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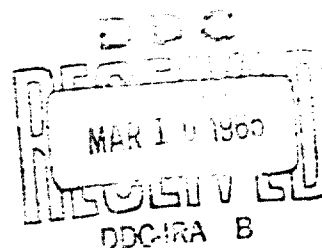
AS AD NO. ~~458212~~

TOR-169(3305) —,
Revision #1

"Hypersonic Wind Tunnel
Facilities in the United States"
Revision #1



AEROSPACE CORPORATION



AEROSPACE CORPORATION
INTEROFFICE CORRESPONDENCE

TO: Holder, Report
TOR-169(3305)-1

CC:

DATE: 18 October 1963

SUBJECT: Revision 1

FROM: Publications

400-7/92

Attached is Revision 1 to Aerospace Corporation Report TOR-169(3305)-1, entitled "Hypersonic Wind Tunnel Facilities in the United States".

This revision package should be physically incorporated into the basic document as instructed by the Revision Summary page, which is included for permanent reference. The superseded pages should be removed and destroyed.

Report No.
TOR-169(3305)-1
Revision 1
October 1963

HYPERSONIC WIND TUNNEL FACILITIES
IN
THE UNITED STATES

March 1963

Prepared by
F. A. Vicente and Nancy S. Foy
Fluid Mechanics Department

AEROSPACE CORPORATION
El Segundo, California

Contract Nos. AF 04(695)-169
AF 04(695)-269

Prepared for
COMMANDER SPACE SYSTEMS DIVISION
UNITED STATES AIR FORCE
Inglewood, California

REVISION SUMMARY

REV. CODE	REV. DATE	REVISION DETAILS	REVISION ACTION	REV. CCN	REVISION APPROVAL(S)
	10/63	Section 1	Revised		<i>For Nancy S. Howell</i>
	10/63	Section 6	Revised		
	10/63	Pages 10-1 to 10-3	Revised		
	10/63	Section 22	Revised		
	10/63	Page 26-3	Revised		
	10/63	Section 32	Revised		
	10/63	Pages 37-1 and 37-2	Revised		
	10/63	Page 38-1	Revised		
	10/63	Page 38-1a	Added		

HYPERSONIC WIND TUNNEL FACILITIES IN THE UNITED STATES

This report presents a compilation of hypersonic wind tunnel facility data, with particular attention given to operating characteristics of the major hypersonic wind tunnels in the United States. The information has been compiled to assist personnel who must evaluate and select facilities for hypersonic wind tunnel test programs.

A brief description is given for each facility. These descriptions include information regarding responsible personnel; nozzle and test section; instrumentation; operational status, where such information is pertinent; data reduction method, whenever this has been available; running times; and particular test capabilities of each facility.

An envelope of Reynolds number versus Mach number was drawn for each facility, using a uniform scale. Since envelopes of stagnation conditions were available in most cases, these also have been drawn on a uniform scale. In these graphs Mach number and Reynolds number represent free stream conditions, and stagnation pressure, temperature, and enthalpy refer to conditions in the reservoir region of the flow.

Since all information in this report was plotted using Mach number as a parameter, graphs are included in the introductory section to correlate Mach number and altitude. These are based on the 1962 U. S. Standard Atmosphere, and consider air to be a perfect gas, with $\gamma = 1.4$ and $R = 1716 \text{ ft}^2/\text{sec}^2 \text{ } ^\circ\text{R}$.

Over-all maps of Reynolds number, stagnation pressure, and stagnation temperature are provided to permit immediate determination that a wind tunnel test can be performed under specific environmental conditions. Once this possibility has been established, specific facility

performance envelopes can be examined to determine which facilities have the capability required for the desired test. It should be emphasized here, however, that the purpose of this report is to serve only as a preliminary guide in facility selection. In every case, the individual facility should be contacted to determine tunnel availability, schedules, and cost, and to verify operational status and tunnel operating parameters.

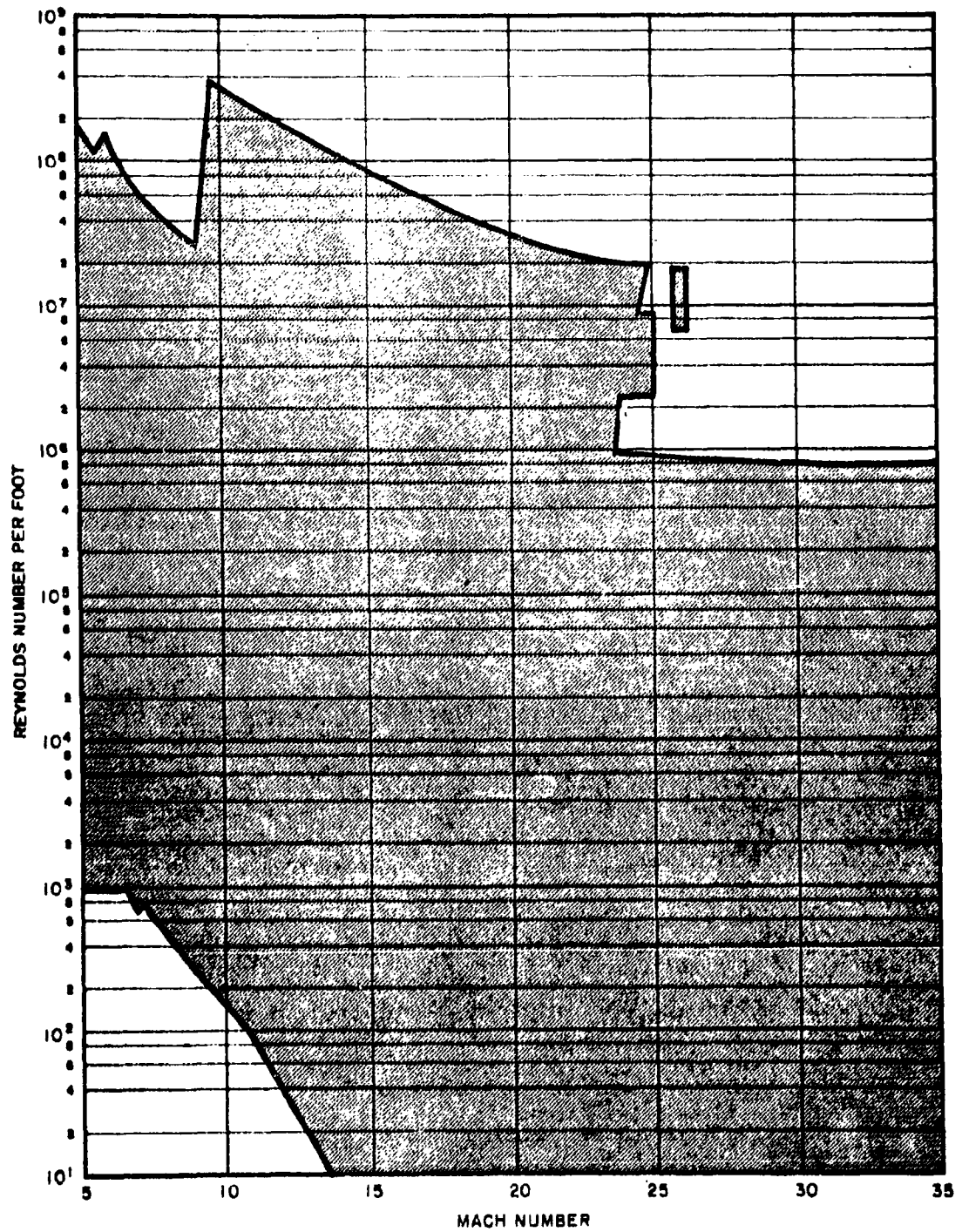
The facilities appear within the report in alphabetical order. However, they are indexed according to the type of tunnel (i. e. continuous, hotshot, blowdown or shock) and the type of organizational management. (i. e. government, industrial, university and non-profit corporations).

A preliminary report was compiled and published in rough draft form in November 1962. The preliminary report included data submitted by the various facilities, as well as information which was available in the literature. Each section was sent to the pertinent facility manager; the sections were corrected, updated, and returned by 37 of the 59 facilities. The basic report incorporated all changes and corrections forwarded by the facility managers from November 1962 to March 1963. This revision includes all changes received between March and September 1963.

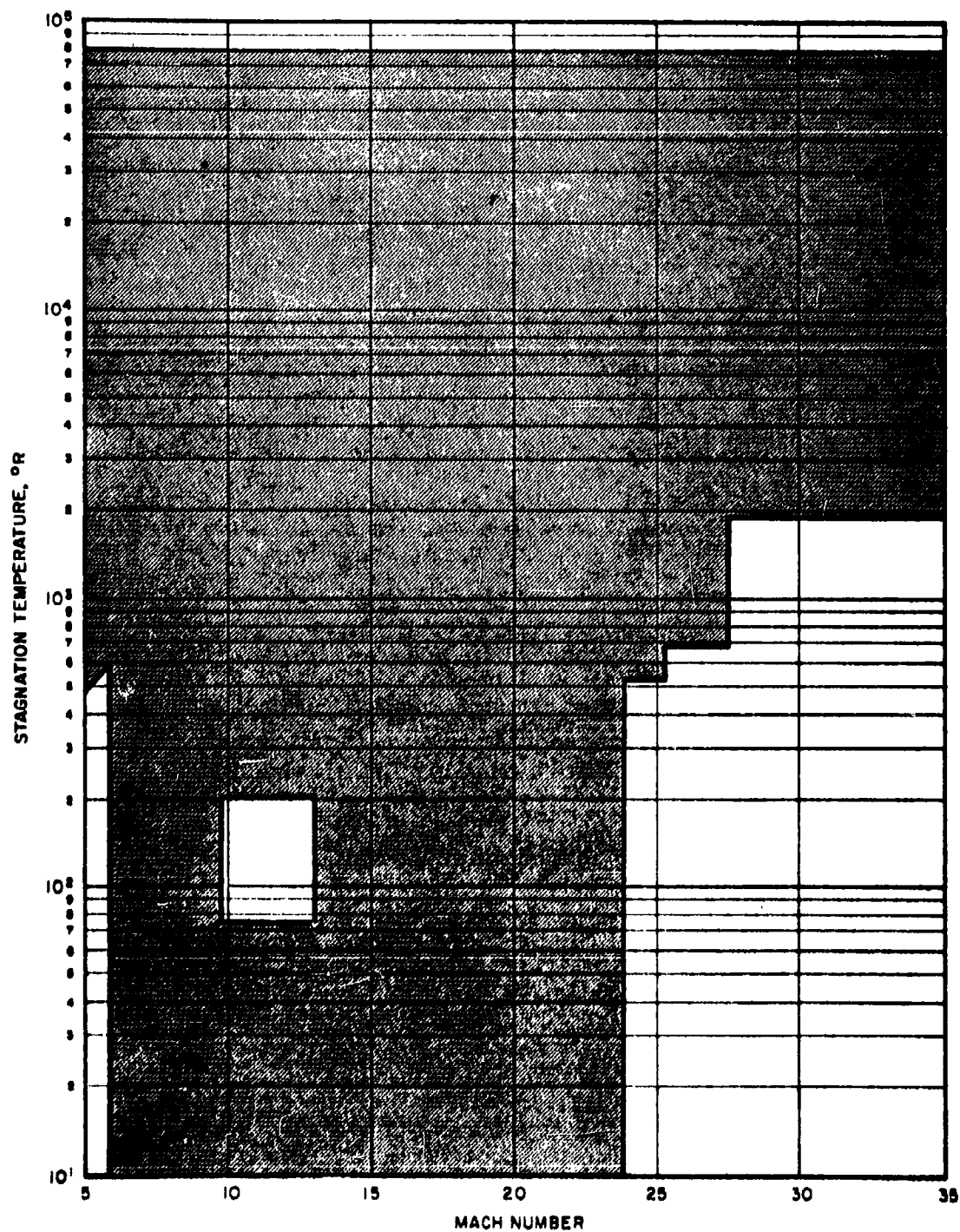
It is hoped that new information will be sent to Aerospace as it becomes available, so that this report can continue to reflect the current status of each facility. Permanent files are maintained within the Fluid Mechanics Department of the Engineering Division of Aerospace Corporation. These files presently contain the material referenced within this report, and are available to interested personnel.

The authors particularly appreciate the assistance of the many facility personnel who have taken extra time and trouble to assure that this report will include the most accurate and timely information available.

