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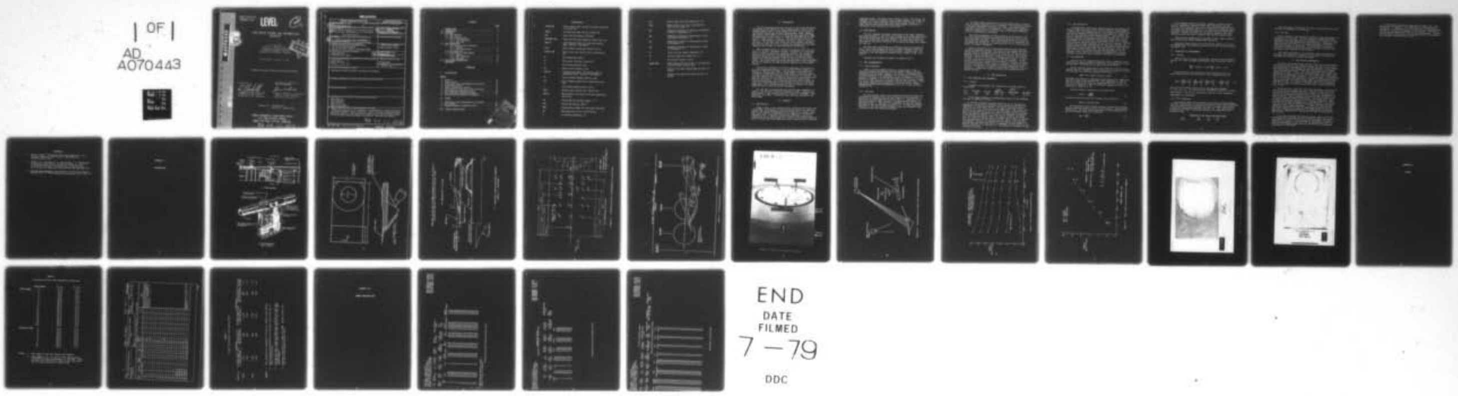

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SPACE SHUTTLE EXTERNAL TANK INSTRUMENTATION EVALUATION

D. W. Stallings
ARO, Inc., AEDC Division
A Sverdrup Corporation Company
von Karman Gas Dynamics Facility
Arnold Air Force Station, Tennessee

Period Covered: January 11, 1979

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FOR THE COMMANDER

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Director of Test Operations
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ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

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Data were obtained on the performance of space shuttle flight instrumentation under simulated flight conditions. These conditions included ablating insulation material. The tests were conducted at a free-stream Mach number of 10 and tunnel stilling chamber conditions of 1800 psia and 1900°R.

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CONTENTS

APPENDIXES

NOMENCLATURE

CENTERLINE	Time at which model reached the tunnel centerline on a given run
CONFIG	Describes the model used for a given run
CPM	Model surface pressure coefficient
EXPOSURE TIME	Total time model was exposed to tunnel flow, sec
GAGE NO	Identification number for each heat-transfer gage. See Fig. 3 and Table 1
H(TT)	Heat-transfer coefficient, Btu/ft^2-sec-°R
INJECT TIME	Model travel time from lift-off to centerline, sec
M	Free-stream Mach number
MU	Free-stream viscosity, lb_f-sec/ft^2
P	Free-stream pressure, psia
PM	Model surface pressure, psia
PORT NO	Identification number for pressure ports in calibration plate. See Fig. 3 and Table 1
PT	Tunnel stilling chamber pressure, psia
PT2	Total pressure downstream of normal shock wave, psia
Q	Free-stream dynamic pressure, psia
QDOT	Measured heat-transfer rate, Btu/ft^2-sec
QDOT-O	Heat-transfer rate based on 0°F wall temperature, Btu/ft^2-sec
RE	Free-stream unit Reynolds number, ft^{-1}
RHO	Free-stream density, lbm/ft^3
RUN	Identification number for each tunnel injection
SF	Heat gage scale factor, Btu/ft^2-sec/mv
T	Free-stream temperature, °R

TGE	Measured gage disk edge temperature, °R
TIME	Elapsed time during a run, beginning when model enters tunnel, sec
TM1	Temperature measured by resistance thermometer on base of calorimeter, °F
TM2	Temperature measured by thermocouple on base of pressure transducer, °F
TM3	Temperature measured by thermocouple on base of microphone, °F
TM4	Temperature measured by thermocouple on base of calorimeter, °F
TT	Tunnel stilling chamber temperature, °R
TW	Corrected gage wall temperature, °R
V	Free-stream velocity, ft/sec
WEDGE ANGLE	Angle between the top surface of the wedge and the free-stream velocity, deg
X	Distance from wedge leading edge (see Fig. 2), inches
Y	Distance from wedge centerline (see Fig. 2), inches

1.0 INTRODUCTION

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 921Z10, Control Number 9Z10-00-9, at the request of the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center (MSFC) for the Martin Marietta Corporation (MMC). The NASA project monitor was Mr. J. Warmbrod, MSFC-ED33 and the MMC project monitor was Mr. H. Carroll. The results were obtained by ARO, Inc., AEDC Division (a Sverdrup Corporation Company), operating contractor for the AEDC, AFSC, Arnold Air Force Station, Tennessee. The test was conducted in the von Karman Gas Dynamics Facility (VKF), Hypersonic Wind Tunnel (C) under ARO Project No. V41C-62.

When the Space Shuttle is launched, the External Tank (ET) will have on it several "instrument islands," consisting of an instrument module enclosed by protective insulation material. The purpose of this test was to evaluate the performance of a typical instrument island by subjecting an actual flight article to conditions representative of those encountered on the LO_2 tank area of the ET during ascent. The island which was tested contained three flight transducers, and was surrounded by the same insulation material as on the flight vehicle.

The test was conducted in the 50-in. Hypersonic Wind Tunnel (C) at a free-stream Mach number of 10 and tunnel stilling chamber conditions of 1800 psia and 1900°R. The specimens to be tested were attached to a wedge model, and the wedge angle-of-attack was varied to produce the desired conditions on the surface of the specimen. The test was initiated with a calibration phase in which the island specimens were replaced by a flat plate instrumented to measure heat-transfer and pressure. The calibration data were used to define the local flow field conditions on the specimen surface as a function of wedge angle. This information was then used to establish the wedge angles at which to test the material specimens.

All test data, including detailed logs and other information required to use the data, have been transmitted to MMC. Inquiries to obtain copies of the test data should be directed to NASA/MSFC - ED33, Huntsville, AL, 35812. A microfilm record has been retained in the VKF at AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel C (Fig. 1) is a closed-circuit, hypersonic wind tunnel with a Mach number 10 axisymmetric contoured nozzle and a 50-in.-diam test section. The tunnel can be operated continuously over a range of pressure levels from 200 to 2000 psia with air supplied by the VKF main compressor plant. Stagnation temperatures sufficient to avoid air liquefaction in the test section (up to 2260°R) are obtained through the use of a natural gas fired combustion heater in series with an electric resistance heater. The entire tunnel (throat, nozzle, test section, and diffuser) is cooled by integral, external water jackets. The tunnel is equipped with a model injection system, which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel may be found in Ref. 1.

2.2 TEST ARTICLE

The 8-in. diameter instrument island module with flight transducer units was attached to a flat plate for mounting on the wedge sample holder. The insulation material was on a separate plate which was installed on top of the island plate as shown in Fig 2. The same island module was thus used for the entire test while the insulation specimens were changed for each run.

The flat plate used during the calibration phase was instrumented with 21 heat-transfer gages, including a flight calorimeter identical to the one in the island module, and contained 11 pressure taps. The locations of the heat gages and pressure taps are shown in Fig. 3 and Table 1.

The model was installed in Tunnel C as shown in Fig. 4.

2.3 TEST INSTRUMENTATION

2.3.1 Test Conditions

Tunnel C stilling chamber pressure is measured with a 500- or 2500-psid transducer referenced to a near vacuum. Based on periodic comparisons with secondary standards, the accuracy (a bandwidth which includes 95-percent of the residuals, i.e. 2σ deviation) of the transducers is estimated to be within ±0.16 percent of pressure or ±0.5 psi, whichever is greater, for the 500-psid range and ±0.16 percent of pressure or ±2.0 psi, whichever is greater, for the 2500-psid range. Stilling chamber temperature measurements are made with Chromel -Alumel thermocouples which have an uncertainty of ±(1.5°F + 0.375 percent of reading in °F).

2.3.2 Test Data

The heat-transfer rates on the calibration plate were measured by thermopile Gardon gages fabricated and installed by VKF personnel. A description of these gages may be found in Ref. 2. Pressures on the plate were measured using the Tunnel C standard pressure system, as described in Ref. 3. Data reduction procedures for the heat transfer and pressure data are discussed in Section 3.2. A flight calorimeter, identical to that used in the instrument island, was included in the calibration plate for comparison purposes.

The three flight transducers in the island module were a calorimeter, a pressure transducer, and a microphone. The calorimeter included a resistance thermometer attached to the base to record any temperature rise on the back of the transducer. In addition VKF technicians attached a thermocouple to the base of each of the three transducers prior to installation in the module.

