101.0   | 103.0  | 103.0  | 110.0     | 109.0  | 107.0  | 101.0  | -92-0   |
|          | 2310 L40    | 128.4         | 121.0   | 121.0  | 115 0  | 123.0     | 110 0  | 112.0  | 107.0  | 101.0   |
|          | 2310 130    | 120.4         | 116.0   | 117.0  | 116 0  | 122 0     | 110.0  | 112.0- | 107.0  | 102.0   |
|          | 2310 L 30   | 177.4         | 100.0   | 100.0  | 113.0  | 110.0     | 114 0  | 110.0  | 107.0  | 103.0   |
|          | 2310 100    | 120.1         | 104.0   | 106-0  | 109.0  | 116.0     | 116.0  | 113.0  | 104 0  | 49.0    |
|          | 2311 148    | 131.7         | 125.0   | 125.0  | 121.0  | 128 0     | 114 4  | 112.0  | 100.0  | 100     |
|          | 2311 184    | 130.4         | 121.0-  | 125.0  | 122.0  | 176 0     | 115.0  | 113.0  | 197.0  | 102-0   |
| -        | 2311 144    | 126-2         | 117.0   | 117.0  | 117.0  | 127.0     | 127.0  | 112 0  | 113.0  | 107.0   |
|          | 2311 170 -  | 123.7         | 102.0   | 110.0  | 112.0  | 117.0     | 120.0  | 114 0  | 110 0  | 102+0   |
|          | 2311 L80    | 121.8         | 105.0   | 107.0  | 112.0  | 115.0     | 118.0  | 114:0  | 100.0  | 103-0   |
|          |             |               |         |        |        |           |        | *****  | 447740 | 4374 44 |

## NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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SILVER STR





### MPP 452 NOZZLE

### 21TUBES, 6 SPOKE ENDS ON OUTER ROW OF TUBES, AR2.6

#### Description

The MPP 452 nozzle is a well ventilated 21 tube nozzle. There are 10 tubes in the outer row with 6 spoke terminations on each, 10 smaller tubes in the inner row and one relatively large tube in the center.

Number of Elements: 11 round convergent tubes and 10 tubes with 6-spoke ends on each

Area Ratio: 2.6

Flow Area: 6.506 square inches

Exit Cant Angle: O degrees





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(21 Tubes, 6 Spoke Ends on Outer Row of Tubes, AR 2.6)

### Remarks

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The MPP 452 nozzle was fabricated for the 707 airplane jet noise suppression program. It is similar to the MPP 152 nozzle except for the 6 spoke nozzle terminations on the outer row of tubes. This nozzle was retested for the SST program. Jet noise characteristics were reported in References D37 and D38. HPP 452

Facility: Annex D (Cell #1) Nozzle and microphone heights are 20 inches

Date: February 13, 1968

T<sub>amb</sub>: 52°F

.R.H.: --

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| Run No. | $\frac{P_{\rm T}/P}{P_{\rm T}}$ | $\frac{T_{T}}{T}$ | VJ (Ideal) | Nozzle                     |
|---------|---------------------------------|-------------------|------------|----------------------------|
| 2378    | 1.8                             | 1000°F            | 1659 fps   | MPP 452                    |
| 2379    | 2.0                             | tt                | 1790       | 11                         |
| 2380    | 2.2                             | 11                | 1900       | 11                         |
| 2381    | 2.48                            | 1t                | 2030       | 11                         |
| 2382    | 3.0                             | tt .              | 2205       | · 11                       |
| 2382    | 3.4                             | tt                | 2311       | 11                         |
| 2360    | 1.8                             | 1000°F            | 1659 fps   | 3.08 Inch Round Convergent |
| 2361    | 2.0                             | 11                | 1790       | 11                         |
| 2362    | 2.2                             | 11                | 1900       | 11                         |
| 2363    | 2.48                            | 11                | 2030       | 11                         |
| 2364    | 3.0                             | 11                | 2205       | 11                         |
| 2365    | 3.4                             | 11                | 2311       | 11                         |