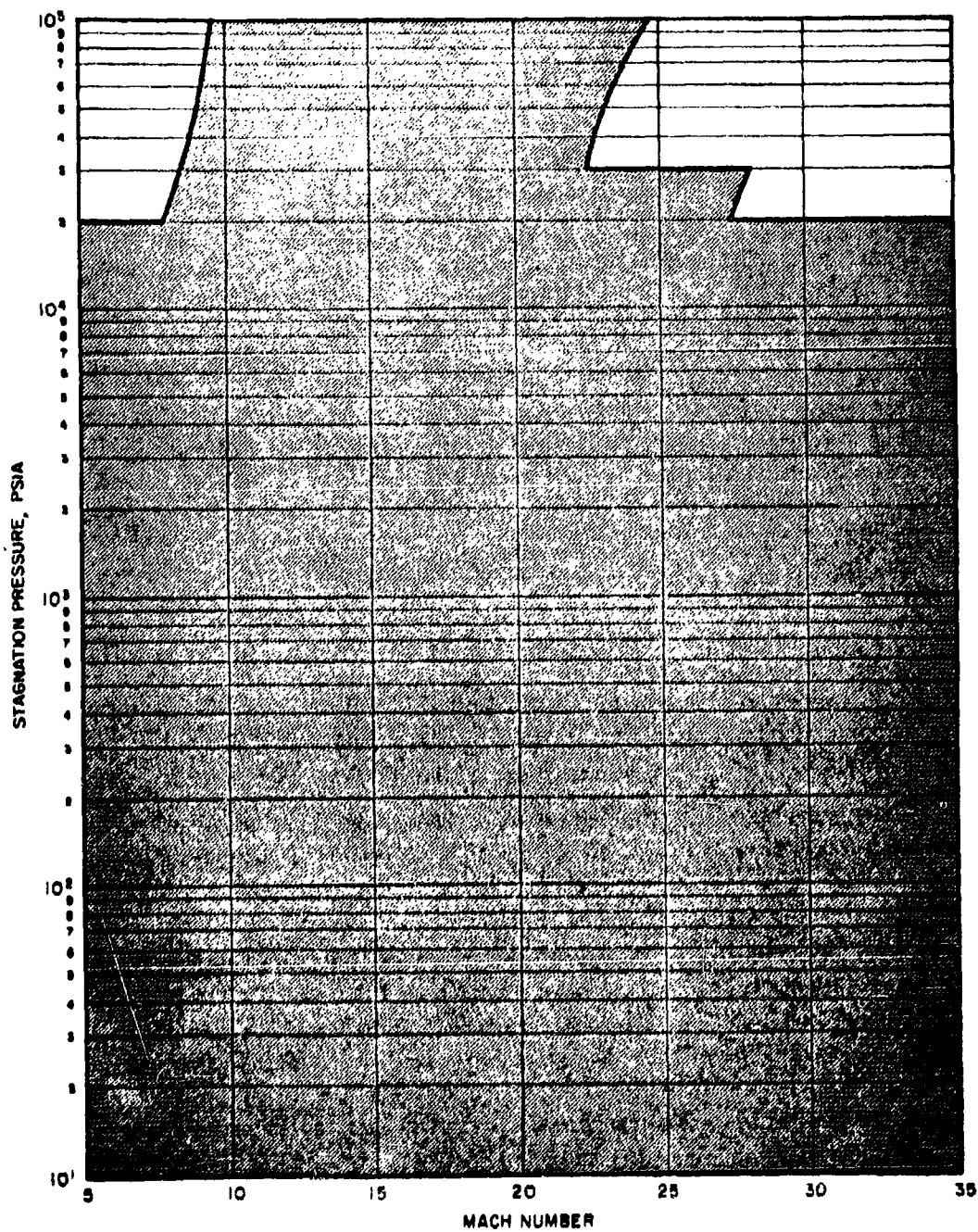
OVERALL PERFORMANCE MAP OF WIND TUNNEL FACILITIES
CURRENTLY OPERATIONAL OR UNDER CONSTRUCTION

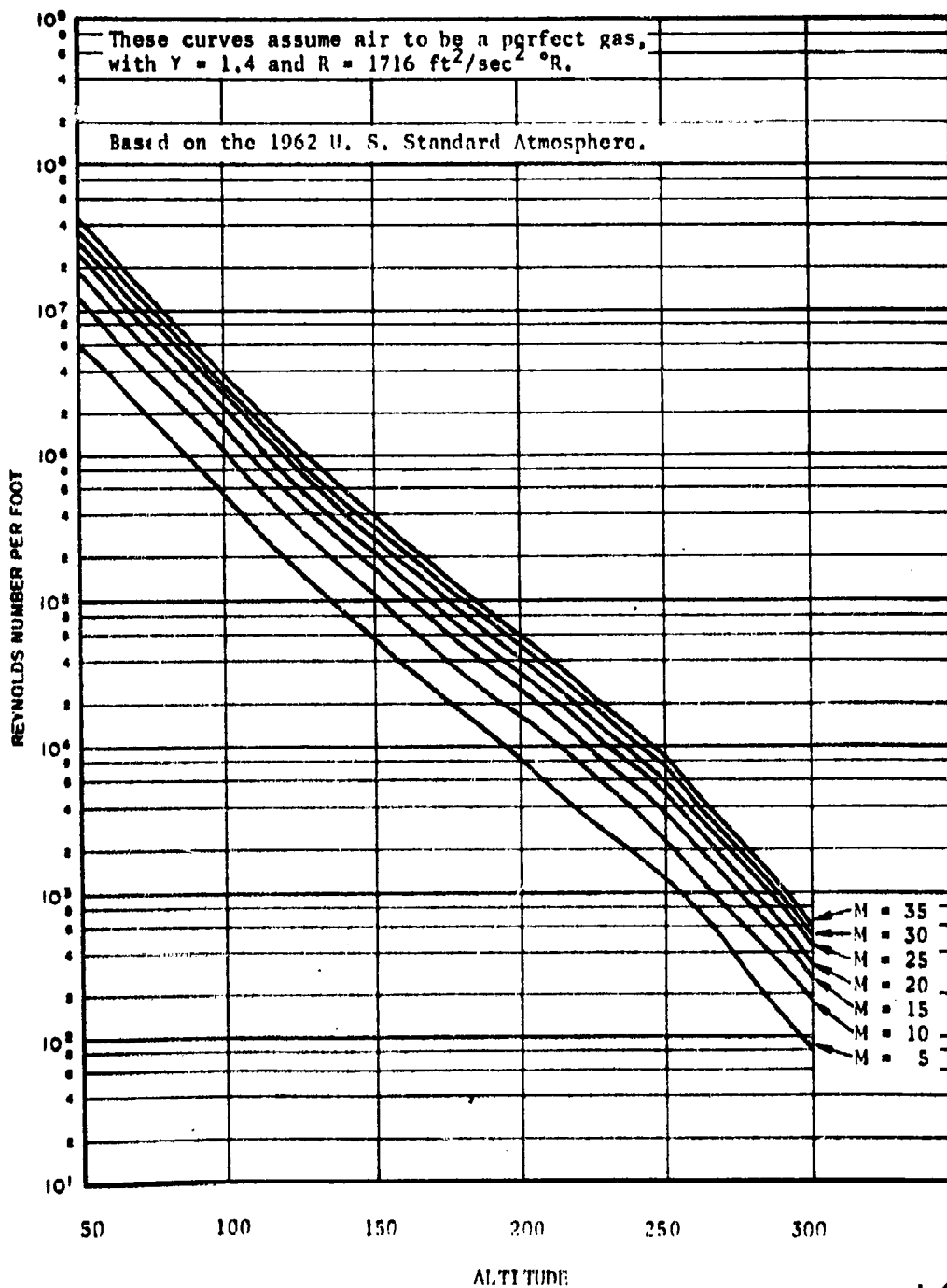


OVERALL PERFORMANCE MAP OF WIND TUNNEL FACILITIES
CURRENTLY OPERATIONAL OR UNDER CONSTRUCTION

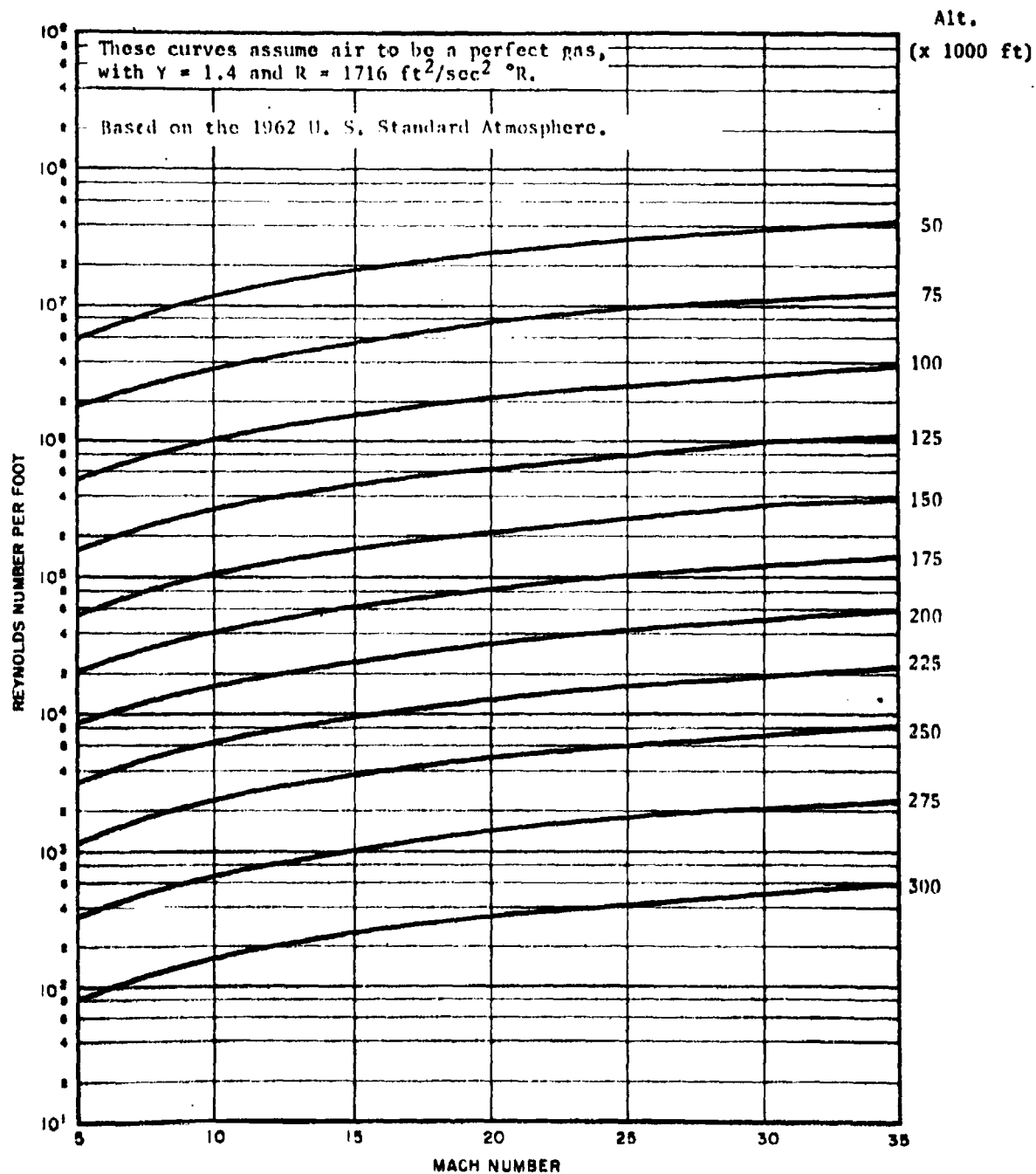


OVERALL PERFORMANCE MAP OF WIND TUNNEL FACILITIES
CURRENTLY OPERATIONAL OR UNDER CONSTRUCTION



REYNOLDS NUMBER PER FOOT
AS A FUNCTION OF ALTITUDE

REYNOLDS NUMBER PER FOOT
AS A FUNCTION OF FREE STREAM MACH NUMBER



REYNOLDS NUMBER-MACH NUMBER-ALTITUDE CHART

Altitude	M = 5	M = 10	M = 15	M = 20	M = 25	M = 30	M = 35
50,000 ft.	5.991+6	1.198+7	1.797+7	2.396+7	2.995+7	3.595+7	4.193+7
75,000 ft.	1.812+6	3.624+6	5.436+6	7.248+6	9.059+6	1.087+7	1.268+7
100,000 ft.	5.268+5	1.053+6	1.579+6	2.107+6	2.634+6	3.161+6	3.687+6
125,000 ft.	1.574+5	3.146+5	4.719+5	6.293+5	7.865+5	9.438+5	1.101+6
150,000 ft.	5.378+4	1.075+5	1.613+5	2.151+5	2.688+5	3.226+5	3.764+5
175,000 ft.	2.016+4	4.033+4	6.049+4	8.065+4	1.008+5	1.210+5	1.411+5
200,000 ft.	8.226+3	1.646+4	2.468+4	3.291+4	4.114+4	4.937+4	5.759+4
225,000 ft.	3.185+3	6.370+3	9.557+3	1.274+4	1.593+4	1.911+4	2.229+4
250,000 ft.	1.189+3	2.379+3	3.568+3	4.756+3	5.946+3	7.135+3	8.325+3
275,000 ft.	3.415+2	6.830+2	1.025+3	1.366+3	1.708+3	2.050+3	2.390+3
300,000 ft.	8.193+1	1.640+2	2.459+2	3.278+2	4.097+2	4.917+2	5.736+2

+7 = $\times 10^7$

These figures assume air to be a perfect gas, with $\gamma = 1.4$
and $R = 1716 \text{ ft}^2/\text{sec}^2 \text{ OR}$.

Based on the 1962 U. S. Standard Atmosphere.

Name of Facility

AVCO Research and Development
Wilmington, Massachusetts

Person Responsible

Herbert Weisblatt
Assistant Section Chief, Experimental Gasdynamics

Type

The 20-Inch Shock Tunnel, which can be either hydrogen or combustion driven, is presently in operation. The tunnel has been calibrated at one operational point (see charts) with the hydrogen driver, and is presently undergoing calibration with the combustion driver.

Nozzle and Test Section

The 20-Inch Shock Tunnel uses a 7⁰ conical nozzle. At present the nozzle expands to a useful test core dia. of 12.5 inches at $M = 14.0$.

Instrumentation and Test Capabilities

Pressure and heat transfer tests may be run in the 20-Inch Shock Tunnel at $M = 14.0$. At present a strain gage force balance is being developed.