The flight transducers are shown installed in the module in Fig. 5. The insulating materials surrounding the island can also be seen. White RTV rubber was used to cover the mounting bolts and to seal the gap around each transducer. The relative sizes of the transducers can be estimated by noting that the mounting bolts are on a circle approximately 7.5 inches in diameter.

Data on the ablation of the insulation materials were obtained through photographic coverage. Two motion picture cameras were used, one in the tunnel shadowgraph system and the other viewing the test specimen directly through a port on top of the tunnel. The grid-line projection system was employed in conjunction with the direct motion pictures. The use of this system is illustrated in Fig. 6. A series of lines is projected on the surface of the test specimen. As the surface recedes due to ablation of the material, the lines, as viewed by the motion picture camera, appear to translate. Thus the pictures contain an indication of the degree of ablation experienced by the material. In addition, the material was visually inspected after each injection to examine the flight instruments for contamination from ablated products.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS AND PROCEDURES

3.1.1 General

A summary of the nominal test conditions at each Mach number is given below.

M	PT, psia	TT, °R	WEDGE ANGLE, deg	QDOT-0 Btu/ft^2-sec	PM, psia
10.17	1800	1900	5.65 - 30	2-12	0.1-1.5

A test summary showing all configurations tested and the variables for each is presented in Table 2.

In the VKF continuous flow wind tunnels (A, B, C), the model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door. When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank and the safety door seals the tunnel from the tank area. After the model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, and the model is injected into the airstream, and the fairing doors are closed. After the data are obtained, the model is retracted into the tank and the sequence is reversed with the tank being vented to atmosphere to allow access to the model in preparation for the next run. The sequence is repeated for each configuration change.

3.1.2 Data Acquisition

Instrumentation outputs were recorded using the VKF digital data scanner, under the control of the random access data system (RADS). A complete data loop consisted of the tunnel condition parameters plus the various transducers which might be on the model for a given run. The test was conducted in three separate phases: heat-transfer calibration, pressure calibration, and instrument island runs. For the heat-transfer and the instrument island runs the data were scanned continuously at the rate of ten (heat-transfer data) or two (island data) loops per second through the entire injection sequence. For the pressure runs the model was injected into the tunnel and the output of the transducers was monitored until it appeared the pressures were stabilized. A single loop of data was then recorded. For a few runs, for which the stabilization time was long (greater than 10 seconds), several loops were recorded at approximately two second intervals so the data could be checked for pressure stabilization.

3.2 DATA REDUCTION

For each run, the tabulated data begin with a listing of tunnel conditions and model information required to characterize the run and use the data. Following this the model data are presented.

The heat-transfer gages used on the calibration plate are direct reading heat flux transducers whose output may be converted to heating rate by means of a laboratory-obtained scale factor, i.e.

$$\text{QDOT} = \text{SF} \times (\text{gage millivolt output}) \qquad (1)$$

Each gage also contains a thermocouple which measures the temperature, TGE, at the edge of the sensing disk. This measurement is used to correct the gage scale factor for temperature effects, and also to calculate, by means of a laboratory-obtained temperature factor, the gage surface temperature, TW.

The heat-transfer coefficient is calculated from

$$\text{H(TT)} = \frac{\text{QDOT}}{\text{TT-TW}} \qquad (2)$$

and the so-called cold-wall heat-transfer rate is given by

$$\text{QDOT-0} = \text{H(TT)}[\text{TT-460}] \qquad (3)$$

The calibration plate pressure data were calculated by multiplying the transducer output by a scale factor obtained during pretest calibrations. The plate surface pressures are also presented in the form of a pressure coefficient defined by:

$$\text{CPM} = \frac{\text{PM-P}}{\text{Q}} \qquad (4)$$

The instrument island calorimeter, pressure transducer, and resistance thermometer (supplied by MMC) were calibrated in the VKF prior to the test and the scale factors which were obtained were used to convert the transducer outputs to the appropriate engineering units. The signal from the microphone was not included in the standard data reduction. Instead, the output was recorded on magnetic tape, and a spectrum analyzer was used to generate power spectral density plots.

Data from the thermocouples on the base of each flight transducer were reduced using standard thermocouple equations.

The model exposure time for the island runs, denoted on the data as EXPOSURE TIME, was measured from the time the model actually entered the tunnel flow.

3.3 UNCERTAINTY OF MEASUREMENTS

3.3.1 General

The accuracy of the basic measurements (PT and TT) was discussed in Section 2.3. Based on repeat calibrations, these errors were found to be

$$\frac{\Delta PT}{PT} = 0.0016 = 0.16\%, \quad \frac{\Delta TT}{TT} = 0.004 = 0.4\%$$

Uncertainties in the tunnel free-stream parameters were estimated using the Taylor series method of error propagation, Eq. (5),

$$(\Delta F)^2 = \left(\frac{\partial F}{\partial X_1}\Delta X_1\right)^2 + \left(\frac{\partial F}{\partial X_2}\Delta X_2\right)^2 + \left(\frac{\partial F}{\partial X_3}\Delta X_3\right)^2 \dots + \left(\frac{\partial F}{\partial X_n}\Delta X_n\right)^2 \qquad (5)$$

where ΔF is the absolute uncertainty in the dependent parameter $F = f(X_1, X_2, X_3 \dots X_n)$ and X_n are the independent parameters (or basic measurements). ΔX_n are the uncertainties (errors) in the independent measurements (or variables).

3.3.2 Test Conditions

The accuracy (based on 2σ deviation) of the basic tunnel parameters, PT and TT, (see Section 2.3) and the 2σ deviation in Mach number determined from test section flow calibrations were used to estimate uncertainties in the other free-stream properties using Eq. (5). The computed uncertainties in the tunnel free-stream conditions are summarized in the following table.

	Uncertainty, (±) percent of actual value		
M	M	P	Q
10.17	0.8	5.3	3.7

The uncertainty in wedge angle of attack, as determined from calibrations, is estimated to be ±0.05 deg.

3.3.3 Test Data

The uncertainty of the calibration plate heat gage measurements is estimated to be ±5 percent. The wall temperature measurements associated with each heat gage have an uncertainty of ±0.5 percent of reading based on the wire manufacturer's specifications. Combination of these uncertainties results in an overall uncertainty in the heat-transfer coefficient of ±6 percent. The measurement uncertainty for the Tunnel C standard pressure system which was used to measure the calibration plate pressures is ±0.3 percent.

The flight transducers in the instrument island were supplied by the user, and insufficient information is available to estimate the measurement uncertainty for these instruments.

4.0 DATA PACKAGE PRESENTATION

In order to successfully meet the test objectives it was necessary to verify, by means of the calibration plate, that the required local flow conditions on the wedge surface could be obtained. It was desired that heat-transfer rates between six and twelve Btu/ft^2-sec be generated on the specimen surface. That these conditions were attained is illustrated by Fig. 7. The actual instrument island test condition was defined by the calibration data at X = 25.5 inches, which is the location of the island flight calorimeter. The data of Fig. 7, interpolated for X = 25.5 inches, are plotted as a function of wedge angle in Fig. 8. This plot was used to choose the wedge angle settings for testing the instrument island. As a matter of interest, Fig. 8 includes data for X = 19.5 in., which are seen to agree well with a similar calibration done in 1976.

The data of Fig. 7 show that the flight calorimeter reading was as much as 30% below the Gardon gage data. Because of this, all of the data were carefully checked for possible errors, and the sponsor requested that a posttest calibration of the two flight calorimeters be done in the VKF. Table 3 presents the scale factors obtained in both the pretest and the posttest calibrations. The average scale factor for Gage S/N 0099 was 2.4% lower in the posttest calibration. This is within the estimated repeatability of the experiment. The average scale factor for Gage S/N 0100 was 6.9% higher, which may indicate a permanent change in gage sensitivity. It should be noted that the VKF pretest calibration of Gage S/N 0099 agreed within one percent with the calibration data supplied by the gage manufacturer, Hy-Cal Engineering. Manufacturer's calibration data were not available for Gage S/N 0100.

It was observed during the installation that both of the flight calorimeters were depressed into the surrounding support structure. Since this will result in a erroneously low measurement the amount of depression was measured. Gage S/N 0099 was approximately 0.015 in. below the surrounding support structure and S/N 0100 was depressed approximately 0.003 inches.

A sample data tabulation is presented in Appendix III. Data nomenclature corresponds to the nomenclature at the beginning of this report. A complete set of data tabulations and photographs was included in the Final Data Package for this project. Photographic results were the primary test data for this investigation. A typical pre and posttest photograph of the insulating material surrounding the instrument island is shown in Fig. 9.