|     |                      |         |               |              | ZZLET           | EST D        | TA           | <u></u>  |                       | <u>,</u>       |                                        |
|-----|----------------------|---------|---------------|--------------|-----------------|--------------|--------------|----------|-----------------------|----------------|----------------------------------------|
|     |                      | OCT     | AVE BA        | NDELEV       | /EL~#           | RE: 0:       | 0002 DY      | NES/CN   | 1 <sup>2</sup> //25-F | T              |                                        |
|     |                      |         | -             | <u> </u>     | MPP-            | 452          |              |          |                       |                |                                        |
|     | RUN NO.              | OASPL   | 500           | 1K           | 2K              | 4K           | 8K           | 16K      | 32K                   | 64K            |                                        |
|     | 2359 L40             | 139+5   | 120.0         | 132.0        | 138.0           | 128+0        | 124.0        | 117.0    | 100.0                 | 107.0          |                                        |
|     | 2359 L50<br>2359 L60 | 137+2   | 123.0         | 131.0        | 13509           | 127.0        | 121.0        | 110.0    | 1110                  | 105.0          |                                        |
|     | 2359 L70             | 12/+6   | 114.0         | 115+0        | 123.0           | 122.0        | 150+0        | 117.8    | 100.0                 | 104.0          |                                        |
|     | 2359 LRO             | 126+3   | 110.0         | 116+0        | 121.0           | 120+0        | 150+0        | 116.0    | 100-0                 | 105.0          |                                        |
|     | 2340 L50             | 121+8   | 114+0         | 115+0        | 112+0           | 116+0        | 105+0-       | 106+0    | · 90+0                | 96.0           |                                        |
|     | 2360 LAD             | 11/+2   | 109.J         | 111.0        | 105+0           | 113.0        | 107.0        | 105+0    | 99+0                  | 91.0           |                                        |
|     | 2360 L70<br>2360 L80 | 113.1   | 104+0         | 106.0        | 102.0           | 108+0        | 105.0        | 103+0    | 97+0                  | 92.0           |                                        |
|     | 2361 L40             | 124+9   | 110.0         | 120+0        | 116-0           | 120+0        | 113.0        | 10840    | 0.00                  | -07+0<br>-07.A |                                        |
|     | 2361 150             | 123.3   | 115+0         | 119+0        | 113+0           | 118+0        | 111.0        | 105+0    | 101.0                 | 95.0           |                                        |
|     | 2361 170             | -119+4  | 111+0         | 113+6        | 107+0           | 115.0        | 110.0        | 108.0    | 102.0                 | 95.0           |                                        |
| ••• | 2361 LAO             | 115+5   | 100+0         | 108+0        | 104+0           | 111+0        | 101+0        | 105+4    | 10C+U                 | 95+0           |                                        |
|     | 2762 1.40            | 150.4   | 118.0         | 155•0        |                 | 122.0        | 110.0        | 111.0    | 107.0                 | 101.0          |                                        |
|     | 2342 L50             | 152+5   | 116.0         | 121+0        | 115.0           | 120+0        | 11++0        | 109+0    | 105.0                 | 100.0          |                                        |
|     | 2362 170             | 12126   | 112.4         | 116+0        | 109.0           | 117+0        | 112.0        | 110.0    | 105+0                 | 96.0           |                                        |
|     | 2362 LPO             | 114+0   | 103.0         | 104+0        | 103+0           | 109+0        | 107.0        | 105+0    | 103.0                 | 95.0           | •                                      |
|     | 2343 L40             | 154+3   | 119.4         | 123.0        | 110+0           | 124+0        | 117.0        | 114.0    | 109-0                 | 104.0          |                                        |
|     | 2343 650             | 127.5   | 118.0         | 122.0        | 110.0           | 123+0        | 437.4        | 112+0    | .109.0                | -104.0         |                                        |
|     | 2363 1.70            | 110.0   | 108.0         | 117+0        | 112+0           | 119+0        | 114+0        | 113.0    | 108.0                 | 102.0          |                                        |
|     | 23-3 LAO             | - 116+1 | 104.0         | 10000        | 104+0           | 114+0        | 112.0        | 110+6    | 307+0                 | 101+0          |                                        |
|     | 2364 1.40            | 131++   | 122.0         | 125.0        | 125.0           | 126.0        | 121-0        | 116.0    | 11200                 | 104.0          |                                        |
|     | 2364 160             | 130+4   | 150+0         | 125.0        | 155.0           | 127.0        | 120.0        | 116.0    | 112+0                 | 100.0          |                                        |
|     | 2364 L70             | 123.4   | 110+0         | 119+0        | 117.0           | 123+0        | 118.0        | 116.0    | 111.0                 | 106.0          |                                        |
|     | 2364 L80             | 120.4   | 107.0         | 109.0        | 113.0           | 119+0        | 416+0        | 115+0.   | .11120_               |                | -To Marchine and South Printerships 1. |
|     | 2345 L40             | 132+1   | 123.0         | 127.0        | 124.0           | 127.0        | 121.0        | 116.0    | 112.0                 | 103.0          |                                        |
|     | 2365 1.50            | 132+1   | 122.0         | 150.0        | 123.0           | 128+0        | 122.0        | 114.0    | _113.0                | 109.0          |                                        |
|     | 2365 LTO             | 120+7   | 117+0         | 121+0        | 116.0           | 125+0        | 120.0        | 118.0    | 113.0                 | 107.0          |                                        |
|     | 2365 L80             | 122.4   | 108.0         | 110+0        | 115+0           | 120+0        | 410+0        | 11/+0    | .11.4+0               | 108.0          | • A                                    |
|     | 2375 L45             | 115+6   | 111.0         | 110-0        | 100.0           | 106.0        | 146 0        | 11440    | - 11100               | 100.0          |                                        |
|     | 2375 L55             | 113+6   | 106.0         | 105.0        | 100+0           | 106.0        | 104-0        | 103+0    | 103.0                 | 99.0           |                                        |