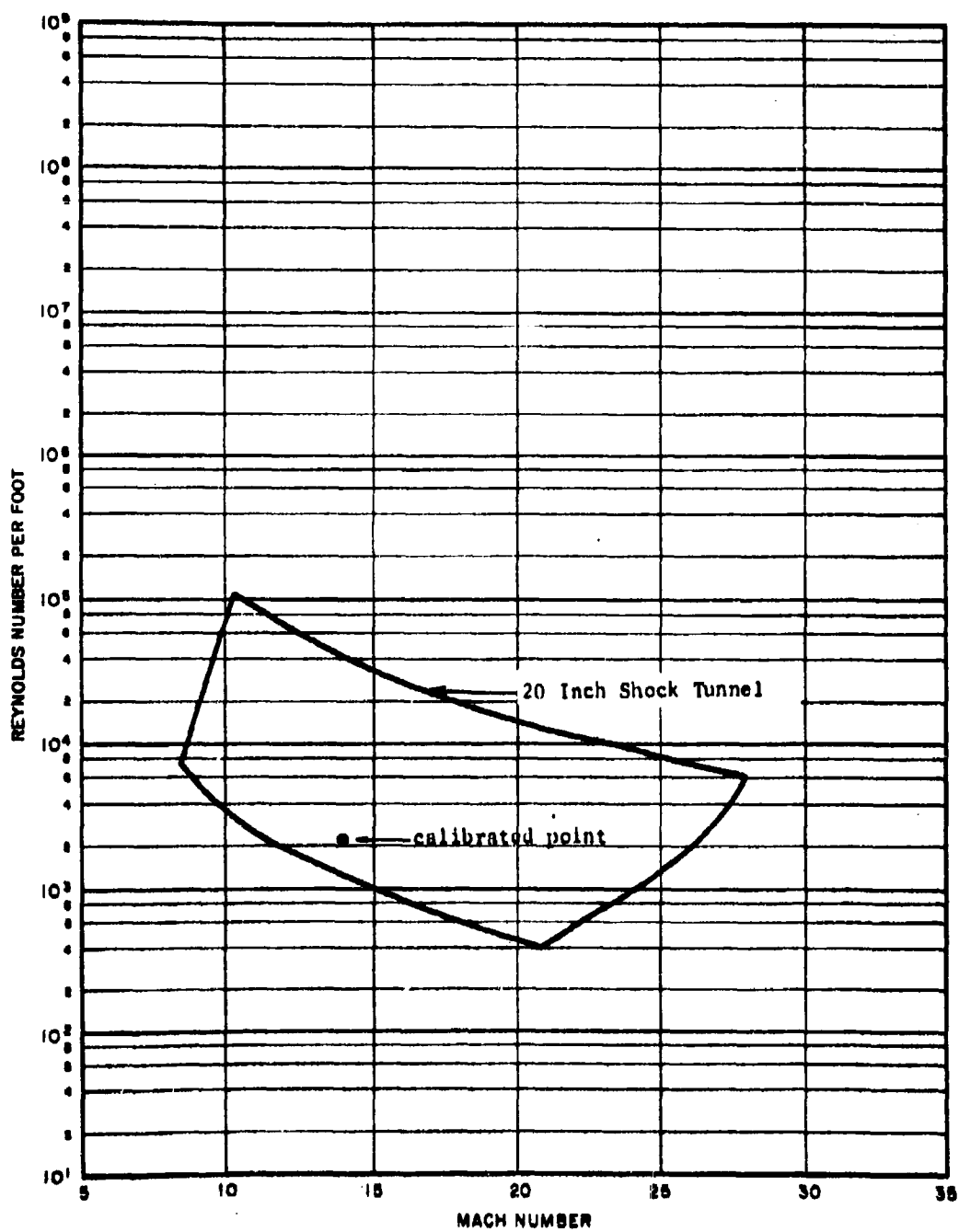
Running Time

The driver sphere technique of tunnel operation developed at AVCO-RAD is currently being used with running times of 4 milliseconds.

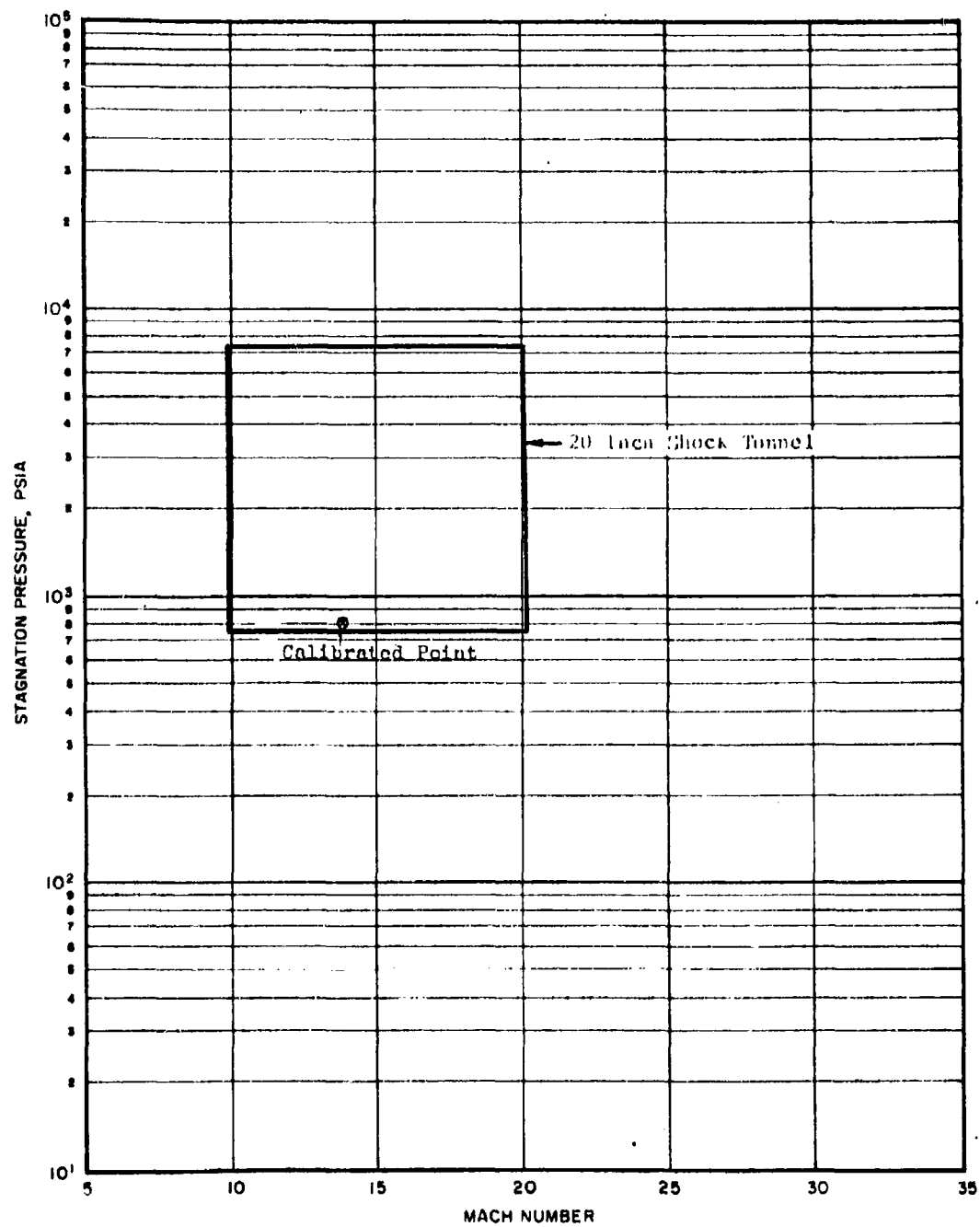
References

1. "Experimental Performance of the AVCO-RAD 20-Inch Shock Tunnel", by K. Heron, H. Weisblatt, and A. Clemente, AVCO-RAD TM-63-26.
2. "Experimental Technique for Tailored Operation of a Combustion Driven Shock Tunnel", by H. Weisblatt and R. F. Flagg, AVCO-RAD TM-61-17.
3. "Development of Very High Enthalpy Shock Tunnels with Extended Steady State Test Times", by B. D. Henshall, R. N. Teng, and A. P. Wood, AVCO-RAD TR-62-16.
4. Letter, H. Weisblatt to N. S. Foy, dated 21 December 1962, with enclosures.
5. Letter, H. Weisblatt to N. S. Foy, dated 2 May 1963, with enclosures.

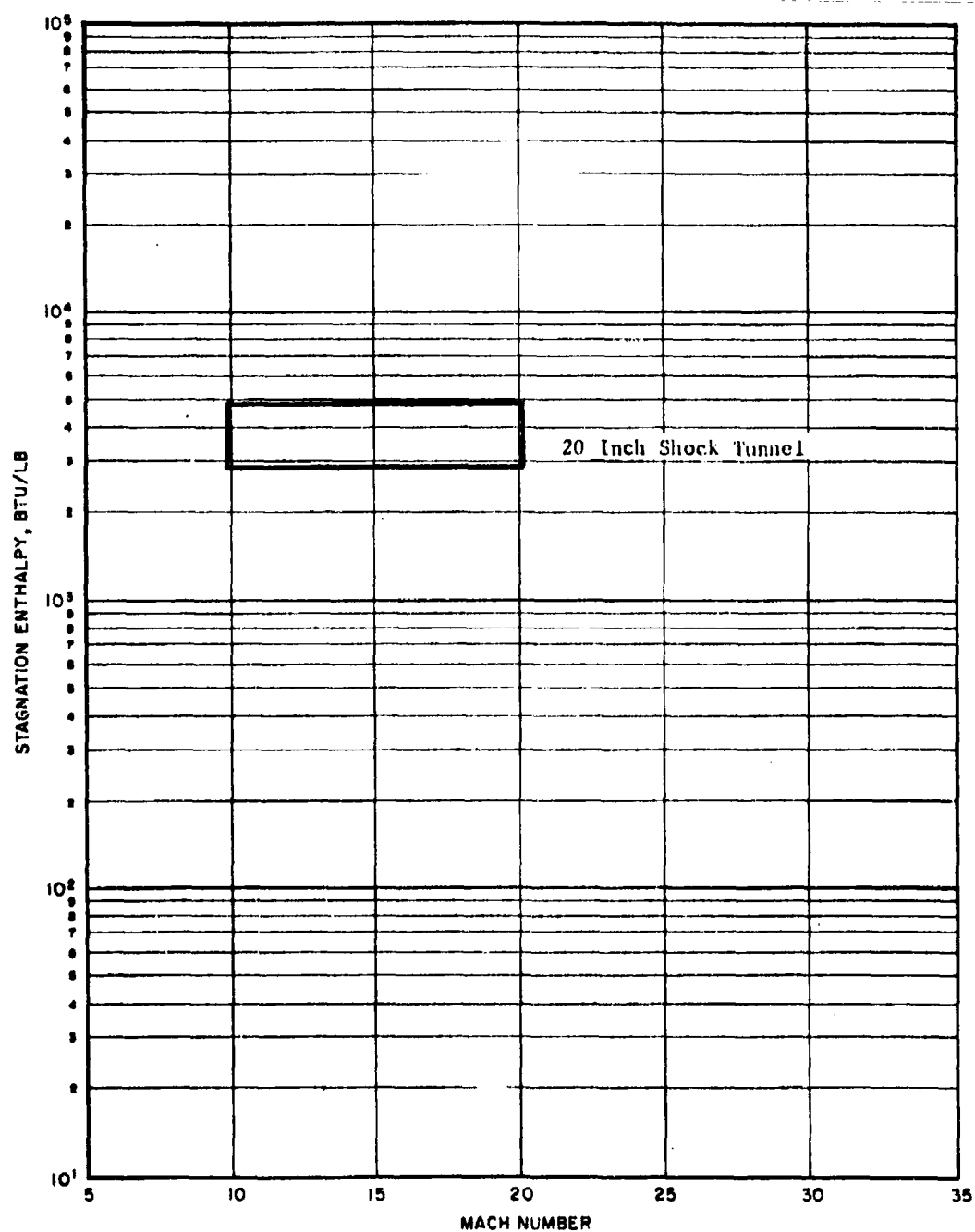
AVCO RAD



AVCO RAD



AVCO RAD



Name of Facility

Cornell Aeronautical Laboratory, Inc.
4455 Genessee Street
Buffalo 21, New York

Persons Responsible

Mr. K. D. Bird - Shock Tunnel Facilities
Mr. John P. Andes - Wave Superheater Hypersonic Tunnel

Type

The following facilities are available at Cornell:

- A) 48 Inch Hypersonic Shock Tunnel
- B) High-Energy Hypersonic Shock Tunnel
- C) Wave Superheater Hypersonic Tunnel, which is a long duration high temperature hypersonic tunnel.

Nozzle and Test Section

- A) Conical nozzles are used for most of the Mach number range in the 48 Inch Tunnel. Contoured M = 8 and M = 16 nozzles are also used with this facility.
- B) The same nozzles, along with a conical nozzle 8 ft in diameter will be used with the High Energy Hypersonic Shock Tunnel.
- C) The Wave Superheater utilizes a conical nozzle expanded to a Mach 6 test section, with a nozzle exit of 8 inches, and another conical nozzle expanded to Mach 15 test section with nozzle exit of 1.5 ft. A contoured nozzle for M = 12 is expected to be operational in January 1964, with 6 ft exit diameter and 15 sec running time. Other intermediate test sections are possible.

Instrumentation and Test Capabilities

- A) and B) Force, pressure, and heat transfer tests may be performed in these facilities. Data processing is accomplished on an IBM 704 computer within minutes after completion of a test.
- C) Force, pressure, and heat transfer tests may be performed in the Wave Superheater, as well as ablation and materials studies and structural tests. Due to the large test section, full scale or near full scale model testing is possible.

Running Times

- A) 48 Inch Hypersonic Shock Tunnel - 4 to 12 milliseconds
- B) High-Energy Hypersonic Shock Tunnel - 4 to 12 milliseconds.
- C) Wave Superheater Hypersonic Tunnel - Running time can be varied from 1 second to 15 seconds.