REFERENCES

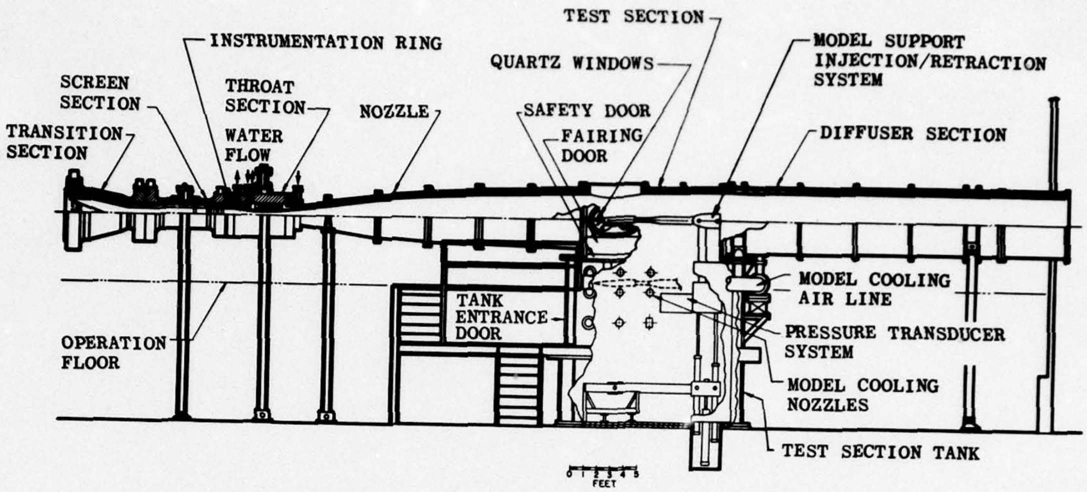
1. Sivells, James C. "Aerodynamic Design and Calibration of the VKF 50-in. Hypersonic Wind Tunnels," AEDC-TDR-62-230 (AD299774) March, 1963.

2. Trimmer, L. L., Matthews, R. K., and Buchanan, T. D. "Measurement of Aerodynamic Heat Rates at the AEDC von Karman Facility," International Congress on Instrumentation in Aerospace Simulation Facilities, IEEE Publication CHO 748-9 AES, September 1973.

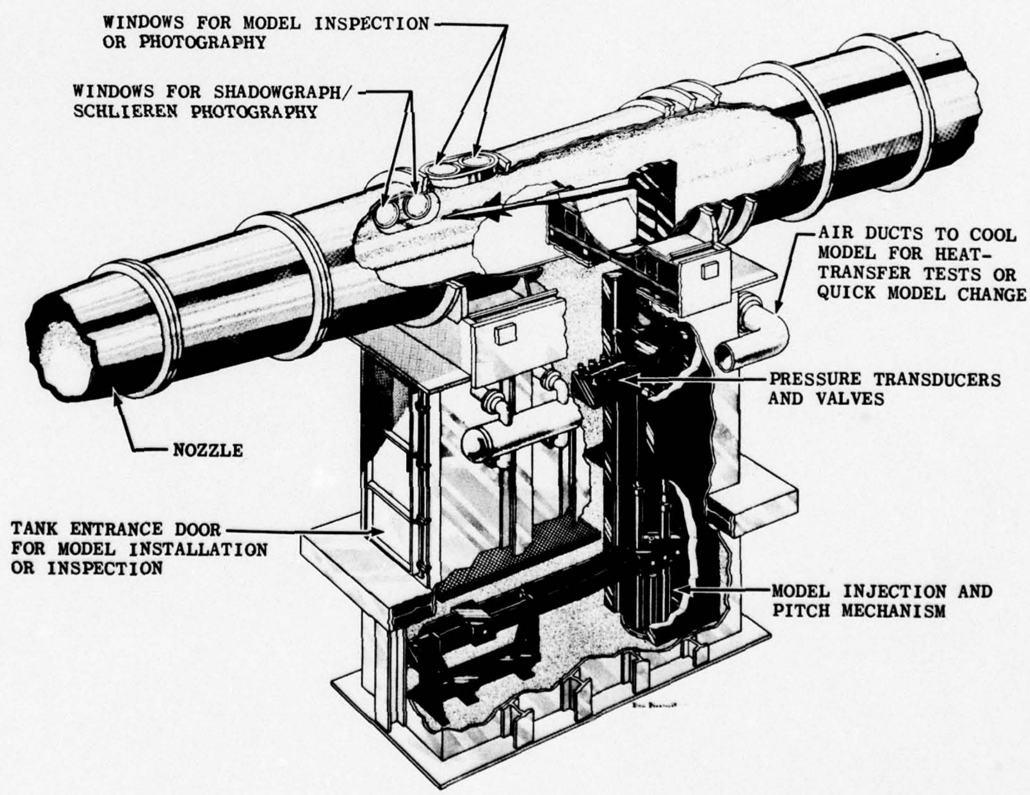
3. Test Facilities Handbook (Tenth Edition) "von Karman Gas Dynamics Facility, Vol. 3." Arnold Engineering Development Center, May 1974.