|     | 2375 LAO             | 113+8   | 104.0         | 104+3        | 98.0            | 107.0        | 105.0        | 107+0    | 105+0                 | 99-0           |                                        |
|     | 2375 175             | 113.2   | 103.0         | 102.0        | 97+0            | 106+0        | 105.0        | 107.0    | 105.0                 | 101.0          |                                        |
|     | 2376 145             | 119+6   | 11560         | 990R         | 105.0           | 101+0        | 105-0        | 104-0    | 100.0                 | 100.0          | •                                      |
|     | 2376 LSS             | 117+0   | 110.0         | 109.0        | 104+0           | .110+0       | 104+0        | 108.0    | 105+0                 | 101+0          |                                        |
|     | 2376 LAO             | 116+6   | 107+0         | 107+0        | 102.0           | \$11.0       | 109.0        | 109.0    | 106.0                 | 101.0          |                                        |
|     | 2376 L65             | 115+5   | 105+0         | 106+0        | 100+0           | 109+0        | 100.0        | 104.0    | 107+0                 | 103.0          |                                        |
|     | 2377 145             | 122.5   | 117.0         | 118.0        | 98+U<br>10x.0   | 104.0        | 105.0        | 106+0    | 104.0                 | 102.0          |                                        |
|     | 2377 1.55            | 119+4   | 112.0         | 112+0        | 10/.0           | 113+0        | 112.0        | 110+0    | 107.0                 | 102.0          |                                        |
|     | 2377 145             | 118+7   | 109.0         | 110+0        | 104+0           | 113.0        | 111.0        | 111.0    | 104+0                 | 103.0          |                                        |
| *   | 2377 175             | 11/+5   | 107.0         | 108+0        | 103+0           | 112+0        | -110.0       | -110+0 - | -148.0                | 104.0          |                                        |
| •   | 23/8 L40             | 109.0   | 10410         | 104+0        | 99.0            | 104+0        | 10/00        | 108.0    | 109:0                 | 103:0          |                                        |
|     | 2378 L50             | 108.2   | 101.4         | 99.0         | 92.0            | 99.0         | 83TU<br>8840 | 102.0    | 99.0                  | 93.0           |                                        |
|     | 2378 170             | 109+4   | 99.           | 97+0         | 91.0            | 101+0        | 101.0        | 105.0    | 101+0                 | 95.0           |                                        |
|     | 2378 LAO             | 105.9   | 94.1          | 92+0         | 90.0            | 99•0<br>05 ° | 101.0        | 105.0    | 103+0                 | 98.0           |                                        |
|     | 23/4 L40             | 111.4   | 101.0         | 105.0        | 9411            | 100.0        | 97+0         | 100.0    | 101.0                 | 95.0           |                                        |
|     | 2379 140             | 110+3   | 103.          | 102.0        | 95.0            | 102+0        | 100.0        | 104.0    | 101+0                 | 96.0           |                                        |
|     | 2379 L70             | 110+4   | 07""<br>141°4 | .99+0        | 93.u            | 104+0        | 102.0        | 100.0    | 102.0                 | - 9/10         |                                        |
|     | 2379 LAD             | 107.0   | 95+1          | 96+A         | 91+0<br>90-0    | 100+0        | 101+0        | 100+1    | 105.0                 | 100.0          |                                        |
|     | 2380 L40             | 113.6   | 110.0         | 107+0        | 98.0            | 102-0        | 102-0        | 102+0    | · · 3 • 0             | 97.0           |                                        |
| •   | 2380 450             | 112.2   | 106.0         | 105.0        | 98.0            | 104.0        | 102.0        | 103.4    | 10.4.4                | 98.A           |                                        |
|     | 2380 L80             | 112+0   | 103.0         | 101+0        | 96.0            | 105+0        | 103.0        | 100+0    | 10410                 | 90.0           |                                        |
|     | 2340 280             | 109+1   | 97.0          | 774Q<br>96-0 | 91.0            | 102:0        | 10,3+0       | 196.0    | 106.0                 | 101:0          |                                        |
|     | 2381 L40             | 511.2   | 113.0         | 112.0        | 102-0           | 105-0        | 106-0        | 10300    | 10920                 | 99 <u>+</u> 0  |                                        |
|     | 23A1 150             | 112+5   | 109.0         | 108.0        | 191.0           | 107+0        | 100.0        | 100+0    | 104+0                 | 100+0          |                                        |
|     | 2381 LF0 -           | 114+5   | 105+0         | 104+0        | 99.0            | 108+0        | 100.0        | 100.0    | 100+0                 | 103.00         |                                        |
|     | 2341 L80             | 117+1   | 99.7          | 101+0        | 97+Q<br>95-0    | 105-0        | 105+0        | 109.0    | 10                    | 103.0          |                                        |
|     | 23H3 140             | 123.6   | 118.0         | 120-0        | 110-11          | 101+0        | 104+0        | 105+0    | 106.0                 | 101.0          |                                        |
|     | 23H3 1.50            | 151++   | 115.0         | 116.0        | 108.0           | 114-0        | 112-0        | 111.0    | 10/+0                 | 103.0          |                                        |
|     | 2383 LAO<br>2383 LZD | 119+3   | 110.0         | 110.0        | 105.0           | 113.0        | 112.0        | 115-4    | 100+0                 | 103.0          |                                        |
| _   | 2383 LAO             | 11/+2   | 105.0         | 105.0        | 101+0-          | 110+0        | 109.0        | 111+0    | .40700<br>110+0       | 106°0 ~        |                                        |
| •   | 2382 L40             | 訪話      | 110.0         | 117.0        | -100+0<br>107-0 | 106.9        | 100.0        | 108.0    | 109.0                 | 104.0          |                                        |
|     | 23H2 L50             | 118.8   | 113.0         | 113+0-       | 106+0           | 111+0        | 109-0        | 104.0    | 100+0                 | 102.0          |                                        |
| •   | 2382 170             | 117.0   | 108.0         | 107.0        | 102+0           | 111+0        | 105-0        | 110+0    | 100+0                 | 102 -          |                                        |
|     | 2282 1 60            | 11440   | 104134        | 104+13       | 99.0            | 108.0        | 100.0        | 110.0    | 109-0                 | 106.0          |                                        |