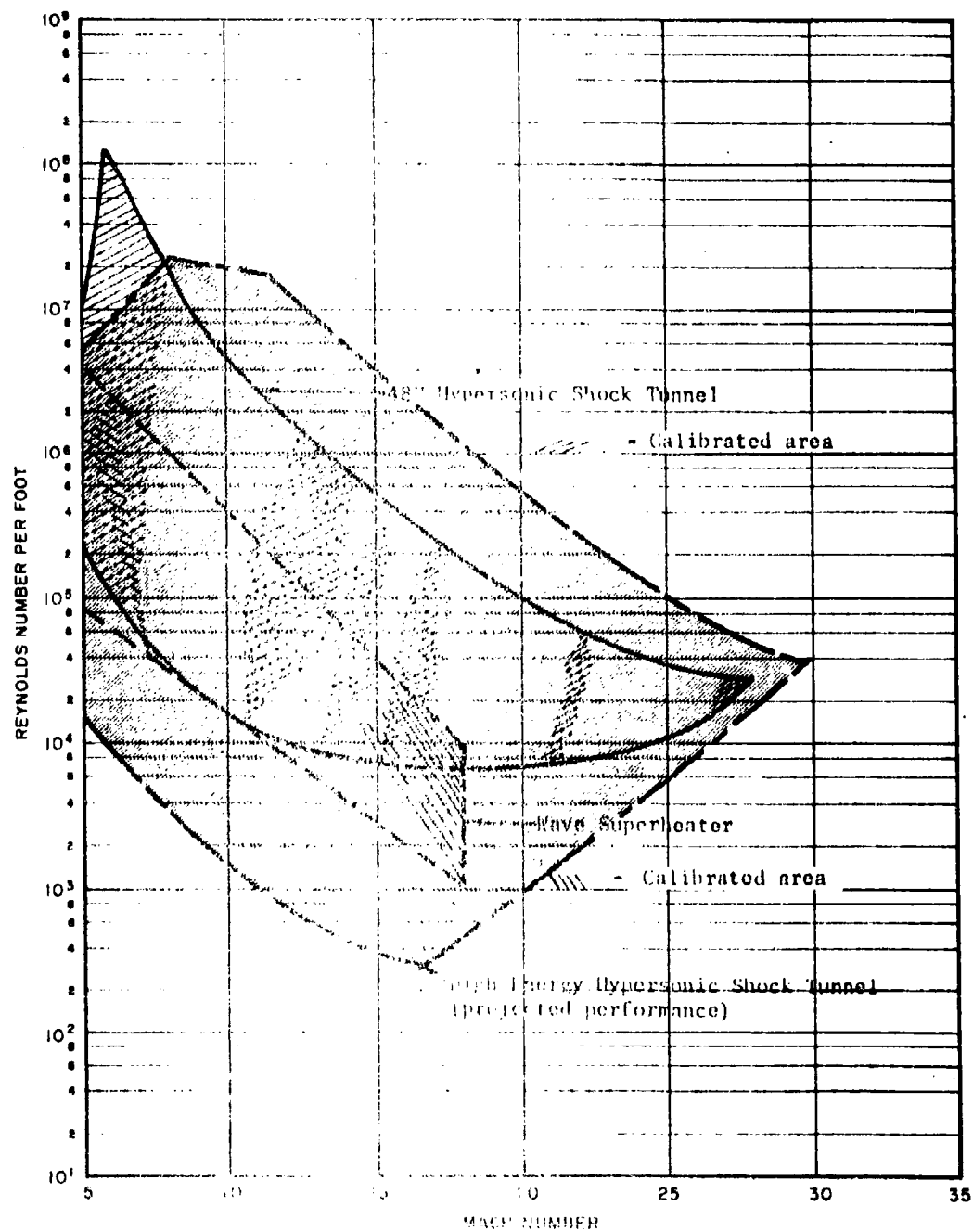
Remarks

- A) The 48 Inch Tunnel is fully operational and calibrated
- B) The High-Energy Hypersonic Shock Tunnel is expected to be operational in late 1963.
- C) Contracted tests have been conducted on ablation experiments in the Mach 6 test section of the Wave Superheater. The M = 15 test section is presently being calibrated and the M = 12 test section is under construction. Full capability of the Wave Superheater has not yet been attained; maximum output thus far has been 6500⁰R and 1000 atms.

References

1. "Cornell Aeronautical Laboratory 48 Inch Hypersonic Shock Tunnel, Description and Capabilities", revised December 1962.
2. "Cornell Aeronautical Laboratory Wave Superheater Hypersonic Tunnel, Description and Capabilities", October 1962.
3. Letter, K. D. Bird to N. S. Foy, dated 9 January 1963, with enclosures.
4. Letter, John P. Andes to N. S. Foy, dated 17 January 1963, with enclosures.
5. Letter, K. D. Bird to N. S. Foy, dated 30 April 1963, with enclosures.
6. Conference between J. Carpenter, CAL, and C. Pel, Aerospace, 16 August 1963.
7. Letter, K. D. Bird to C. Pel, dated 22 August 1963, with enclosures.

CONCEPT AERONAUTICAL LABORATORY



Name of Facility

NASA-Langley Research Center
Aero-Physics Division - Small Hypersonic Facilities
Langley Field, Virginia

Person Responsible

NASA Director, NASA-Langley Research Center

Type

Following are the smaller hypersonic facilities in the Aero-Physics Division at NASA-Langley. They are all of the intermittent blowdown type.

- A) 11 Inch Hypersonic Tunnel
- B) 20 Inch Mach 6 Tunnel
- C) 22 Inch Mach 8.5 Tunnel
- D) 22 Inch Helium Tunnel
- E) Mach 8 Variable Density Hypersonic Tunnel
- F) Mach 6 Low Density Hypersonic Tunnel
- G) Shock Tunnel
- H) Hotshot Tunnel
- I) Mach 17 Nitrogen Facility

Nozzle and Test Section

- A) The 11 Inch Hypersonic Tunnel has four interchangeable nozzles, two for air ($M = 6.8$ and 9.6) and two for helium ($M = 10.5$ and 18). The 6.8 nozzle is two-dimensional, the 9.6 nozzle is contoured three-dimensional with a square throat and test section, and the helium nozzles are contoured axisymmetric. Test section size ranges from 10.5 inches square or round at the center of the test section to 11.0 inches square or round at the end of the nozzle.
- B) The 20 Inch Mach 6 Tunnel has a 20 by 20.5 inch test section, with fixed nozzle.
- C) The 22 Inch Mach 8.5 Tunnel has a circular test section, 22 inches in diameter.

- D) The 22 Inch Helium Tunnel has a circular test section, 22 inches in diameter, and utilizes conical and contoured nozzles. The conical nozzle has interchangeable throats, which give a Mach number range of approximately 15 to 28. The contoured nozzles are designed for $M = 18, 22,$ and 26 . Useable test core is about 14 inches for the conical nozzle (at all Mach numbers) and about 10 inches for the contoured nozzle at $M = 21$.
- E) The Mach 8 Variable Density Hypersonic Tunnel has a circular test section, 18 inches in diameter.
- F) The test section for the Mach 6 Low Density Hypersonic Tunnel is 12 inches by 14 inches.
- G) The Shock Tunnel has a $12\text{-}1/2$ degree half-angle conical nozzle expanding to a 3-foot diameter test section.
- H) The Langley Hotshot Tunnel ($M = 16\text{-}24$) has a 10 degree conical nozzle expanding to a 24-inch test section.
- I) The Mach 17 Nitrogen Facility has an axisymmetric contoured nozzle with an 18-inch test section.

Instrumentation and Test Capabilities

- A) The 11 Inch Hypersonic Tunnel is not connected with an automatic data reduction system. No injection mechanism is available for heat transfer tests, but rather the "quick start" technique is used for such tests. This facility is equipped to do pressure and temperature investigations and force testing.
- B) The 20 Inch Mach 6 Tunnel is presently equipped to obtain 6 component static force and moment data, pressure distributions, and heat transfer data. The data can be recorded on a Beckman 210 digital data recording system.
- C) The 22 Inch Mach 8.5 Tunnel is presently equipped to obtain 6 component static force and moment data and pressure distributions. The data can be recorded on the Beckman 210 digital data recording system.
- D) The 22 Inch Helium Tunnel is presently equipped to obtain 6 component static force and moment data, pressure distribution (up to 40 pressure leads per test) and heat transfer data (up to 72 thermocouples per test). The data can be recorded on either of two types of instruments: 30 channels are available on oscillographs, and up to 99 channels on a Beckman 210 digital data recording system. For visual observation of the flow, a conventional single pass Schlieren system is available.

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Running Times

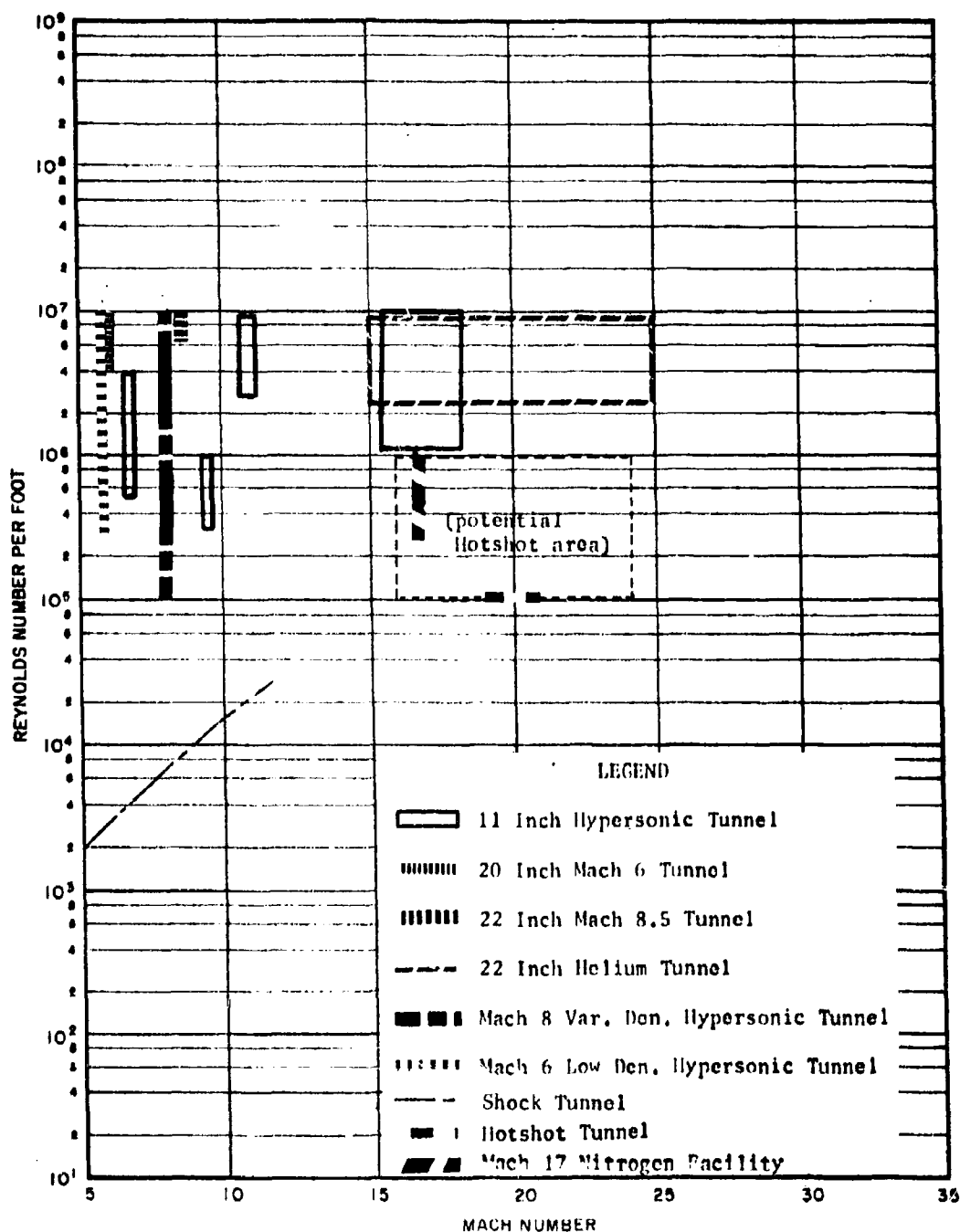
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- G) Shock Tunnel - about 1 millisecond
- H) Langley Hotshot Tunnel - 20 to 80 milliseconds
- I) Mach 17 Nitrogen Facility - up to 15 minutes

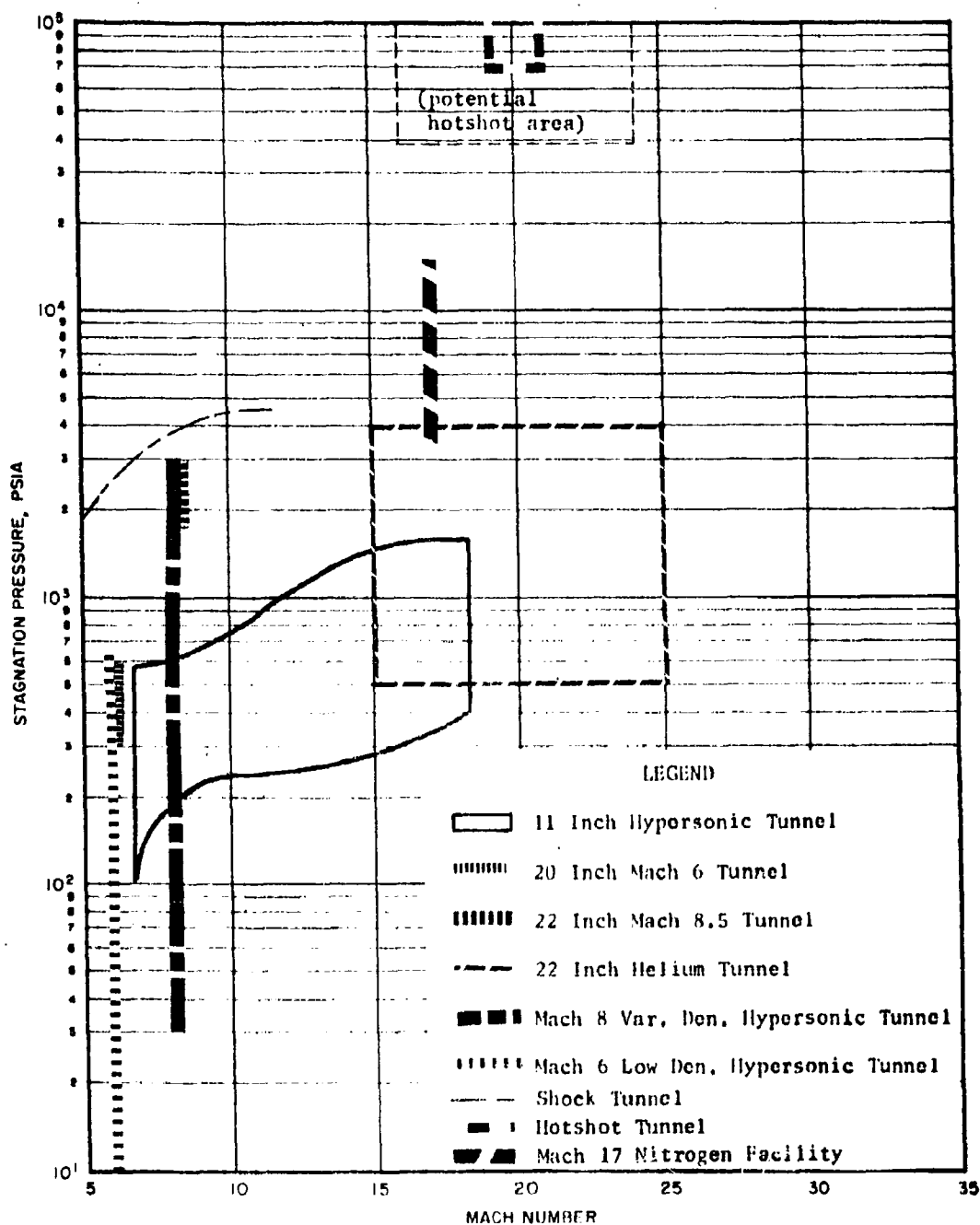
References

1. Letter, Floyd L. Thompson to F. A. Vicente, 13 September 1962.
2. "National Wind Tunnel Summary", NASA Report, July 1961.
3. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, dated April 1960.
4. Letter, Floyd L. Thompson to N. S. Foy, dated 23 January 1963, with enclosures.
5. Letter, Floyd L. Thompson to N. S. Foy, dated 12 June 1963, with enclosures.