APPENDIX I

ILLUSTRATIONS

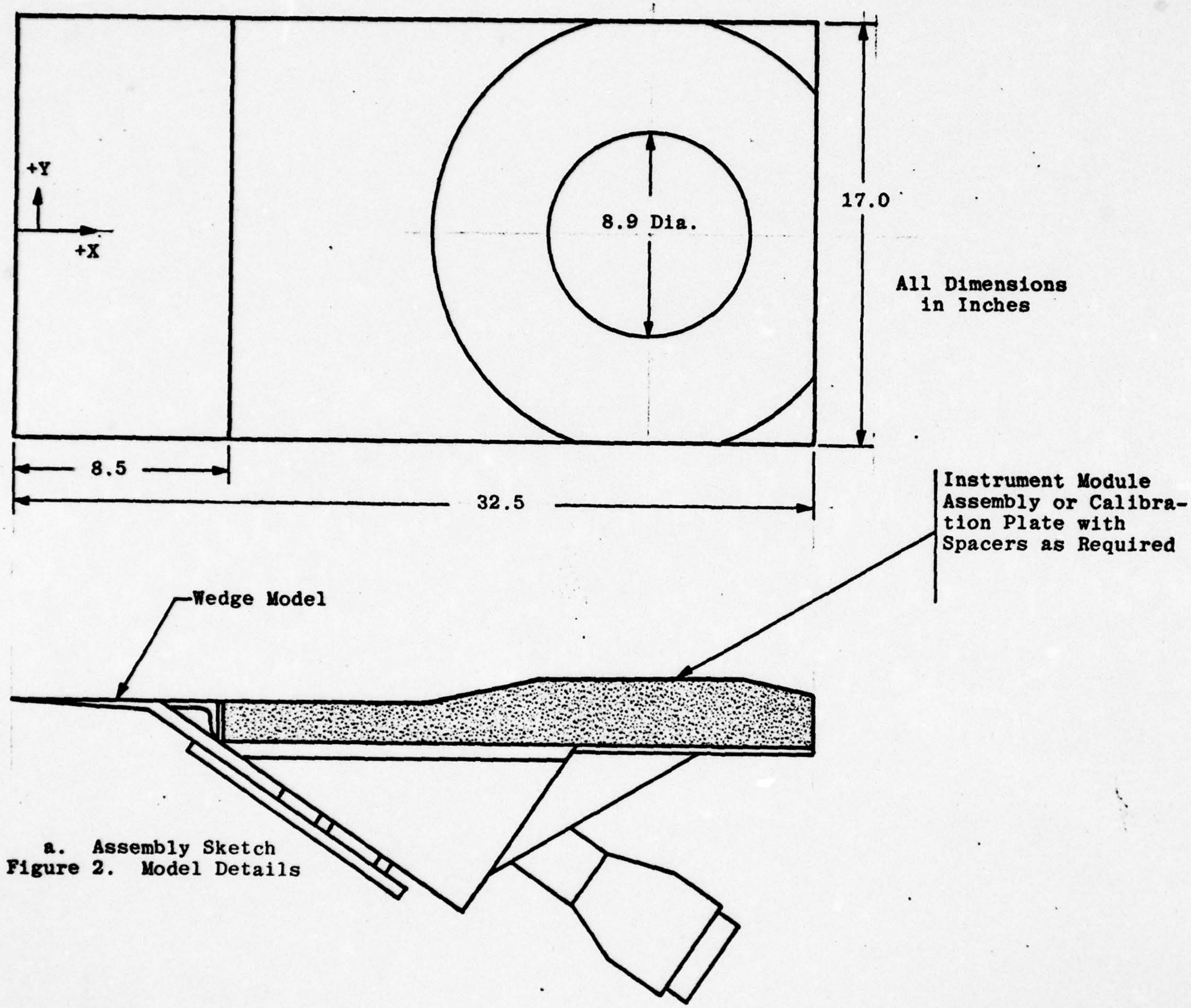


a. Tunnel assembly



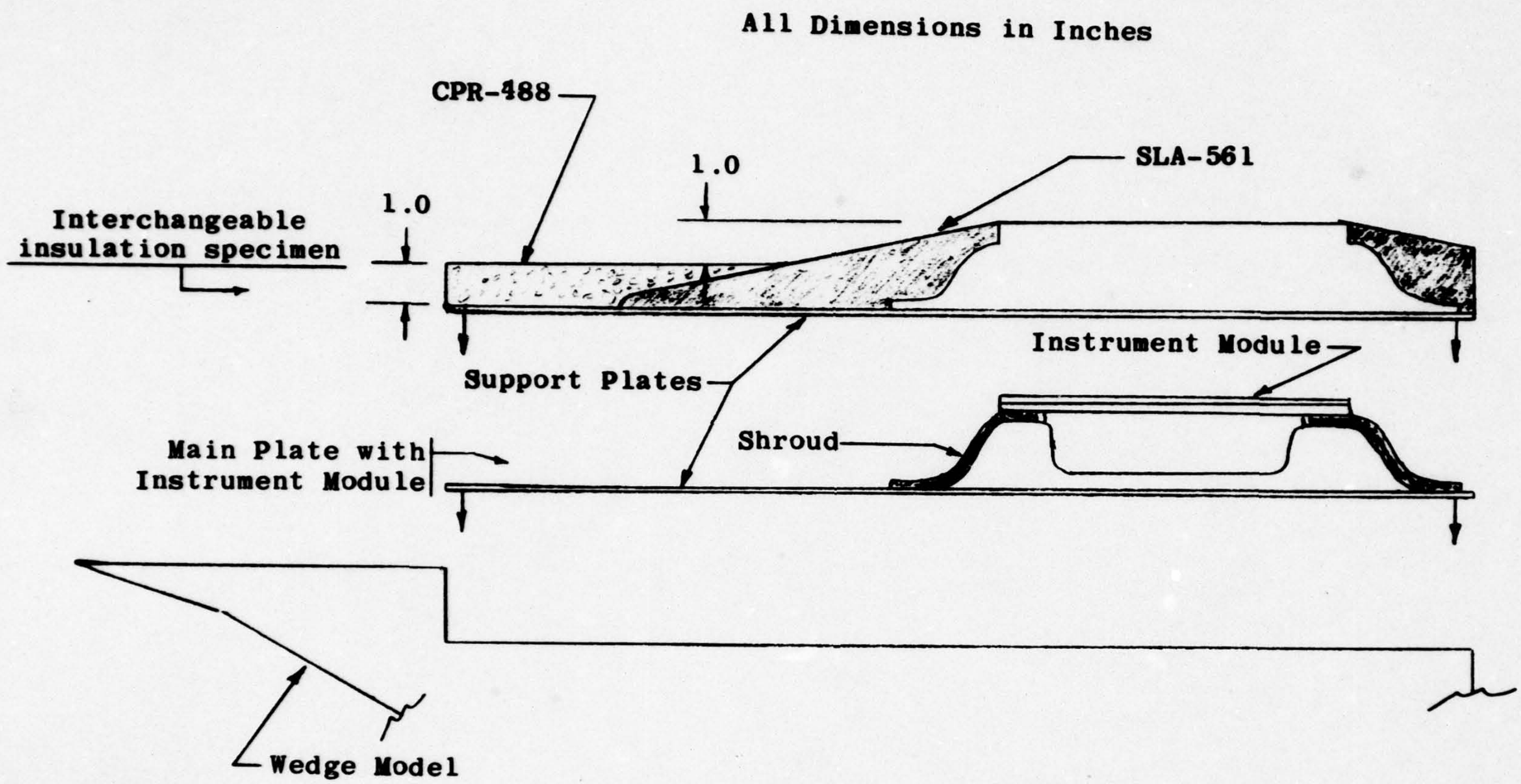
b. Tunnel test section

Fig. 1 Tunnel C



a. Assembly Sketch
Figure 2. Model Details

CPR-488 and SLA-561 are MMC designations for two types of insulation material used on the external tank.