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# NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

MPP 452 PBSTATIC2 • P<sub>co</sub> PBSTATIC1 21 TUBES, OUTER RCW WITH GREATREX ENDS • PT As C<sub>Fg</sub> = (THRUST-DRAG) MEASURED ) ಕೆಟ್ಟಿ (MASS FLOW) MEASURED  $C_D =$ AB 1.0 DISCHARGE COEFFICIENT (Co) THRUST COEFFICIENT (C<sub>Fg</sub>) 6.0 8.0 8.0 ł £. 1.2 1.6 2,0 2.4 2.8 3.2 3.6 4.0  $\tilde{P}RESSURE RATIO (P_T / P_{\infty})$ PRESSURE RATIO ( $P_T / P_{\infty}$ ) 1.00 BASE PRESSURE RATIO (PB/P. 660 560 560 560 560 560 560 THRUST COEFFICIENT (C<sub>F9</sub>) PBSTATIC 2 PBSTATIC 1.2 1.6 2.4 2.8 3.2 3.6 4.0 2.0 D PRESSURE RATIO (PT / Pc) VENTILATION PARAMETER (AS/AB)

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### 253 TUBE HOZZLE

(253 Tubes, AR 4.0)

### Remarks

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The jet noise characteristics of the 253 tube nozzle were reported in Reference D39. A full scale 259 tube, AR 4.0 nozzle was constructed for testing on the J-75 engine.

The full scale nozzle was

intended for testing at the Boardman, Oregon, test site, however, these plans were never carried out. The model scale 253 tube nozzle and the full scale 259 tube nozzle tests would have demonstrated the validity of scaling assumptions. 253 TUBES

Facility: Annex D (Cell #1) Nozzle and microphone heights are 20 inches.

Date: February 14, 1968

Tamb: 53°F

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R.H.: 42%

| <u>Run No</u> .      | $\frac{P_{T}}{P_{P}}$ | $\frac{T_T}{T}$ | V <sub>J</sub> (Ideal)   | Nozzle                            |
|----------------------|-----------------------|-----------------|--------------------------|-----------------------------------|
| 2402<br>2403<br>2404 | 1.8<br>2.0<br>2.2     | 1000°F<br>"     | 1659 fps<br>1790<br>1900 | 253 Tubes<br>"                    |
| 2405<br>2405         | 2.48                  | 11<br>11        | 2030                     | 11                                |
| 2408<br>2407         | 3.4                   | 11              | 2311                     | 11                                |
| 2384                 | 1.8                   | 1000°F<br>"     | 1659 fps<br>1790         | 2.86 Inch Rôund Convergent Nozzle |
| 2386                 | 2.2                   | 11              | 1900                     | n                                 |
| 2387                 | 2.48                  | 11              | 2030                     | 11                                |
| 2388<br>2389         | 3.0<br>3.4            | 11<br>11        | 2205<br>2311             | 11<br>11                          |