NASA LANGLEY RESEARCH CENTER
Aero-Physics Division - Small Hypersonic Facilities

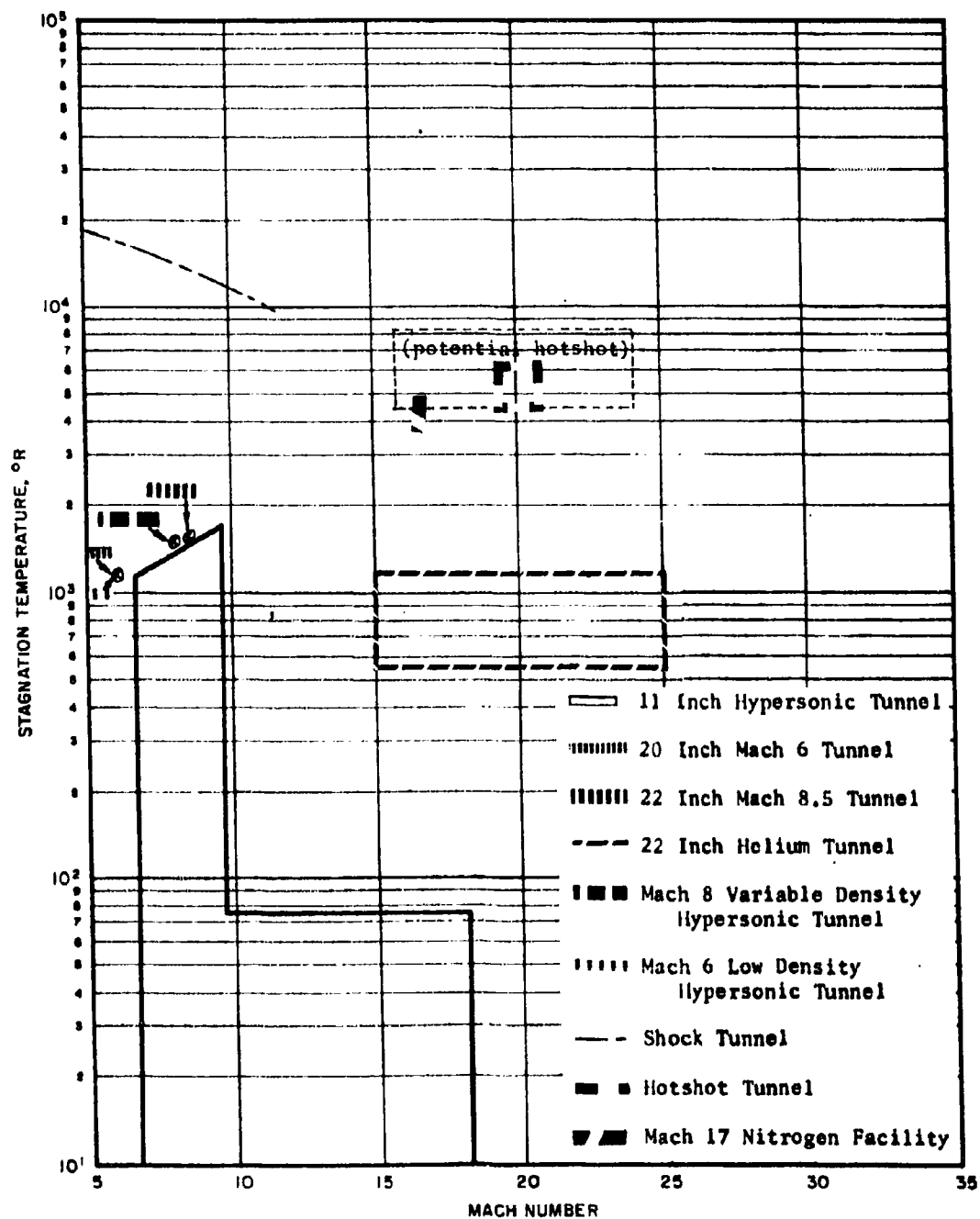


NASA LANGLEY RESEARCH CENTER
Aero-Physics Division - Small Hypersonic Facilities



NASA LANGLEY RESEARCH CENTER

Aero-Physics Division - Small Hypersonic Facilities



Name of Facility

NASA Langley Research Center
Other Divisions - Small Hypersonic Facilities
Langley Field, Virginia

Person Responsible

NASA Director, NASA Langley Research Center

Type

The following small hypersonic facilities are operated by divisions other than the Aero-Physics Division at NASA Langley. The 2 by 2 Foot Low Density Hypersonic Tunnel is of the continuous type. All the other facilities listed are of the intermittent blowdown type.

- A) 12 Inch Hypersonic Ceramic Heated Tunnel
(Applied Materials and Physics Division)
- B) Hypersonic Aeroelasticity Tunnel (Helium)
(Dynamic Loads Division)
- C) 15 Inch Hypersonic Flow Apparatus
(Full-Scale Research Division)
- D) 2 by 2 Foot Low Density Hypersonic Tunnel
(Full-Scale Research Division)

Nozzle and Test Section

- A) The 12 Inch Hypersonic Ceramic Heated Tunnel has a 12 inch diameter test section, enclosed free jet with downstream diffuser. It has a Mach number capability of 13.
- B) The Hypersonic Aeroelasticity Tunnel has an 8 inch diameter test section at $M = 7$. At $M = 15$ the test section is 24 inches in diameter.
- C) The 15 Inch Hypersonic Flow Apparatus has a 15 inch diameter axisymmetric test section, and a Mach number capability of 10.4.
- D) The 2 by 2 Foot Low Density Hypersonic Tunnel has a 24 by 24 by 54 inch test section, with a Mach number range of 3 to 7.

Instrumentation and Test Capabilities

These facilities are used for research, development and evaluation. No information is available on their specific instrumentation and test capabilities at this time.

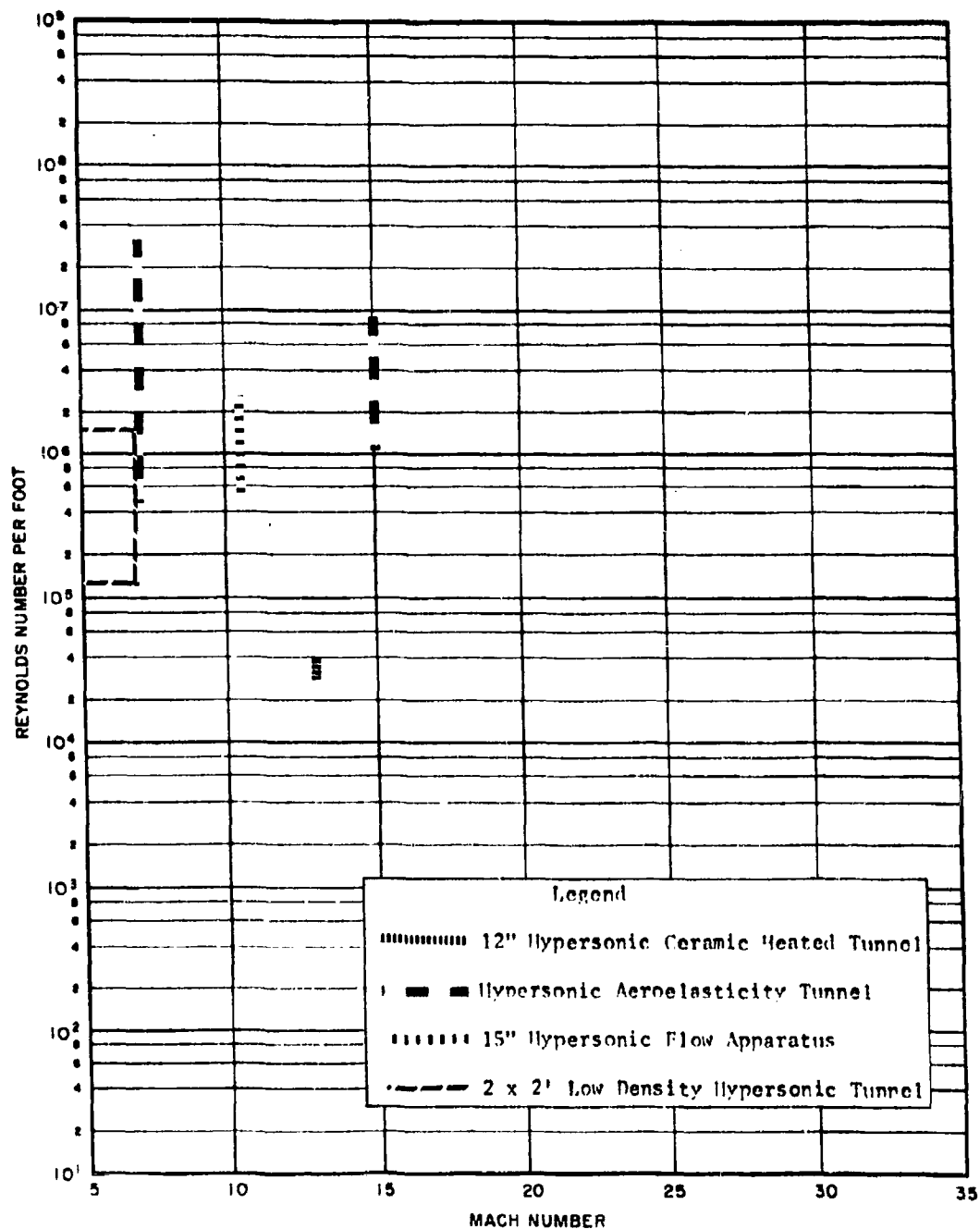
Running Times

- A) 12 Inch Hypersonic Ceramic Heated Tunnel - 30 seconds.
- B) Hypersonic Aeroelasticity Tunnel - 20 seconds.
- C) 15 Inch Hypersonic Flow Apparatus - 10 minutes.
- D) 2 x 2 Foot Low Density Hypersonic Tunnel - continuous.

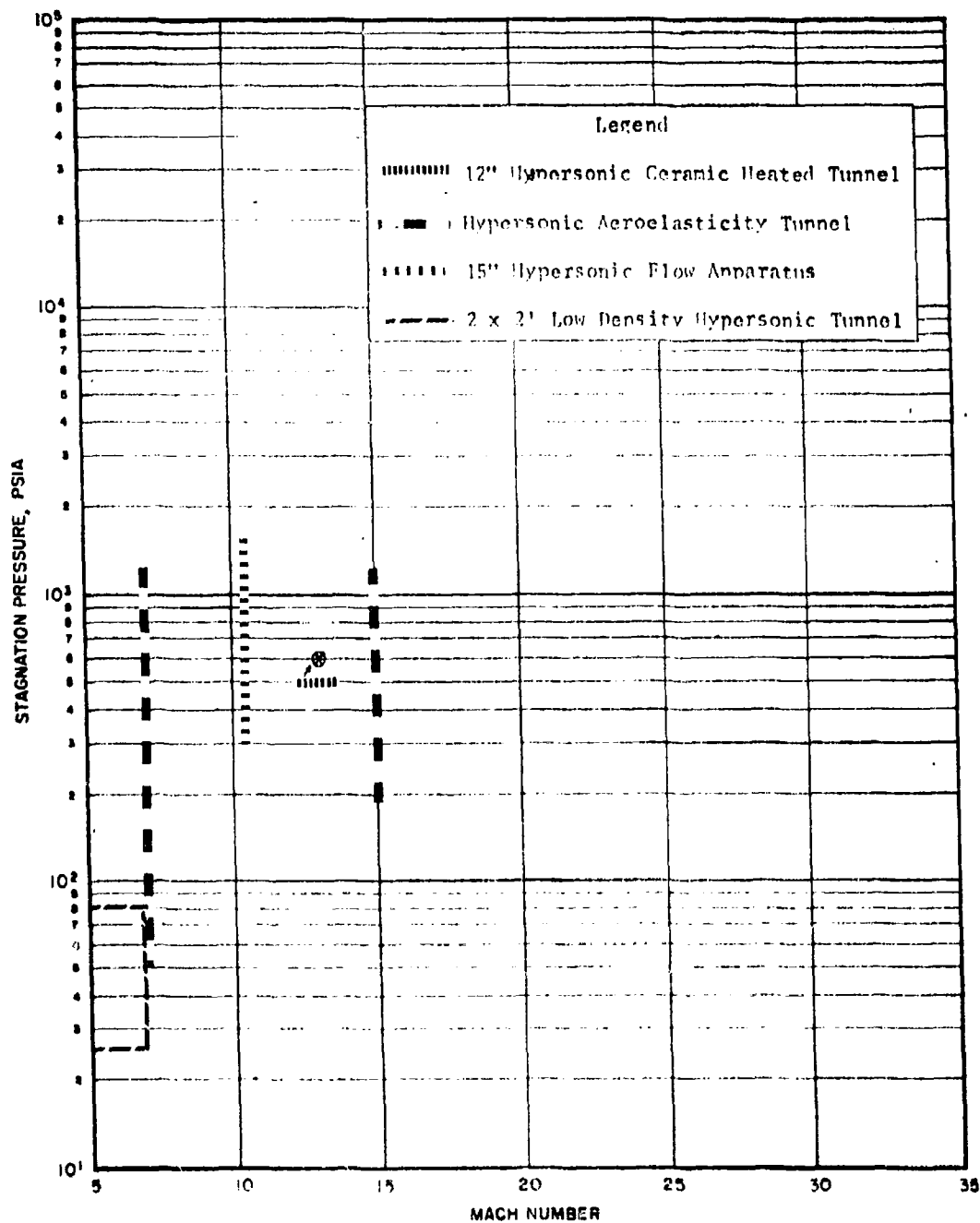
References

1. "National Wind Tunnel Summary", NASA Report, July 1961.
2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, April 1960.
3. Letter, Floyd L. Thompson to N. S. Foy, dated 23 January 1963, with enclosures.