b. Instrument module specimen assembly

Figure 2. Concluded

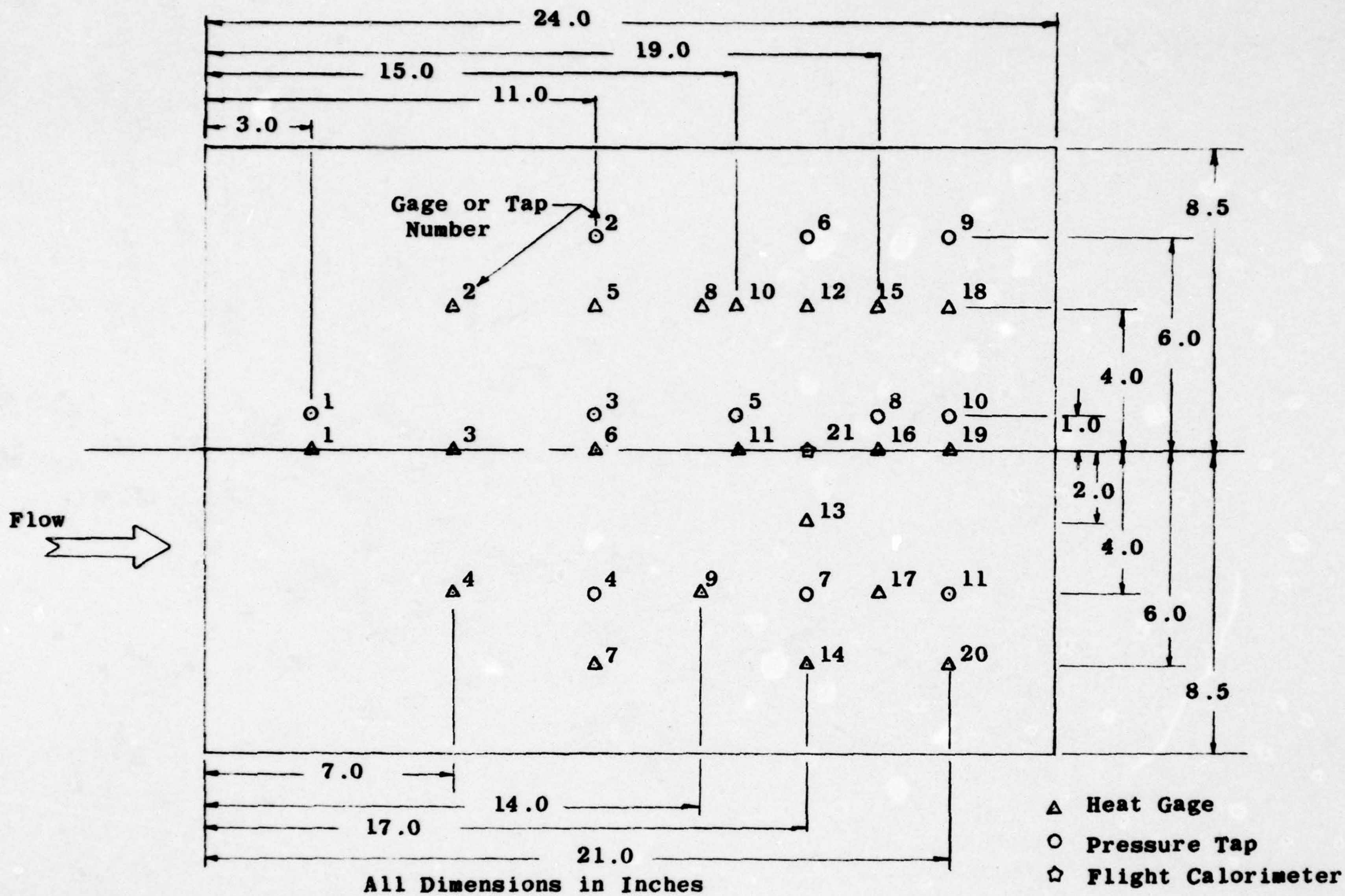


Figure 3. Calibration Plate Instrumentation Locations

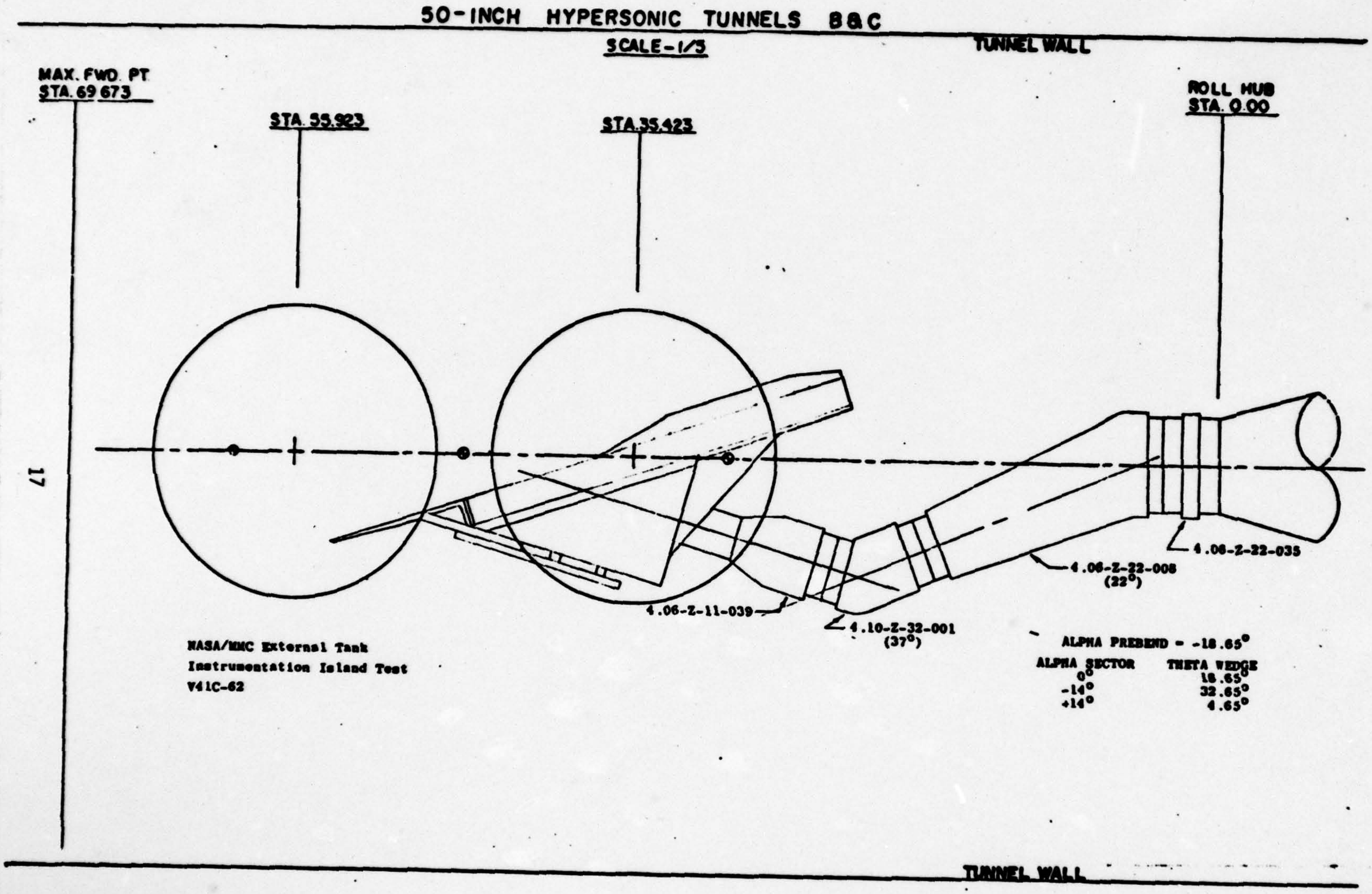


Figure 4. Installation Sketch

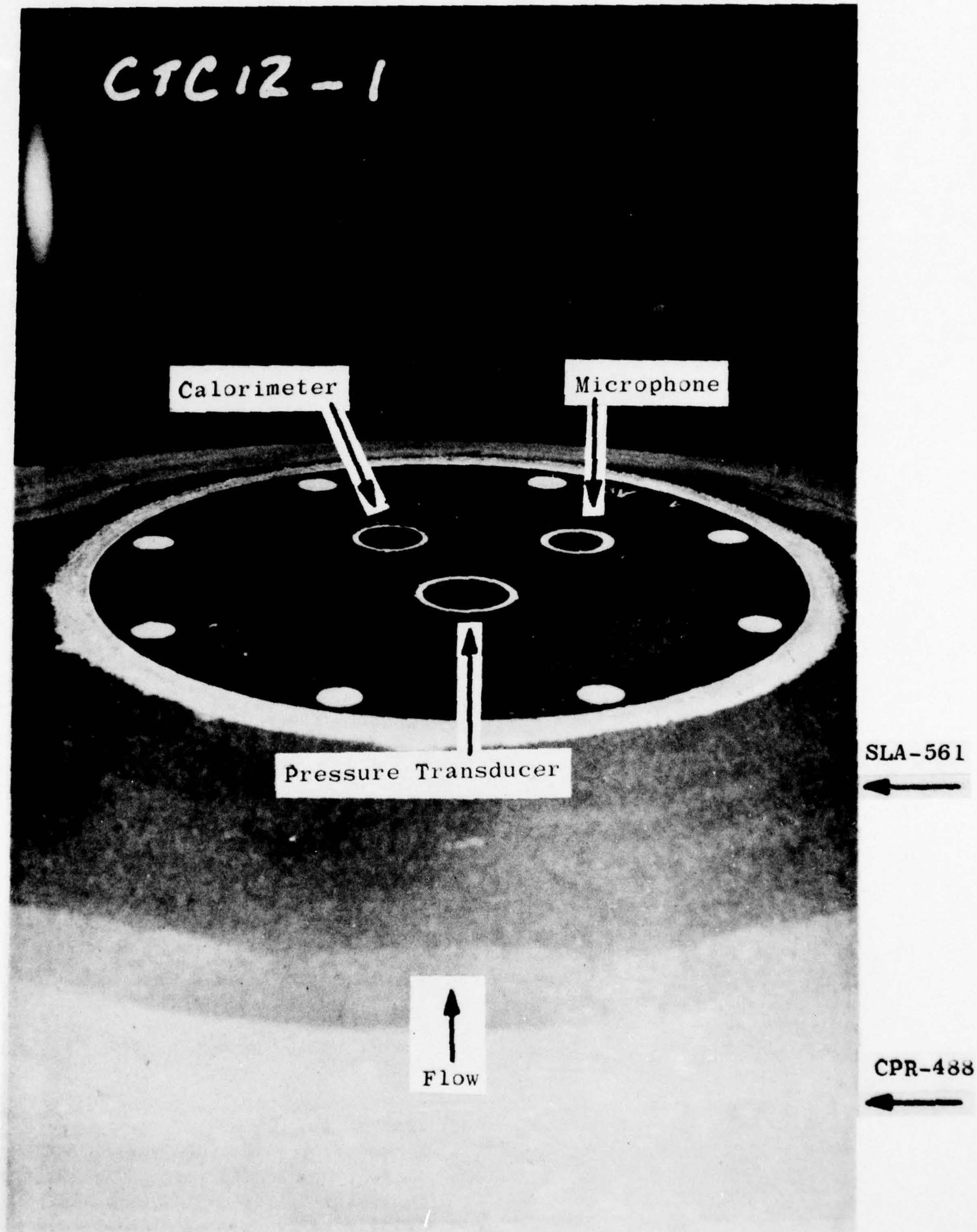


Figure 5 Flight Transducers in Module

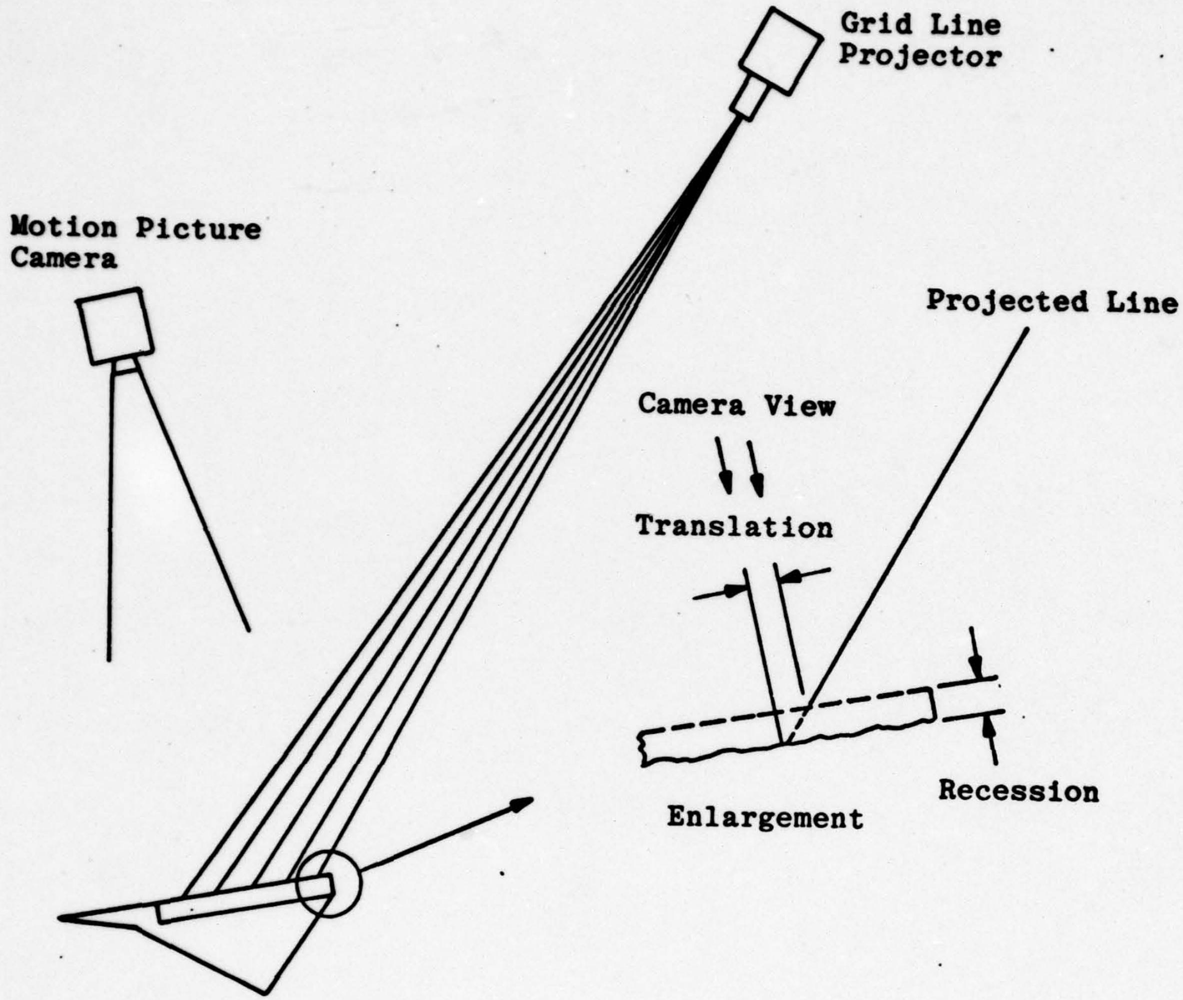


Figure 6. Illustration of Grid Line Projection System

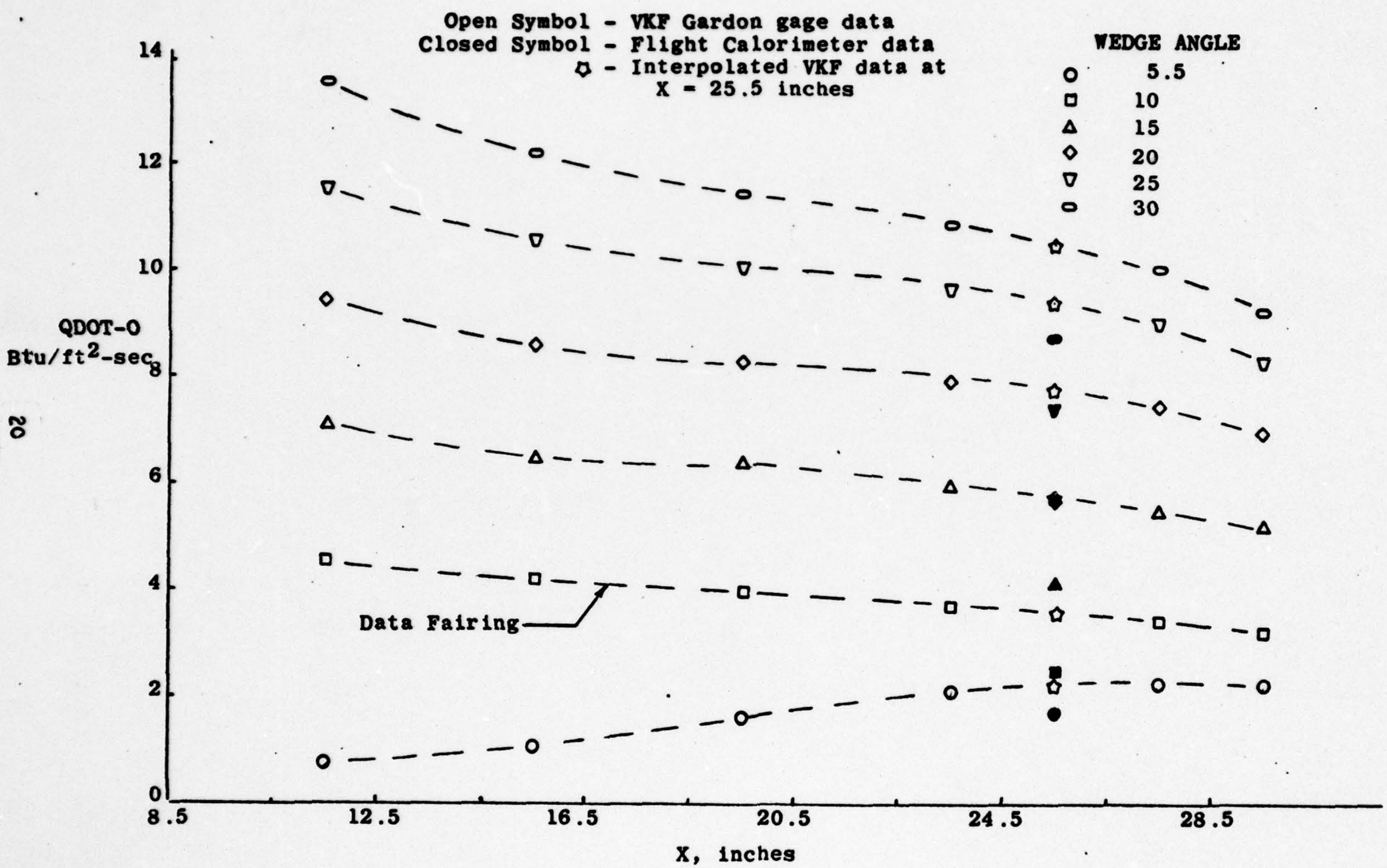


Figure 7 Test Conditions Calibration Data

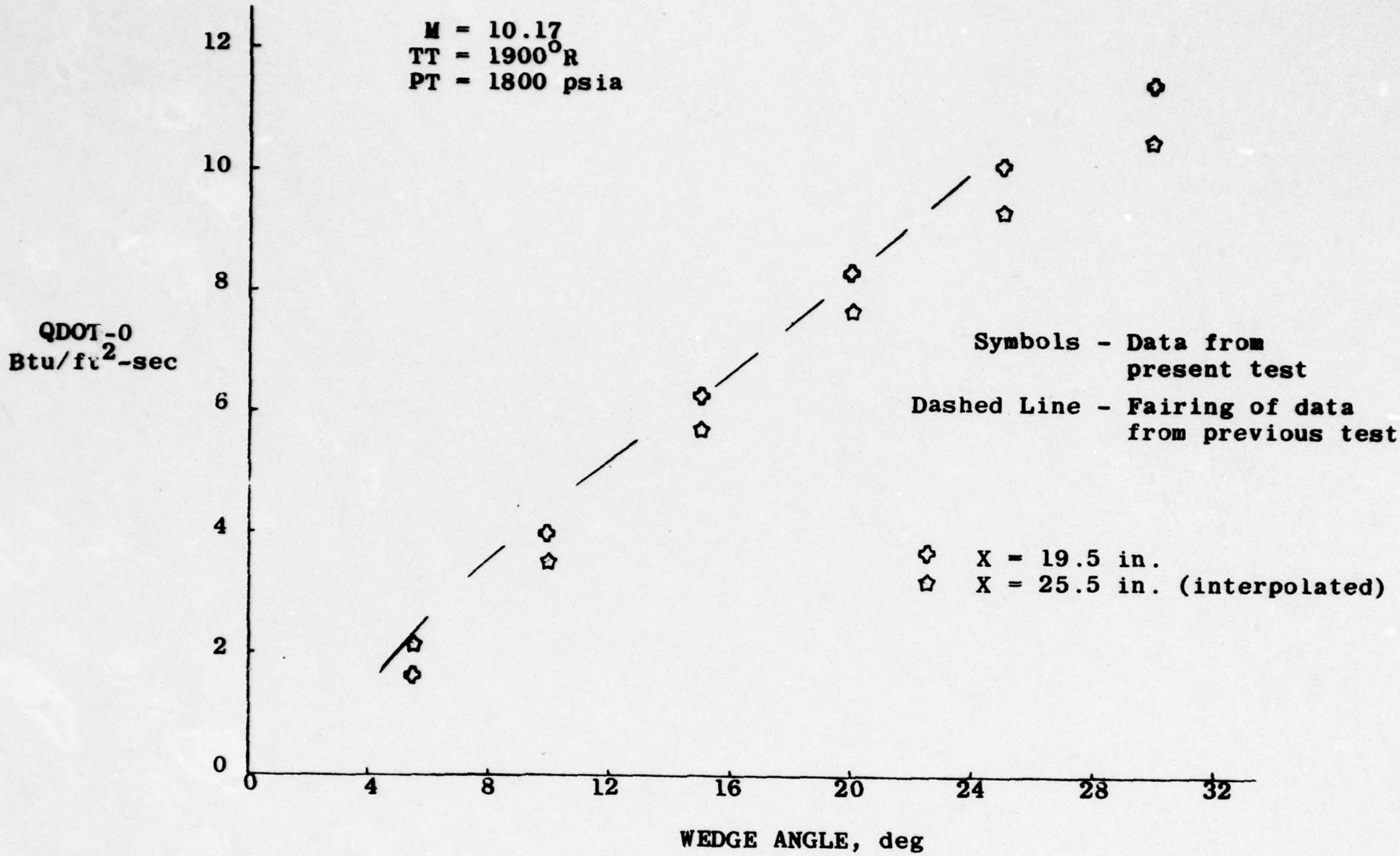
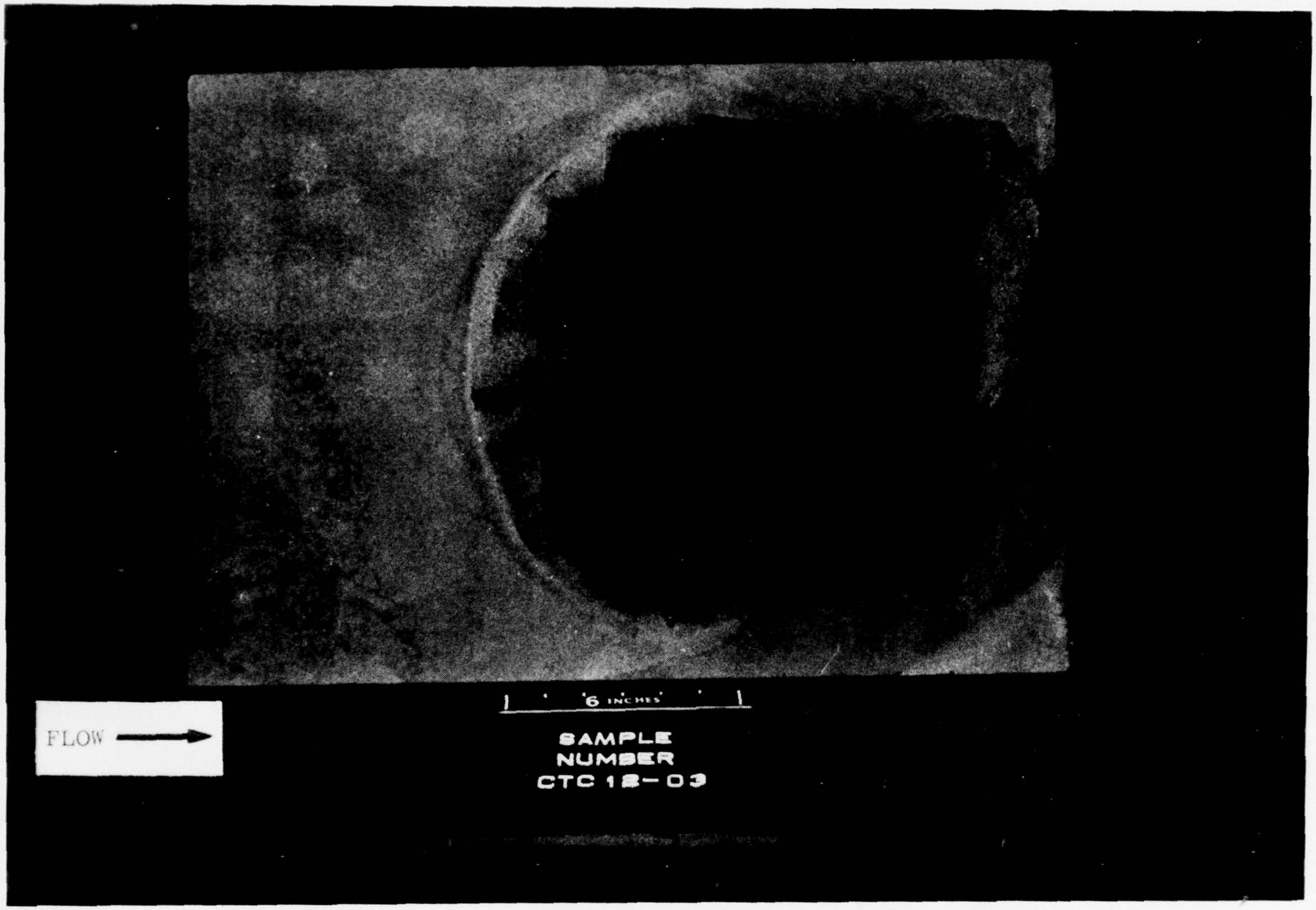
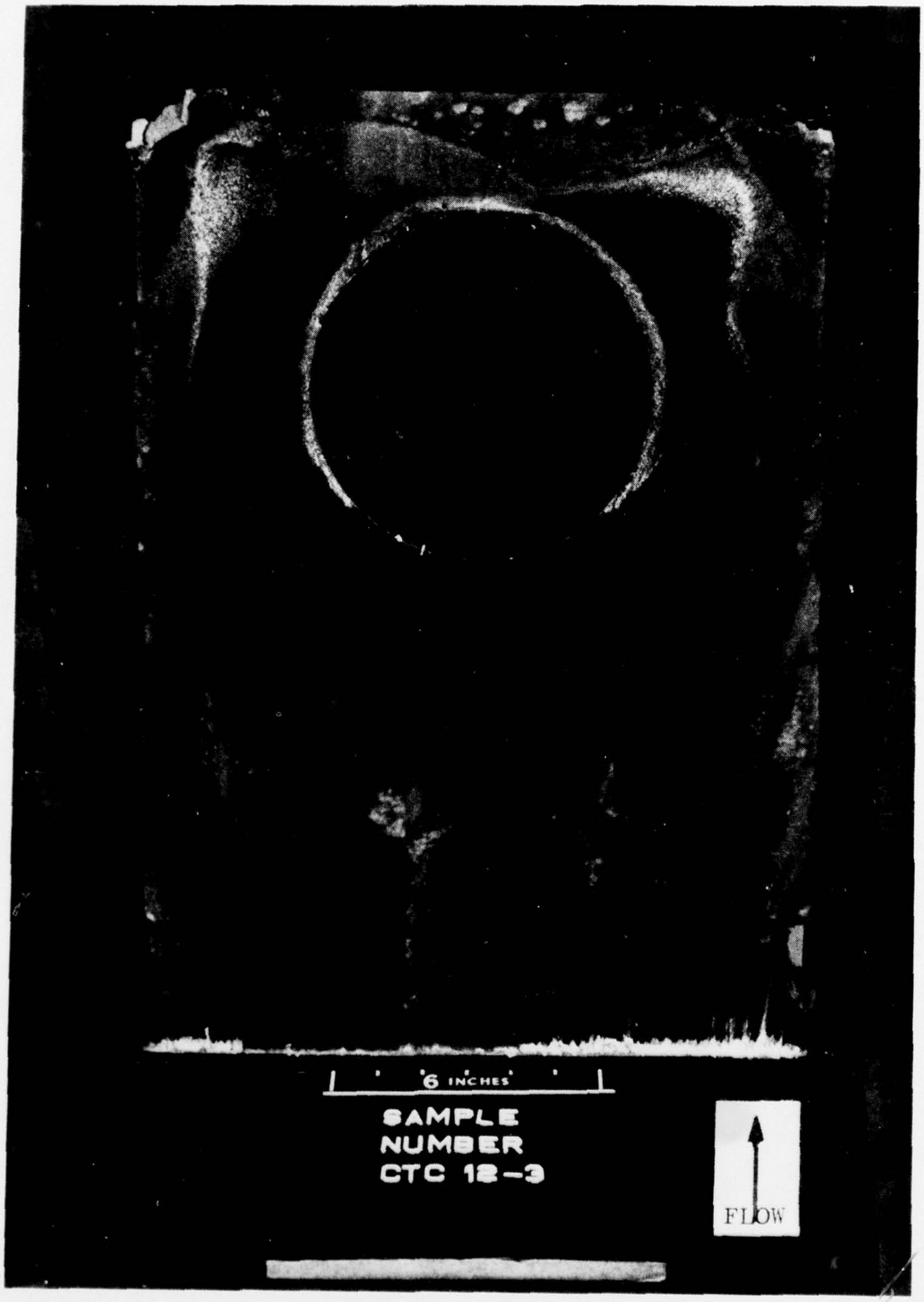


Figure 8. Test Conditions Calibration Summary



a. Pretest

Fig. 9 Pre- and Posttest Material Photographs



b. Posttest

Fig. 9 Concluded

APPENDIX II

TABLES

TABLE 1

Calibration Plate Instrumentation Locations