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### 253:TUBES: NOZZLE TEST DATA

OCTAVE BAND LEVEL- RE: 0.0002 DYNES/CM2//25 FT

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| RU     | N NO.  | OASPL  | 500          | ١K    | 2     | ₩     | 8K            | 16K     | 32K   | 64K   |
|--------|--------|--------|--------------|-------|-------|-------|---------------|---------|-------|-------|
| 240    | 2 I.40 | 105.0  | 96.0         | 92.0  | 82.0  | 88.0  | 94.0          | 101.0   | 99.0  | 94.0  |
| 240    | 2 LSO  | 105.6  | 94.0         | 92.0  | 84.0  | 89.0  | 95.0          | 101.0   | 101.0 | 95.0  |
| 240    | 2 L60  | 107.5  | 93.0         | 91.0  | .83.0 | 92.0  | 96.0          | 104.0   | 102.0 | 98.0  |
| 240    | 2 L70  | 103.1  | 90.0         | 87.0  | 81.0  | 87.0  | 92.0          | 99.0    | 98.0  | 94.0  |
| 240    | 2 L80  | 104.5  | 90.0         | 88.0  | 82.0  | 88.0  | 92.0          | 100.0   | 100.0 | 96.0  |
| 240    | 3 L40  | 106.7  | 98.0         | 94.0  | 84.0  | 89.0  | 95.0          | 102.0   | 101.0 | 97.0  |
| 240:   | 3 L50  | 106.7  | 97.0         | 95.0  | 85.0  | 90.0  | 96.0          | 102.0   | 101.0 | 97.0  |
| 240    | 3 L60  | 108.6  | 95.0         | 98.0  | 84.0  | 93.0  | 97.0          | 105.0   | 103.0 | 99.0  |
| 240    | 3 L70  | 105.1  | 92,0         | 90.0  | 83.0  | 39.0  | 93.0          | 101.0   | 100.0 | 96.0  |
| 240:   | 3 L80  | 106.5  | <b>9</b> 2,0 | 90.0  | 83.0  | 90.0  | 94.0          | 102.0   | 102.0 | 98.0  |
| 2404   | 4 L40  | 107.8  | 10İ.O        | 97:0  | 87.0  | 91:0  | 9510          | 102.0   | 102.0 | 98.0  |
| 2404   | 4 L50  | 107.2  | 98.0         | 97.0  | 88.0  | 92.0  | 96.0          | 101.0   | 102.0 | 98.0  |
| 2404   | 4 L60  | 108.7  | 96.0         | 95.0  | 87.0  | 94.0  | 97.0          | 104.0   | 104.0 | 99.0  |
| 2404   | L70    | 105.6  | 93.0         | 92.0  | 85.0  | 90.0  | 94.0          | . 100.0 | 101.0 | 98.0  |
| 2404   | L80    | 106.6  | 93.0         | 92.0  | 85.0  | 91.0  | 94.0          | 100.0   | 103.0 | 99.0  |
| 2405   | 5 L40  | 109.4  | 104.0        | 101.0 | 91.0  | 94.0  | 95.0          | 102.0   | 103.0 | 98.0  |
| 240    | 5 L50  | 108.3  | 101.0        | 100.0 | 91.0  | 95.0  | 96.0          | 101.0   | 102.0 | 99.0  |
| 2405   | 5 L60  | 108.9  | 98.0         | 97.0  | 89.0  | 97.0  | 97.0          | 103.0   | 104.0 | 100.0 |
| 2405   | 5 L70  | 106.4  | 95.0         | 94.0  | 88.0  | 92.0  | 95.0          | 100.0   | 102.0 | 98.0  |
| 2405   | 5 L80  | 107.3  | 95.0         | 94.0  | 88.0  | 93.0  | 95.0          | 101.0   | 103.0 | 100.0 |
| 2406   | 5 L40  | 113.6  | 110.0        | 106.0 | 96.0  | 99:0  | 99.0-         | 104.0   | 105.0 | 101.0 |
| 2406   | i L50  | 112.0  | 106.0        | 104.0 | 96.0  | 101.0 | 99.0          | 103.0   | 102.0 | 105.0 |
| 2406   | 5 L60  | 111.3  | 103.0        | 101.0 | 94.0  | 101.0 | 99.0          | 105.0   | 105.0 | 102.0 |
| 2406   | 5 L70. | 109.3  | 99.0         | 98.0  | 93.0  | 97.0  | 98.0          | 103.0   | 104.0 | 101.0 |