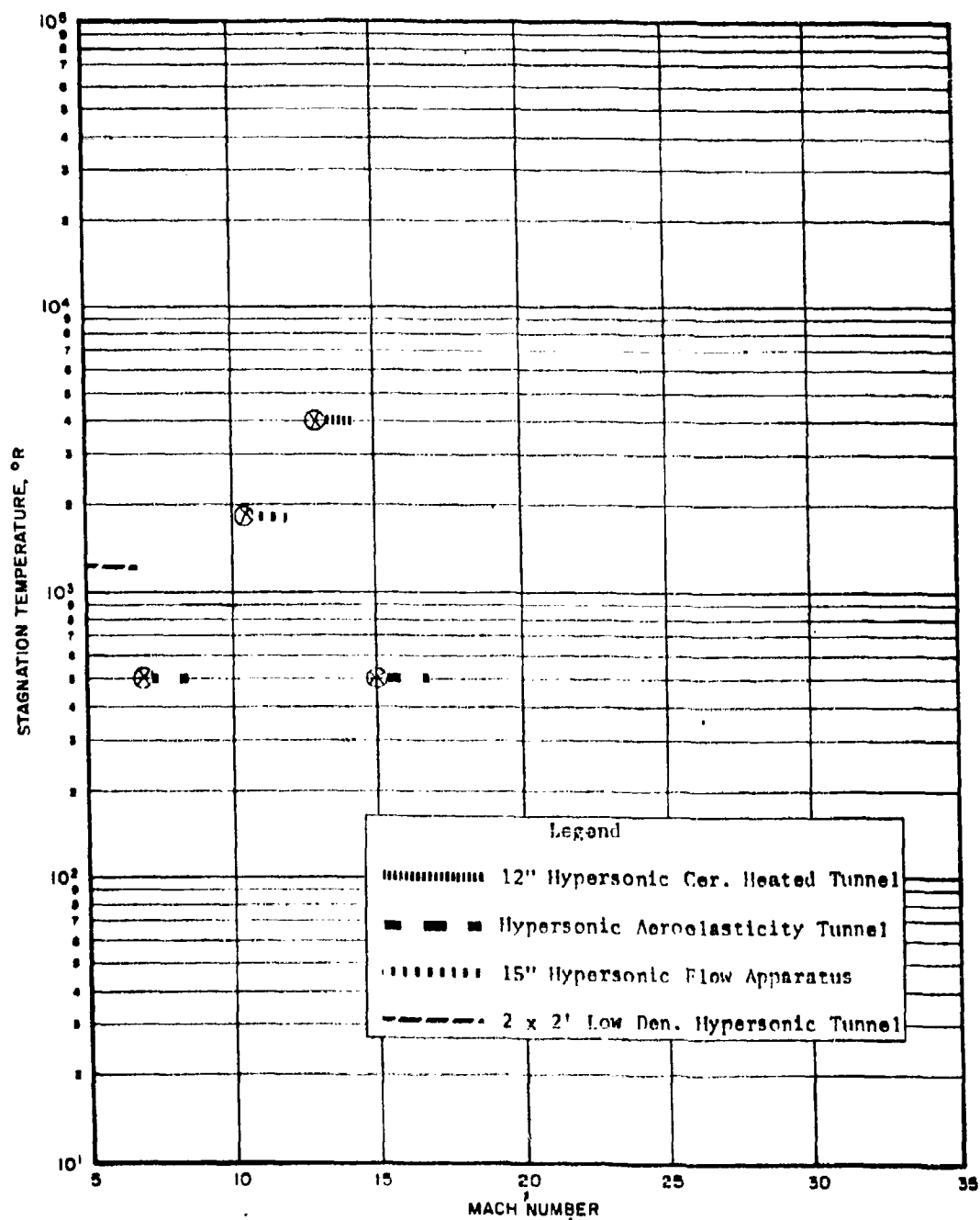
NASA LANGLEY RESEARCH CENTER
Other Divisions - Small Hypersonic Facilities



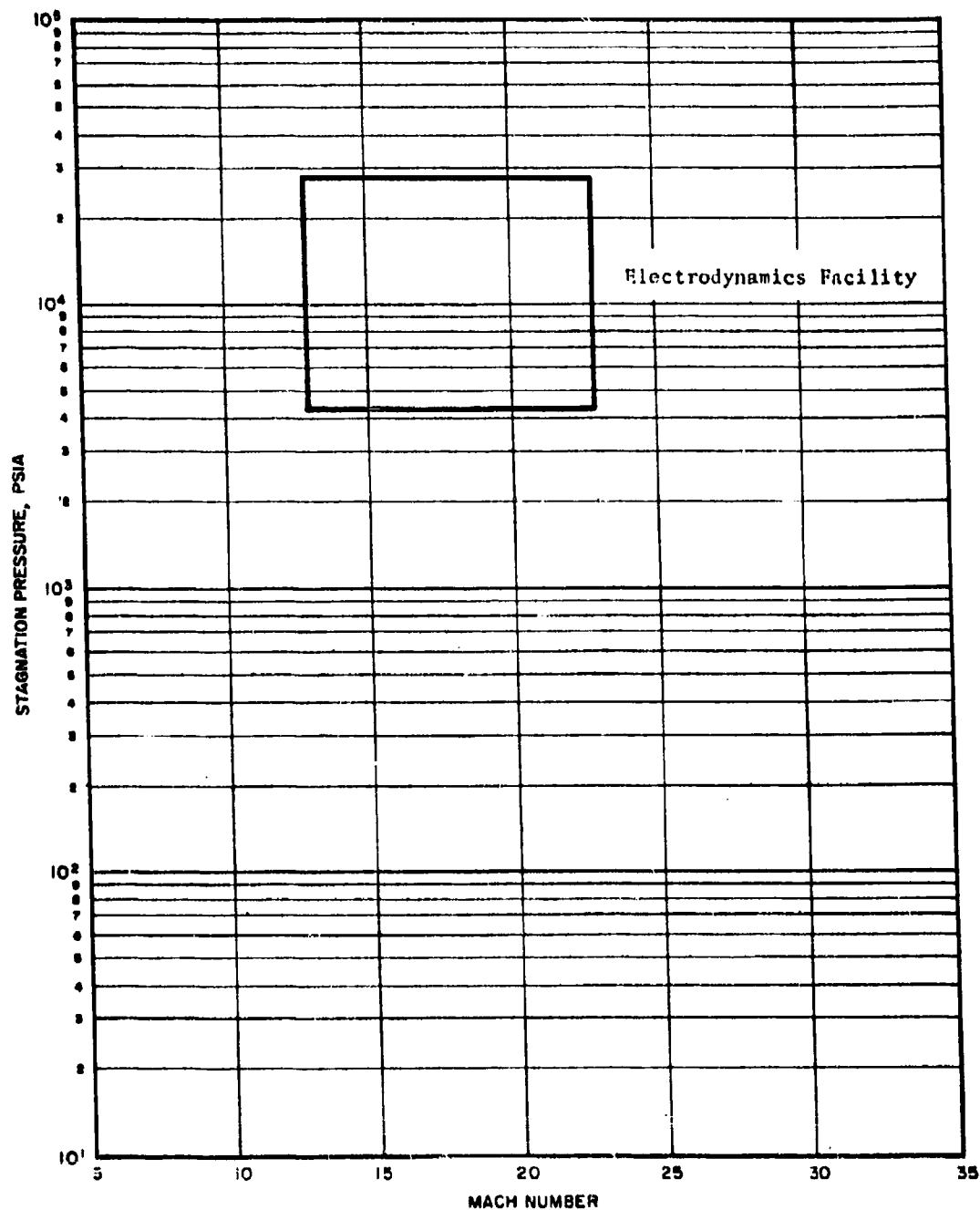
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Other Divisions - Small Hypersonic Facilities



NORTH AMERICAN AVIATION, INC.
Space & Information Systems Division



Name of Facility

Rhodes and Bloxsom
7343 Deering Avenue
Canoga Park, California

Persons Responsible

D. Bloxsom, Jr.
B. V. Rhodes

Type

- A) The 60 Inch Hypervelocity Tunnel is an arc driven hotshot, utilizing a 100,000 joule capacitor. It was built in 1959.
- B) The 16 Inch Wind Tunnel is a blowdown type facility with an 1800°F air heater. It was built in early 1963. Stagnation pressures of 1500 psia blow down through the heater and nozzle into a dump tank through a diffuser. Back pressures initially available to the flow are 1 micron Hg.

Nozzle and Test Section

- A) Four nozzles are available for the 60 Inch Hypervelocity Tunnel. These are:
 - 1. 9° total angle conical nozzle with 12-inch diameter free jet. This jet has an isentropic core of approximately 9 inches diameter. Models may be tested with 9-inch diameter frontal face without tunnel blockage. Model lengths up to four feet have been tested successfully.
 - 2. 16° total angle, conical nozzle with 21-inch diameter free jet. This jet has an isentropic core of approximately 14.5 inches diameter. Models may be tested with 14.4-inch diameter frontal face without tunnel blockage. Model lengths up to three feet have been tested successfully.
 - 3. Contoured nozzle with 34-inch diameter free jet. This jet has an isentropic core approximately 28 inches in diameter. Models may be tested with 28-inch diameter frontal face without tunnel blockage. Model lengths may be up to four feet.
 - 4. 45° total angle conical nozzle with 60-inch free jet. This jet has an isentropic core of approximately 48 inches. Models may be tested with 28 inches frontal face without tunnel blockage, although model length is usually limited to one foot.

A) 60 Inch Hypervelocity Tunnel (continued)

Two types of driver are available for the 60 Inch Hypervelocity Tunnel. These are:

1. Exponential decay steady flow driver, which permits pressures of 20,000 psi and temperatures of 80,000°R. Testing times vary from .1 to 10 milliseconds.
2. Square wave unsteady flow driver, which is similar to a shock tube driver and permits pressures of 20,000 psi and temperatures of 80,000°R. Testing times vary from .05 to 2 milliseconds, depending upon supply temperature.

B) Three nozzles are available for the 16 Inch Wind Tunnel:

1. 30° total included angle conical nozzle with 4-inch diameter free jet. This jet will accommodate models up to 3 inches diameter and 6 inches long.
2. 30° total included angle conical nozzle with 16-inch diameter free jet. This nozzle will accommodate models of similar size to (1).
3. Contoured nozzle with 10-inch diameter free jet. This jet will accommodate models up to 3 inches diameter and 12 inches long.

Instrumentation and Test Capabilities

- A) Simultaneous measurements have been made in the 60 Inch Hypervelocity Tunnel of pressure, temperature, and density in stagnation chambers and behind normal shocks in the test sections. Pressure distributions are measured by inertial pressure transducers to 2 percent precision, characteristic length .1 inch. Due to the matching of flight specific enthalpy, radiation and ionization studies have been made. Velocity measurements have been made in the nozzle and around various models by seeding the flow with small particles. Flow visualization is made by shadowgraph, Schlieren, and self-luminosity. Ballistic mounting of models has permitted lift, drag, and moment coefficients to be measured to 1 percent precision in gas dynamic to free molecule flow. Heat transfer is measured by short time resistance heating elements (15 percent) and heat sensitive paint (5 percent, lengths of .001 inch).
- B) Spring balance is available in the 16 Inch Wind Tunnel for lift, drag, and stability testing on aerodynamic models and ramjet type engines. Pressure distributions are measured by means of special transducers. Shadowgraph and Schlieren flow visualization

B) 16 Inch Wind Tunnel (continued)

techniques are available. Heat transfer is measured by a special surface which changes various colors, permitting the heat transfer rates to be determined to 5 percent precision over every .001 inch of surface.