	Gage Number	X, in.	Y, in.
Heat Gages	1	11.5	0.0
	2	15.5	+4.0
	3	15.5	0.0
	4	15.5	-4.0
	5	19.5	+4.0
	6	19.5	0.0
	7	19.5	-6.0
	8	22.5	+4.0
	9	22.5	-4.0
	10	23.5	+4.0
	11	23.5	0.0
	12	25.5	+4.0
	13	25.5	-2.0
	14	25.5	-6.0
	15	27.5	+4.0
	16	27.5	0.0
	17	27.5	-4.0
	18	29.5	+4.0
	19	29.5	0.0
	20	29.5	-6.0
	21	25.5	0.0
Pressure Taps	1	11.5	+1.0
	2	19.5	+6.0
	3	19.5	+1.0
	4	19.5	-4.0
	5	23.5	+1.0
	6	25.5	+6.0
	7	25.5	-4.0
	8	27.5	+1.0
	9	29.5	+6.0
	10	29.5	+1.0
	11	29.5	-4.0

NOTES:
1. Heat Gage 21 was the Flight Calorimeter
2. Heat Gages 4, 8, 17, and 18 were experimental transducers under development in the VKF. Their accuracy and reliability has not been verified for all the conditions of this test.

TABLE 2. Test Summary

PAGE	OF	
1	1	Sverdrup | ARO, Inc.

USER	PROJECT TITLE	PROJECT	DATE
Martin Marietta Corporation	NASA/MMC ET Instrument Island Test	V41C-62	Jan. 11, 1979
REPRESENTATIVE(S): H. Carroll	MODEL: Instrument Island and Insulation	ARO TEST PERSONNEL: D. Stallings	

RUN	Configuration	Config. Confirmed	M	PT psia	TT °F	Wedge Angle deg						Time	Remarks
1	Cal. Plate		10.17	1800	1440	5.65							Runs 1,2,and 3-data questionable on some gages due to hot air impingement on back side
2						10							
3						5.65							
4						5.65							
5						10							
6						15							
7						20							
8						25							
9						30							
10						5.65							
11						10							
12						15							
13						20							
14						25							
15	↓					30							
16	CTC12-1					11							
17	CTC12-2					16							
18	CTC12-3					23							
19	CTC12-4		↓	↓	↓	Var.							Aborted due to tunnel flow problem.
20	CTC12-4		10.17	1800	1440	Var.							