| 2406   | 5 1,80 | 109.2  | 99.0         | 98.0  | 92.0  | 97.0  | 97.0          | 102.0   | 105.0 | 109.0 |
| 2407   | L40    | 115.9° | 113.0        | 109.0 | 100.0 | 103.0 | 100.0         | 104.0   | 105.0 | 102.0 |
| 2407   | / L50  | 114.1  | 109.0        | 108.0 | 99.0  | 104.0 | 201.0         | 103.0   | 105.0 | 102.0 |
| 2407   | 1 L60  | 112.7  | 105.0        | 105.0 | 97.0  | 104.0 | 101.0         | 105.0   | 105.0 | 102.0 |
| 2407   | / L70  | 111.5  | 102.0        | 101.0 | 96.0  | 101.0 | 101.0         | 104.0   | 106.0 | 103.0 |
| · 2407 | L80    | 110.5  | 101.0        | 100.0 | 95.0  | 100.0 | 99.0          | 103.0   | 105.0 | 102.0 |
| 2384   | L40    | 121.8  | 113.0        | 117.0 | 113.0 | 117.0 | 109.0         | 104.0   | 98.0  | 94.0  |
| 2,384  | L50    | 119.3  | 111.0        | 115.0 | 109.0 | 114.0 | 107.0         | 103.0   | 98.0  | 91.0  |
| 2384   | L60    | 116.4  | 106.0        | 109.0 | 104.0 | 113.0 | 107.0         | 105.0   | 99.0  | 92.0  |
| 2384   | L70    | 112.6  | 102.0        | 105.0 | 100.0 | 108.0 | 105.0         | 103.0   | 99.0  | 92.0  |
| 1 2384 | 1.80   | 109.8  | 100.0        | 102.0 | 99.0  | 105.0 | 102.0         | 100.0   | 96.0  | 90.0  |
| 2385   | 5 L40  | 124.9  | 115.0        | 119.0 | 115.0 | 121.0 | 114.0         | 110.0   | 104-0 | 101.0 |
| 2385   | 5 L50  | 122.3  | 113.0        | 118.0 | 113.0 | 117,) | <b>111.</b> 0 | 105.0   | 102.0 | 97.0  |
| 2385   | i 160  | 119.3  | 108.0        | 112.0 | 107.0 | 116.0 | 110.0         | 108.0   | 102.0 | 96.0  |
| 2385   | 5 L70  | 115.3  | 103.0        | 107.0 | 103.0 | 111.0 | 108.0         | 106.0   | 102.0 | 96.0  |
| 2385   | 5 L80  | 112.0  | 101.0        | 103.0 | 101.0 | 107.0 | 105.0         | 103.0   | 100.0 | 93.0  |
| 2386   | 5 L40  | 128.2  | 117.0        | 120.0 | 120.0 | 125.0 | 118.0         | 113.0   | 109.0 | 105.0 |
| 2386   | L50    | 125.7  | 115.0        | 119.0 | 117.0 | 122.0 | 116.0         | 110.0   | 106.0 | 101.0 |
| 2386   | 160    | 121.2  | 110.0        | 111.0 | 110.0 | 118.0 | 113.0         | 111.0   | 105.0 | 99.0  |
| 2386   | 5 L70  | 117.2  | 105.0        | 108.0 | 105.0 | 113.0 | 110.0         | 108.0   | 104.0 | 98.0  |
| 2386   | 5 L80  | 112.2  | 101.0        | 103.0 | 102.0 | 107.0 | 105.0         | 104.0   | 100.0 | 93.4  |
| 2387   | 140    | 129.5  | 119.0        | 123.0 | 119.0 | 126.0 | 119.0         | 115.0   | 111.0 | 108.0 |
| 2387   | L50    | 128.3  | 117.0        | 122.0 | 117.0 | 125.0 | 118.0         | 114,0   | 110.0 | 106.0 |
| 2387   | L60    | 124.2  | 112.0        | 116.0 | 111.0 | 121.0 | 115.0         | 114.0   | 109.0 | 103.0 |
| 2387   | L70    | 119.3  | 107.0        | 110.0 | 106.0 | 115.0 | 112.0         | 111.0   | 107.0 | 102.0 |
| 2387   | 180    | 116.2  | 104.0.       | 106.0 | 105.0 | 111.0 | 109.0         | 109.0   | 105,0 | 99.0  |
| 2388   | 5 L40  | 130.7  | 121.0        | 125.0 | 122.0 | 126.0 | 120.0         | 116.0   | 112.0 | 109.0 |
| 2388   | L50    | 131.3  | 119.0        | 124.0 | 121.0 | 128.0 | 122.0         | 118.0   | 114.0 | 109.0 |