Running Times

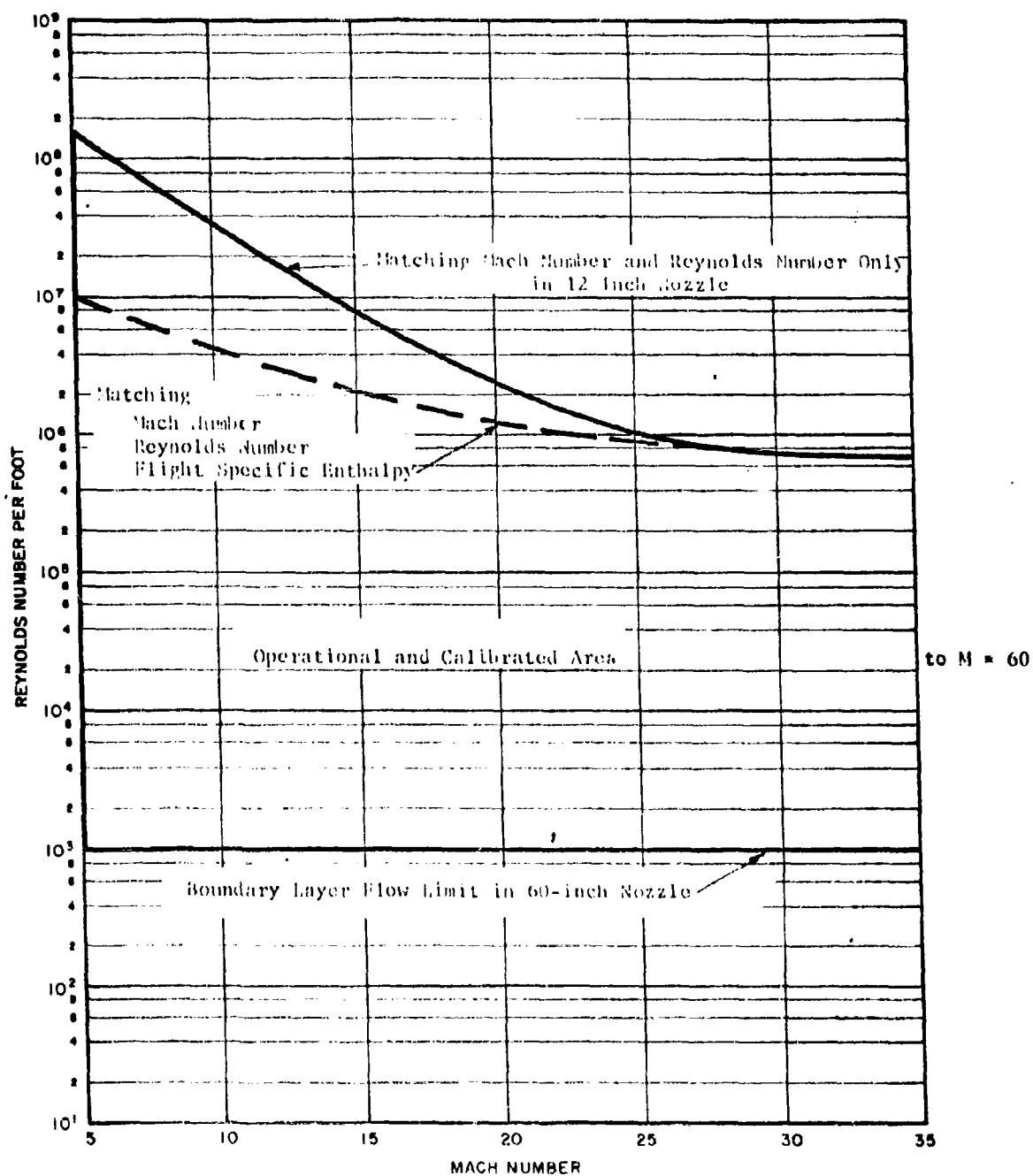
- A) Running times for the 60 Inch Hypervelocity Tunnel are described under "Nozzle and Test Section".
- B) Running times in the 16 Inch Wind Tunnel vary from .5 second at high pressure to 1 minute at low pressures.

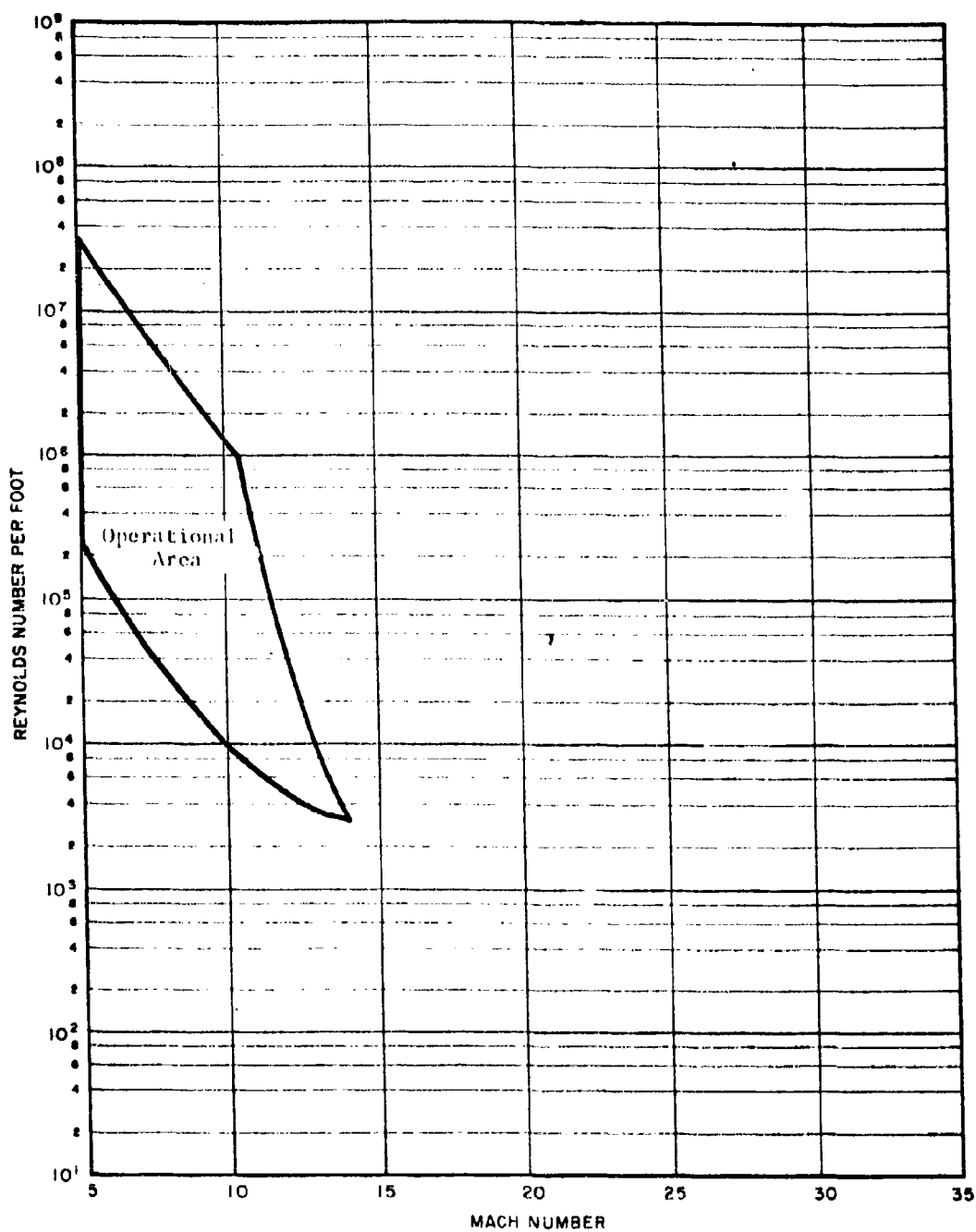
Remarks

- A) The test gas used in the 60 Inch Hypervelocity Tunnel is air. Above 8000°R the air is increasingly dissociated and ionized. This amount of dissociation and ionization is present in the test section as the flows are out of equilibrium. The flow, however, returns to equilibrium behind strong shock waves in the test section at high Reynolds numbers. The particle contamination due to the erosion of electrodes, tunnel ducts, and diaphragms is less than 2 parts per million of the air test gas mass at 8000°R. The wind tunnel can also be used to accelerate microparticles to 70,000 ft/sec to study shock wave structure at initial air pressures of 20 microns Hg (60 inch shock tube) and 20,000 microns (.5 inch shock tube). Tunnel opening and closing processes have very small effects on forces and heating.
- B) Since the heater elements in the 16 Inch Wind Tunnel are stainless steel, the particle impurity level is extremely low.

References

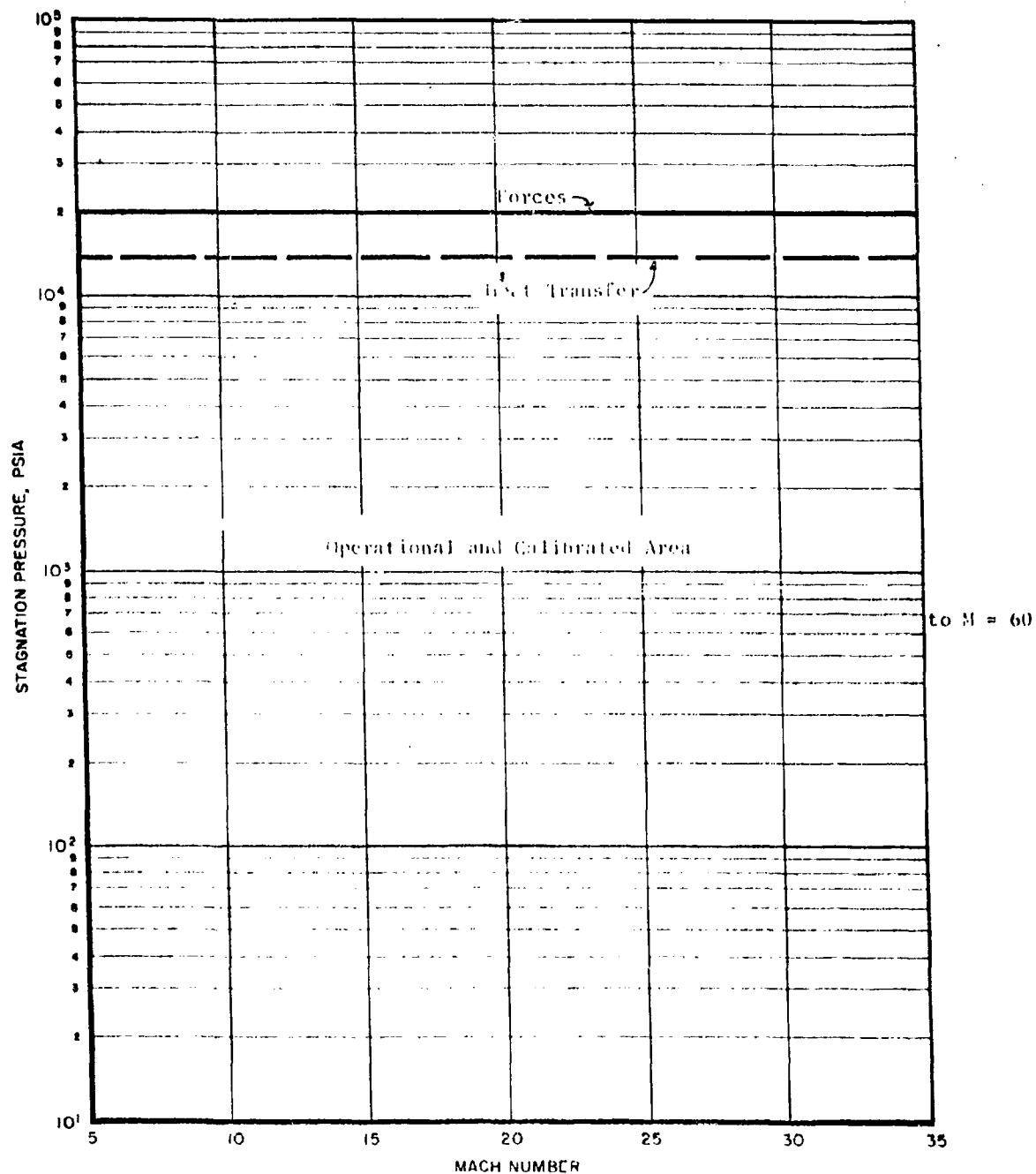
1. Letter, D. E. Bloxsom to N. S. Foy, dated April 25, 1963, with enclosures.
2. Calibration Brochure, Rhodes and Bloxsom, 1963.
3. "Experimental Effect of Bluntness and Gas Rarefaction on Drag Coefficients and Stagnation Heat Transfer on Axisymmetric Shapes in Hypersonic Flow", by B. V. Rhodes and D. E. Bloxsom, Journal of the Aerospace Sciences, Vol. 29, No. 12, December 1962.