AEDC Arnold AFSC Tenn

TABLE 3

Flight Calorimeter Calibration Data

Gage S/N	Pretest		Posttest		
	Incident Heat Flux Btu/ft^2-sec	Scale Factor Btu/ft^2-sec/mv	Incident Heat Flux Btu/ft^2-sec	Scale Factor Btu/ft^2-sec/mv	Percent Change
0099	3.14	.292	3.02	.287	1.7
	5.35	.289	5.00	.280	3.1
0100	3.08	.297	3.02	.318	7.0
	5.39	.292	5.00	.312	6.8

NOTES:

1. The calibration equipment utilizes a radiant heat source.
2. Each data point represents an average value from two or more irradiations.
3. During the test, Gage S/N 0099 was installed in the flat calibration plate and Gage S/N 0100 was in the instrument island module.
4. Pretest calibration of Gage S/N 0099 agreed within one per cent with manufacturer's data.

APPENDIX III

SAMPLE TABULATED DATA

ARO, INC. AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/MMC ET INSTRUMENT ISLAND TEST

DATE COMPUTED 12-JAN-79
TIME COMPUTED 03:30:11
DATE RECORDED 12-JAN-78
TIME RECORDED 0:38:19
PROJECT NUMBER V41C-62

RUN	CONFIG	M	PT PSIA	TT,DEG R	RE,FT-1	WEDGE ANGLE,DEG
5	CAL PLATE	10.17	1796.90	1898.7	2.176E+06	9.926

T (DEGR)	P (PSIA)	Q (PSIA)	V (FT-SEC)	RHO (LBM/FT3)	MU (LB-SEC/FT2)	PT2 (PSIA)
92.24	0.04	2.685	4788.	1.085E-03	7.422E-08	4.98

	GAGE NO	X (IN)	Y (IN)	QDOT (BTU/FT2-SEC)	TGE (DEGR)	TW (DEGR)	H(TT) (BTU/FT2-SEC-R)	QDOT-O (BTU/FT2-SEC)
	1	11.500	0	4.376	515.88	527.07	3.191E-03	4.591
	2	15.500	4	4.129	517.64	528.29	3.013E-03	4.336
	3	15.500	0	3.999	507.35	517.69	2.896E-03	4.167
*	4	15.500	-4	3.424	569.15	569.15	2.576E-03	3.706
	5	19.500	4	3.695	514.02	523.48	2.687E-03	3.866
	6	19.500	0	3.737	531.97	541.43	2.754E-03	3.962
	7	19.500	-6	3.183	520.88	529.05	2.324E-03	3.344
*	8	22.500	4	0.580	529.88	529.88	4.234E-04	0.609
	9	22.500	-4	3.474	520.35	529.21	2.537E-03	3.650
	10	23.500	4	3.559	517.47	526.61	2.594E-03	3.733
	11	23.500	0	3.539	507.56	516.71	2.561E-03	3.685
	12	25.500	4	3.359	515.36	524.01	2.443E-03	3.516
	13	25.500	-2	3.547	529.11	538.22	2.607E-03	3.751
	14	25.500	-6	2.902	528.69	536.12	2.130E-03	3.064
	15	27.500	4	3.513	517.43	526.33	2.560E-03	3.684
	16	27.500	0	3.243	527.29	535.56	2.379E-03	3.424
*	17	27.500	-4	2.748	529.88	529.88	2.007E-03	2.888
*	18	29.500	4	2.934	538.49	538.49	2.157E-03	3.104
	19	29.500	0	3.033	531.59	539.31	2.231E-03	3.211
	20	29.500	-6	2.899	519.31	525.65	2.112E-03	3.038
x	21	25.500	0	2.382	529.88	529.88	1.740E-03	2.504

* VKF Schmidt-Boelter gages
x HyCal flight transducer

Calibration Plate Heat-Transfer Data

ARO, INC - AEDC DIVISION
A SVERDRUP CORPORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENN

DATE COMPUTED 1[illegible] JAN-79
DATE RECORDED 12-JAN-78
TIME COMPUTED 03:03
TIME RECORDED 1:24: 8

PROJECT NO V41C-62
NASA/MMC ET INSTRUMENT ISLAND TEST

RUN	CONFIG	M	PT,PSIA	TT,DEG R	RE, FT-1	WEDGE ANGLE,DEG
10	CAL PLATE	10.17	1799.75	1896.67	0.218E+07	5.44

T (DEGR)	P (PSIA)	Q (PSIA)	V (FT/SEC)	RHO (LBM/FT3)	MU (LBF-SEC/FT2)	PT2 (PSIA)
92.1	0.037	2.690	4785.39	0.109E-02	0.741E-07	4.992

PORT NO	X (IN)	Y (IN)	PM (PSIA)	PM/P	PM/PT2	CPM
1	11.5	1	0.102	2.737	0.020	0.024
2	19.5	6	0.103	2.767	0.021	0.024
3	19.5	1	0.108	2.902	0.022	0.026
4	19.5	-4	0.103	2.770	0.021	0.024
5	23.5	1	0.110	2.966	0.022	0.027
6	25.5	6	0.106	2.856	0.021	0.026
7	25.5	-4	0.103	2.780	0.021	0.025
8	27.5	1	0.112	3.004	0.022	0.028
9	29.5	6	0.109	2.931	0.022	0.027
10	29.5	1	0.110	2.953	0.022	0.027
11	29.5	-4	0.100	2.690	0.020	0.023

Calibration Plate Pressure Data

ARO, INC. - [illegible]DC DIVISION
A SVERDRUP [illegible]ORATION COMPANY
VON KARMAN GAS DYNAMICS FACILITY
ARNOLD AIR FORCE STATION, TENNESSEE
NASA/MMC ET INST. ISLAND TEST

DATE COMPUTED [illegible]-JAN-79
TIME COMPUTED 05:12:01
DATE RECORDED 12-JAN-79
TIME RECORDED 3:36: 6
PROJECT NUMBER V41C-62

50 INCH HYPERSONIC TUNNEL C

RUN	CONFIG	M	PT,PSIA	TT,DEG R	RE,FT-1	WEDGE ANGLE,DEG
16	CTC12-1	10.17	1798.75	1898.67	2.178E+06	11.03

T (DEG R)	P (PSIA)	Q (PSIA)	V (FT/SEC)	RHO (LBM/FT3)	MU (LBF-SEC/FT2)	PT2 (PSIA)	INJECT TIME (SEC)	CENTERLINE (HOUR MIN SEC MSEC)	EXPOSURE TIME (SEC)
92.2	0.037	2.688	4788.1	1.087E-03	7.422E-08	4.988	5.01	3 36 24 454	87.72

WEDGE ATTITUDE AND TEMPERATURE HISTORY

TIME (SEC)	WEDGE ANGLE (DEG)	QDOT (BTU/FT2-SEC)	PM (PSIA)	TM1 (DEG F)	TM2 (DEG F)	TM3 (DEG F)	TM4 (DEG F)
2.20	11.01	3.806	0.325	70.	74.	72.	73.
2.70	10.93	3.834	0.323	70.	74.	72.	73.
3.20	10.93	3.456	0.328	70.	74.	72.	73.
3.70	10.92	3.861	0.328	70.	74.	72.	73.
4.20	10.92	3.877	0.323	70.	74.	72.	73.
4.70	10.92	3.906	0.326	70.	74.	72.	73.
5.20	10.92	3.920	0.322	70.	74.	72.	73.
5.70	10.92	3.927	0.325	70.	74.	72.	73.
6.20	10.93	3.943	0.323	70.	74.	72.	73.
6.70	10.92	3.952	0.323	70.	74.	72.	73.
7.20	10.92	3.956	0.325	70.	74.	72.	73.
7.70	10.92	3.949	0.326	71.	74.	72.	73.
8.20	10.92	3.960	0.326	71.	74.	72.	73.
8.70	10.92	3.975	0.328	71.	74.	72.	73.
9.20	10.93	3.970	0.325	71.	74.	72.	73.
9.70	10.92	3.998	0.322	71.	74.	72.	73.
10.20	10.93	4.000	0.323	71.	74.	72.	74.
10.70	10.92	4.009	0.322	71.	74.	72.	74.
11.20	10.92	4.013	0.328	71.	74.	72.	74.
11.70	10.92	4.014	0.322	71.	74.	72.	74.
12.20	10.92	4.020	0.322	71.	74.	72.	74.
12.70	10.92	4.012	0.322	72.	74.	72.	74.
13.20	10.92	4.016	0.323	72.	74.	72.	74.
13.70	10.92	4.013	0.326	72.	74.	72.	74.
14.20	10.93	4.021	0.325	72.	74.	72.	74.
14.70	10.93	4.025	0.328	72.	74.	72.	75.
15.20	10.92	4.025	0.326	72.	74.	72.	75.
15.70	10.92	4.030	0.322	72.	74.	72.	75.
16.20	10.92	4.023	0.323	72.	74.	72.	75.
16.70	10.92	4.025	0.328	72.	74.	72.	75.
17.20	10.92	4.023	0.320	73.	74.	72.	75.

Instrument Island Data