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

### 253 TUBES NOZZLE TEST DATA

OCTAVE BAND LEVEL-dB RE: 0.0002 DYNES/CM2/25 FT

| RUN NO.  | OASPL | 500   | ١K    | 2K    | 4K    | ۶K    | 16K   | 32K   | 64K    |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| 2388 L60 | 126.3 | 113.0 | 117.0 | 114.0 | 123.0 | 118.0 | 117.0 | 112.0 | 107.0  |
| 2388 L70 | 122.8 | 108.0 | 111.0 | 110.0 | 118.0 | 116.0 | 116,0 | 111.0 | 107-,0 |
| 2388 L80 | 120.2 | 106.0 | 108.0 | 108.0 | 115.0 | 114.0 | 113.0 | 109.0 | 104.0  |
| 2389 L40 | 132.2 | 123.0 | 127.0 | 124.0 | 127.0 | 121.0 | 117.0 | 113.0 | 110.0  |
| 2389 L50 | 132.2 | 121.0 | 126.0 | 123.0 | 128.0 | 123.0 | 118.0 | 115.0 | 110.0  |
| 2389 L60 | 129.1 | 115.0 | 120,0 | 119.0 | 126.0 | 120.0 | 118.0 | 114.0 | 108.0  |
| 2389 L70 | 124.8 | 110.0 | 113.0 | 115.0 | 220.0 | 118.0 | 117.0 | 113.0 | 108.0  |
| 2389 L80 | 122.3 | 107.0 | 111.0 | 113.0 | 117.0 | 116.0 | 114.0 | 111.0 | 105.0  |

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

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#### 29xx8400 NOZZLE

#### (RC PRIMARY NOZZLE AND EJECTOR WITH 8 CHUTES)

#### Description

The primary nozzle is a 4.1-inch diameter round convergent nozzle set 2.25 inches upstream from the ejector throat. The ejector has a total length of 9.1 inches. The diameter of the ejector inlet is 7.3 inches, tapering down to a diameter of 6.35 inches in an axial distance of 2.98 inches. The remainder of the ejector is cylindrical. Eight chutes are situated in the fully expanded jet flow. The chutes are 1.5 inches long and 0.45 inches wide set at an angle of 37.4 degrees relative to the jet axis. The leading edge of the chutes is positioned about 0.75 inches downstream of the primary nozzle exit or 1.5 inches upstream of the ejector throat. Ejector area to primary nozzle exit area ratio is 2.4. Chute penetration of the jet is approximately 40%.



### D352

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(RC Primary Nozzle and Ejector with 8 Chutes)

### Remarks

Chuted ejector configuration 29 xx 8400 represents the "best" angle of attack chute position tested for a parametric study conducted during 1967. Fifteen ejector types and 28 chute types were tested in about 70 different combinations, see Reference D40. Test results for the 29 xx 8400 model configuration are reported in References D41, D42 & D43. The conclusion was that chuted ejector configurations where the chutes intercept the fully expanded flow can result in significant noise suppression but only with an extravagant loss in thrust. 29-4400

Facility: Annex D (Cell #1) Nozzle and Microphone Heights are 20 Inches.

Date: January 24, 1968

Tamb: 51°F

R. H.: 92%

| <u>Run No</u> .      | P <sub>T</sub> /P <sub>o</sub> | $\frac{\mathbf{T_T}}{\mathbf{T}}$ | V <sub>J</sub> (Ideal)            | Nozzle                                     |
|----------------------|--------------------------------|-----------------------------------|-----------------------------------|--------------------------------------------|
| 2097<br>2098<br>2099 | 2.7<br>3.0<br>3.3              | 2540°F<br>"                       | 3000 fps<br>3150<br>3 <b>3</b> 00 | 29xx8400<br>"                              |
| 2091<br>2092<br>2093 | 2.7<br>3.0<br>3.3              | 2540°F<br>"                       | 3000 fps<br>3150<br>3300          | 4.1 Inch Round Convergent Nozzle<br>"<br>" |