RHODES AND BLOXSON
60 Inch Hotshot

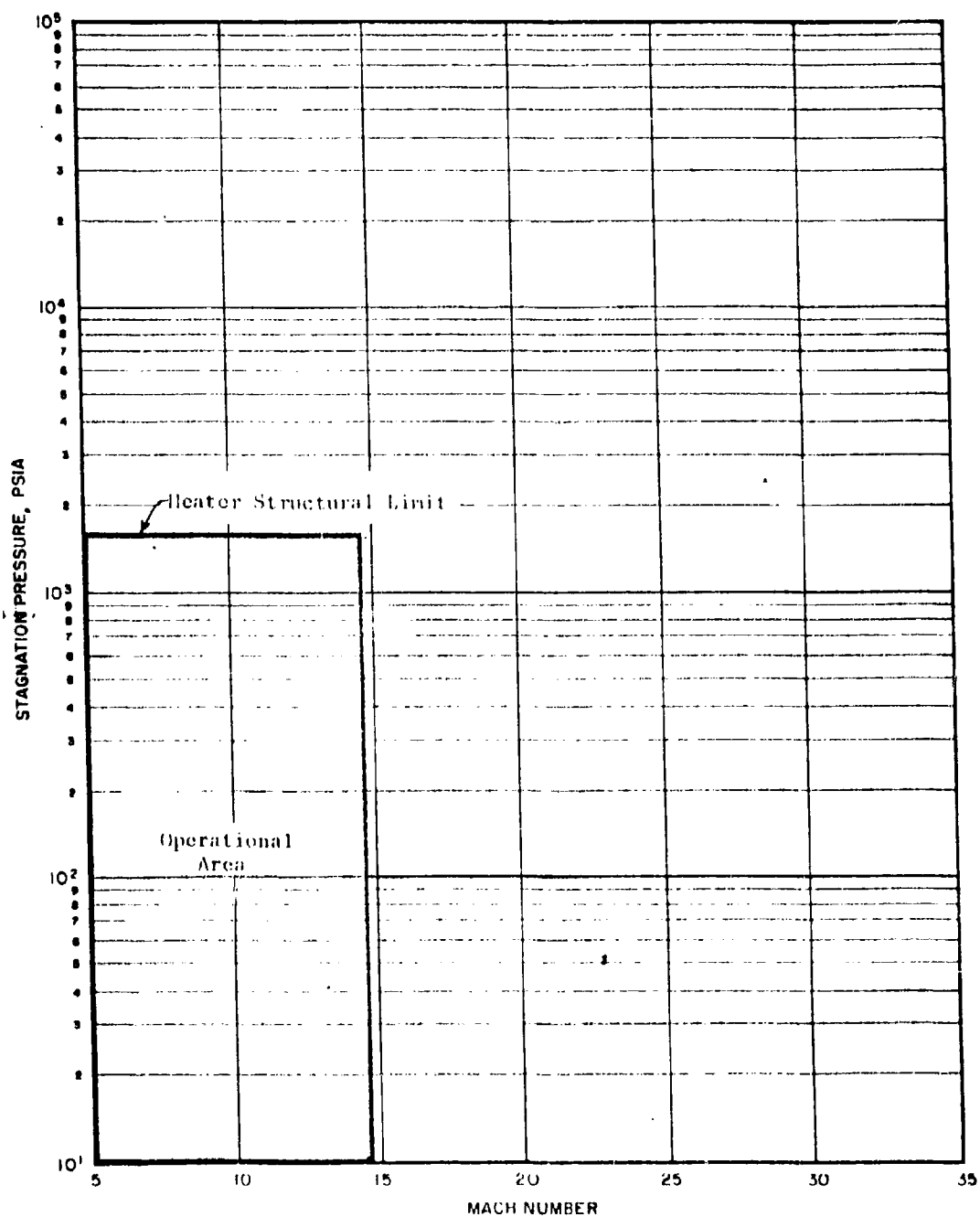
RHODES AND BLOXSON
16 Inch Wind Tunnel

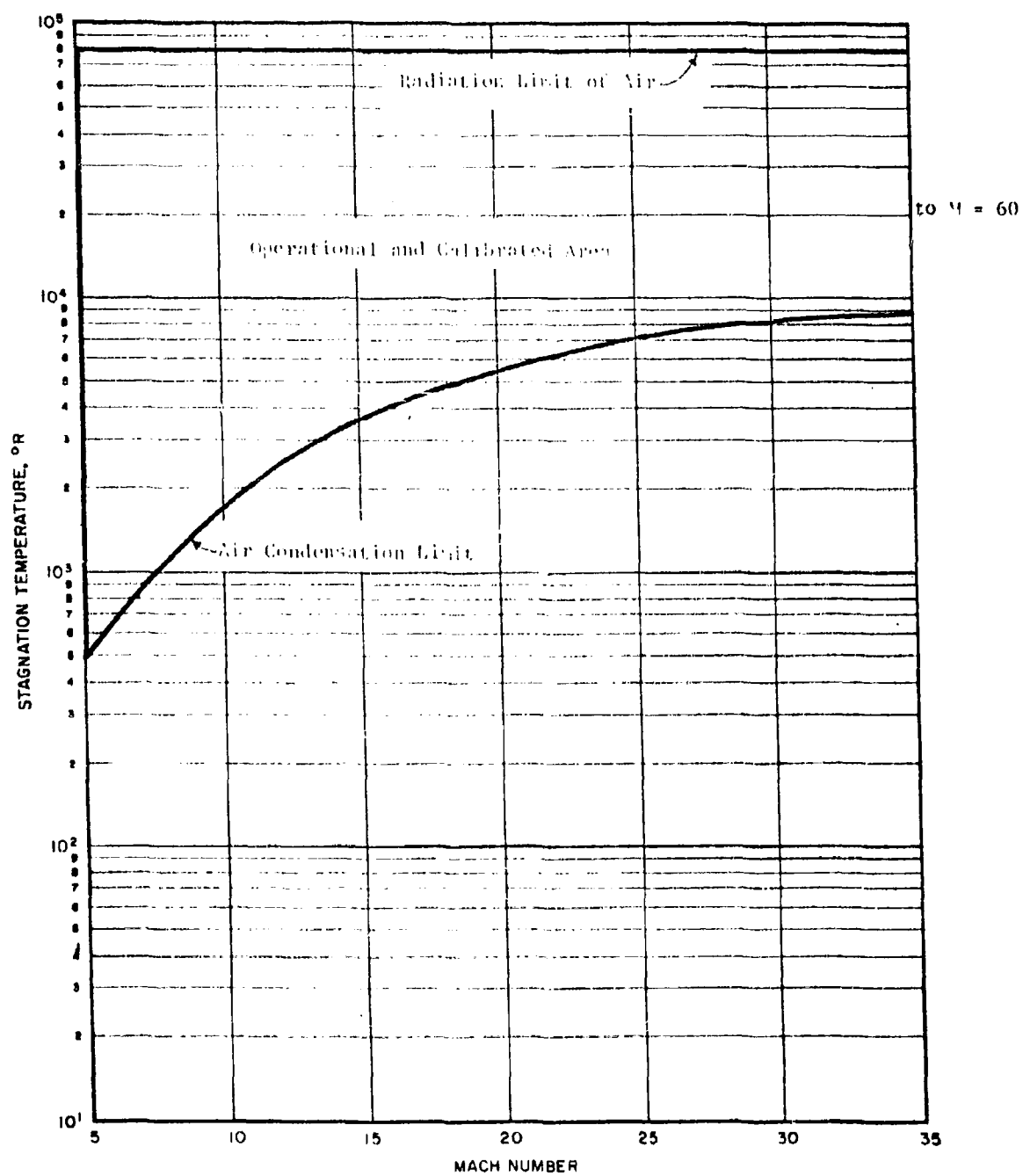
RHODES AND BLOXSON

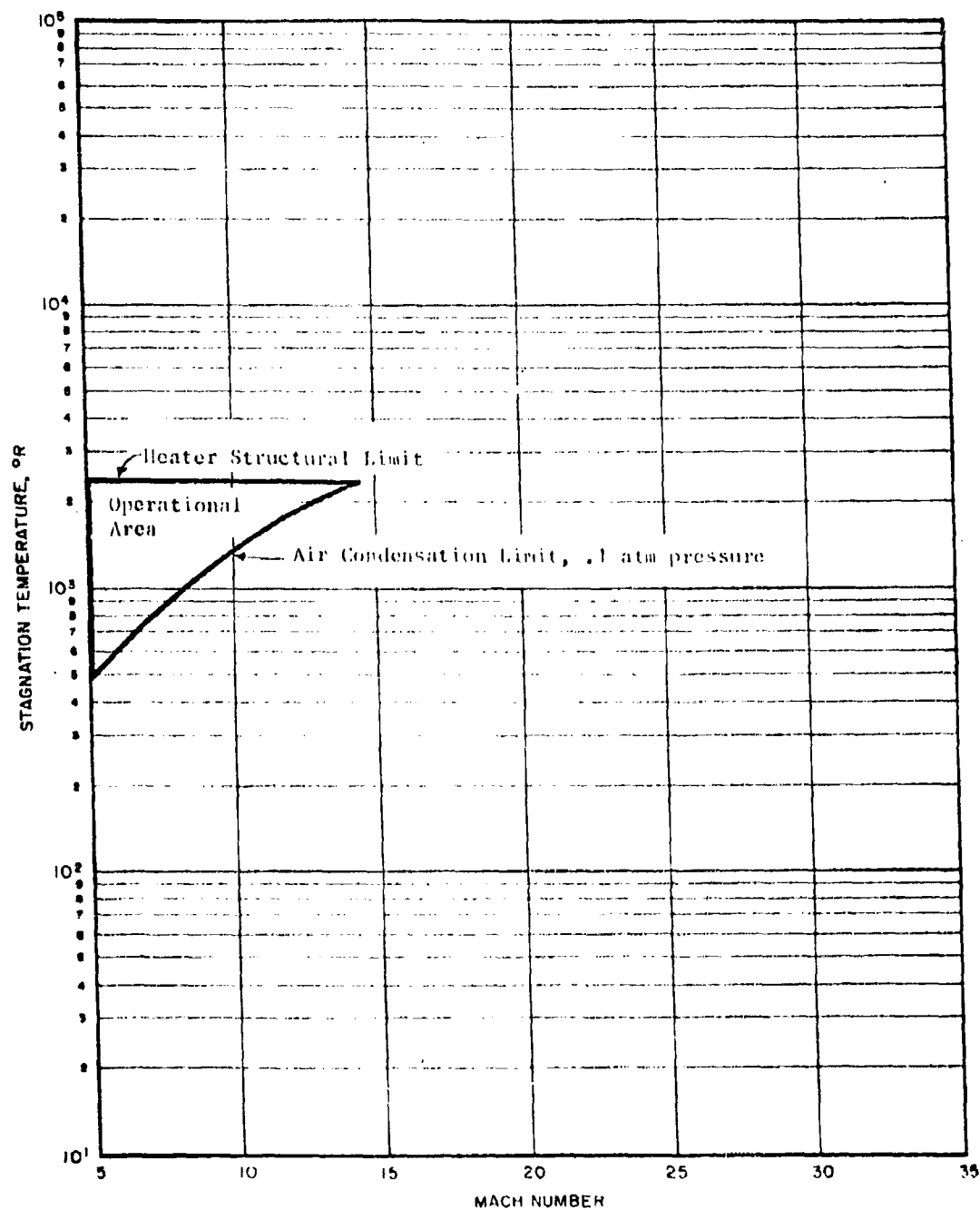
60 Inch Hotshot



RHODES AND BLOSSOM
16 Inch Wind Tunnel



RHODES AND BLOXSON
60 Inch Hotshot

RHODES AND BLONSON
16 Inch Wind Tunnel

Name of Facility

Shock Tunnel Facilities
U. S. Naval Ordnance Laboratory
Silver Spring, Maryland

Person Responsible

Dr. V. C. Dawson, Chief, Gas Dynamics Division

Type

Three hypersonic shock tunnels are in operation at U. S. N. O. L. These are:

- A) 1.5 Inch Hypersonic Shock Tunnel No. 1, which is of the free-jet type.
- B) 1.5 Inch Hypersonic Shock Tunnel No. 2, which is of the cone-nozzle type.
- C) 4 Inch Hypersonic Shock Tunnel No. 3, which is of the free-jet type.

Nozzle and Test Section

- A) Hypersonic Shock Tunnel No. 1 expands from a 1.5 inch diameter barrel into a 6-foot diameter tank. It can accommodate a 3-inch diameter model at $M = 8$, and an 8-inch diameter model at $M = 12$. The Mach number range is from 4.7 to 16.
- B) Hypersonic Shock Tunnel No. 2 expands from .25 inch diameter to 29 inches diameter, using a conical nozzle, emptying into a 6-foot diameter dump tank. It can accommodate an 8-inch diameter model at $M = 12$. Total Mach number range is from 4 to 16.
- C) Hypersonic Shock Tunnel No. 3 expands from a 4-inch diameter barrel into an 8-foot diameter tank. It can accommodate a 7-inch diameter model at $M = 8$, and a 20-inch diameter model at $M = 14$. Total Mach number range is from 5.6 to 16.

Instrumentation and Test Capabilities

- A) Hypersonic Shock Tunnel No. 1 is used to measure pressure and temperature distributions.
- B) Hypersonic Shock Tunnel No. 2 is used to study gas flow characteristics, shock wave attenuation, real gas effects, driver gas mixture efficiencies and nozzle designs.

- C) Hypersonic Shock Tunnel No. 3 is used to measure pressure and temperature distributions, flow characteristics, and real gas effects.

Running Time

- A) Hypersonic Shock Tunnel No. 1 - 400 to 1200 microseconds.
- B) Hypersonic Shock Tunnel No. 2 - 2 milliseconds.
- C) Hypersonic Shock Tunnel No. 3 - 2 to 3 milliseconds.

References

1. "Capabilities of the Naval Ordnance Laboratory Aeroballistic Facilities", brochure.
2. Letter, K. R. Enkenhus to F. A. Vicente, 29 August 1962.
3. Letter, K. R. Enkenhus to N. S. Foy, 10 July 1963.

Name of Facility

Wind Tunnel Facilities
Aerodynamics Department
U. S. Naval Ordnance Laboratory
Silver Spring, Maryland

Persons Responsible

Mr. S. M. Hastings, Chief, Applied Aerodynamics Division
(Hypersonic Tunnel No. 8)

Dr. E. L. Harris, Chief, Aerophysics Division
(Hypersonic Tunnel No. 4)

Type

- A) Hypersonic Tunnel No. 8 is an open jet semi-continuous tunnel, operating in the Mach number range from 5 to 10. This tunnel has a 150 atm. bottled air storage supply and a 1500°F pebble bed heater. The tunnel is used primarily for developmental testing.
- B) Hypersonic Tunnel No. 4 is a closed jet semi-continuous wind tunnel currently operating at $M = 16$ with nitrogen. A supply temperature of 4000°R is generated by a graphite electric heater at supply pressures up to 100 atm. The tunnel may also be operated with air at Mach numbers from 6.8 to 10 and supply pressures up to 50 atm.

Nozzle and Test Section

- A) Hypersonic Tunnel No. 8 has Mach 5, 6, and 8 two-dimensional two-dimensional nozzles of 18.5 by 18.5 inches exit size. Also available are 24-inch diameter Mach 9 and 10 axisymmetric nozzles.
- B) Hypersonic Tunnel No. 4 has a conical Mach 16 nozzle with 12-inch exit diameter for nitrogen operation. Available for air operation are a Mach 6.8 two-dimensional nozzle with a 10 by 10 inch exit, and axisymmetric Mach 8 and 10 nozzles with exit diameters of 8 and 12.5 inches respectively.

Instrumentation and Test Capabilities

- A) Hypersonic Tunnel No. 8 has 100 channels for the measurement of pressures and steady state temperatures, and 10 channels for force measurements. Data is recorded on magnetic tape and reduced on an IBM 7090. Up to 50 transient temperature measurements can be recorded simultaneously on oscillographs. An analog coefficient computer is also available for on-line data plotting for force tests.
- B) The facilities for recording data in Hypersonic Tunnel No. 4 are generally similar to those in Hypersonic Tunnel No. 8; however, the tunnel is primarily used for basic research investigations.

Running Time

- A) Tunnel No. 8 - 1 minute to continuous.
- B) Tunnel No. 4. - 15 minutes to continuous.

Both tunnels are connected to a continuous 100,000 cfm pumping plant. The running time is limited by the capacity and pump-up time of the high pressure bottled storage fields.

References

1. "Capabilities of the Naval Ordnance Laboratory Aeroballistic Facilities", brochure.
2. Letter, K. R. Enkenhus to F. A. Vicente, dated 29 August 1962.
3. Letter, K. R. Enkenhus to N. S. Foy, dated 10 July 1963, with enclosures.

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