### NOZZLE TEST DATA

OCTAVE BAND LEVEL- RE: 0.0002 DYNES/CH2//25 FT

### 291.18400

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| RUN NO.    | OASPL  | 500    | ١K    | Ж      | <b>4K</b> | 8K    | 16K     | 32K   | -64K   |
|------------|--------|--------|-------|--------|-----------|-------|---------|-------|--------|
| 7097146    | 127.5  | 124.0  | 124-0 | 113.0  | 114.0     | 109.0 | 106.0.  | 102.0 | 98.0   |
| 2097 1 50  | 129.2  | 126-0  | 125.0 | 115.0  | 118.0     | 113.0 | 109.0   | 105.0 | 100-0  |
| 2097 1.60  | 125.8  | 122.0  | 119.0 | 112.0  | 119.0     | 114.0 | 112.0   | 107.0 | 101.0  |
| 2097 170   | 123.5  | 119.0  | 115.0 | 110.0  | 118.0     | 115.0 | 113.0   | 103.0 | :103.0 |
| 2097 80    | 122.0  | 116.0  | 111.0 | 108.0  | 116.0     | 116.0 | 115.0   | 110.0 | 103.0  |
| 2028 1 40  | 129.7  | 125.0  | 126.0 | 116.0  | 117.0     | 112.0 | 108.0   | 103.0 | 100-6  |
| 2098 150   | 130.4  | 125.0  | 127.0 | 116.0  | 120.0     | 116.0 | 112.0   | 107.0 | 107.0  |
| 2098 140   | 126.9  | 123.0  | 120.0 | 113.0  | 120.0     | 116.0 | 114-0   | 109.0 | 103.0  |
| 2098 176   | 125.4  | 121.6  | 117.0 | 112.0  | 119.0     | 116:0 | 114.0   | 110.0 | 104.0  |
| 2098 1 80  | 123.3  | 117.0  | 113.0 | 109.0  | 117.0     | 110.0 | 115.0   | 110.0 | 104.0  |
| 2029 1 40  | 131.2  | -128.0 | 127.0 | 117-9  | 1-19.0    | 115.0 | 111.0   | 106.0 | 103.0  |
| 2199 1.50  | 132.3  | 129.0  | 128.0 | 1-17.0 | 121.0     | 118.0 | 113.0   | 108.0 | 104.0  |
| 2099 160   | 129.2  | 120.0  | 121.0 | 1-14.0 | 122.0     | 118.0 | 116.0   | 110.0 | 105.0  |
| 2699 173   | 127.2  | 123.0  | 118.0 | 113.0  | 121.0     | 118.0 | 116.0   | 110.0 | 105.0  |
| 2099 180   | 124.9  | 120.0  | 114.0 | 111.0  | 118.0     | 117.0 | 116.0   | 111.0 | 105.0  |
| 2091 140   | 132.8  | 129.0  | 128-0 | 121.0  | 124.0     | 118.0 | * 114.0 | 108.0 | 164.0  |
| 2091 150   | 136.2  | 130-0  | 132.0 | 125.0  | 129.0     | 125.1 | 120.0   | 115.0 | -0-0   |
| 2091-160   | 136.3  | 127.0  | 128.0 | 125.0  | 133.0     | 127.0 | 124.0   | 119.0 | 113.0  |
| 2091 170   | 131.7  | 123.0  | 123.0 | 120.0  | 128.0     | 123.0 | 120.0   | 115.0 | 7-10-0 |
| 2091 180   | 127.1  | 117.0  | 116.0 | 116.0  | 123.0     | 120.0 | 118.0   | 113.0 | 106.0  |
| 2092 140   | 133.9  | 129.0  | 130.0 | 123.0  | 125.0     | 119.0 | 116.0   | 110.0 | 105.0  |
| 2092 1.50  | 137.2  | 131.0  | 133.0 | 126.0  | .130.0    | 126.0 | 121.0 * | 116,0 | 111.0  |
| 2092 160   | 136.9  | 128.0  | 129.0 | 126.0  | 133:0     | 128.0 | 125.0   | 119.0 | 114.0  |
| 2092 170   | 132.4  | 125.0  | 124.0 | 120.0  | 128.0     | 124.0 | 121.0   | 116.0 | 111.0  |
| 2092 1 50  | 128.4  | 119.0  | 117.0 | 117.0  | 1-24.0    | 122.0 | 119.0   | 114.0 | 107.0  |
| · 2095 140 | 134.7  | 130.0  | 131.0 | 124-0  | 125.0     | 120 C | 116.0   | 110.7 | 106.0  |
| 2093 150   | 137.9  | 132.0  | 134.0 | 127.0  | 130.0     | 126.0 | 122.0   | 116.0 | 111.0  |
| 2093 LEU   | 137.8  | 130.0  | 130.0 | 127.0  | . 134.0   | 128.0 | 125.0   | 120.0 | 114.0  |
| 2093 L70   | .133.6 | 127.0  | 129.0 | .122.0 | 129.0     | 125-0 | 122.0   | 117.0 | 112.0  |
| 2095 180   | 129.0  | 121.0  | 115.0 | 118.0  | 125.0     | 123.0 | 120.0   | 115.0 | 108.(- |

NOTE: THIS DATA MICLUDES GROUND REFLECTION INTERFERENCE



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