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Technical Data and Information on Foreign Test Facilities

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The Honorable Robert A. Roe
Chairman, Committee on Science, Space, and Technology
House of Representatives

Dear Mr. Chairman:

As requested, we reviewed investment in foreign aerospace vehicle research and technological development efforts. We briefed representatives of the Subcommittee on Transportation, Aviation, and Materials, House Committee on Science, Space, and Technology, previously on the results of our review. This report provides technical data and information on foreign aerospace test facilities (wind tunnels and air-breathing propulsion test cells) and their capabilities.

This report is the first in a planned series of reports on aerospace investment in foreign countries. Subsequent reports will address aerospace investment in individual countries and our overall evaluation and conclusions.

Appendix I includes an explanation of the facility data sheets (a summary of each individual facility's performance characteristics and cost information, as well as narrative statements describing the facility's technical capabilities and research or test programs currently being conducted); a description of wind tunnels and air-breathing propulsion test cells; a quick reference to facilities by country; and our objectives, scope, and methodology. Appendix II provides a definition and explanation of each data element used in this report. Appendixes III through X contain individual facility data sheets by country and photographs, schematic drawings, and/or schematic diagrams of the facility's layout, where available. Appendix XI contains a list of facility installation addresses. A glossary of technical terms appears at the end of this report.

The Departments of Defense, State, and Commerce; the National Aeronautics and Space Administration; and the Central Intelligence Agency commented on a draft of this report and concurred with the facts as presented. Their comments appear in appendixes XII through XVI. Technical and editorial comments by the Department of Defense and the National Aeronautics and Space Administration were provided separately and have been incorporated in the report where appropriate.

Appendix V Aerospace Test Facilities in France

Appendix X Aerospace Test Facilities in West Germany

Abbreviations

1MG	1-m Windkanal Goettingen (Goettingen 1-m Wind Tunnel)
AC/DC	alternating current/direct current
ACT	Australian Capital Territory
A/D	analog/digital
AEDC	Arnold Engineering Development Center
AFB	Air Force Base
AFWAL	Air Force Wright Aeronautical Laboratories
AGARD	Advisory Group for Aerospace Research and Development
ANU	Australian National University
ARA	Aircraft Research Association
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
ATD	aerothermodynamic
ATF	altitude test facility
atm	atmosphere
BAe	British Aerospace
BMFT	Bundesministerium fuer Forschung und Technologie (Federal Ministry for Research and Technology)
BNSC	British National Space Centre
CAD/CAM	computer aided design/computer aided manufacturing
CARS	coherent anti-Stokes Raman scattering
CEAT	Centre d'Etudes Aerodynamiques et Thermiques (Aerodynamics and Thermics Study Center)
CEPr	Centre d'Essais des Propulseurs de Saclay (Saclay Propulsion Test Center)
CEPRA	Centre d'Essais des Propulseurs et de Recherches Aerospatiales (Propulsion and Aerospace Research Test Center)
CERT	Centre d'Etudes et de Recherches de Toulouse (Toulouse Research and Study Center, commonly referred to as the Toulouse Research Center)
CFD	computational fluid dynamics
CIRA	Centro Italiano Ricerche Aerospaziali (Italian Aerospace Research Center)
cm	centimeter
CNES	Centre National d'Etudes Spatiales (National Center for Space Studies)
CNRS	Centre National de la Recherche Scientifique (National Center for Scientific Research)
CWT	Cold Wind Tunnel
DARPA	Defense Advanced Research Projects Agency

HST	High-Speed Wind Tunnel
Hz	hertz
IHI	Ishikawajima-Harima Heavy Industries
IMF	Institut de Mecanique des Fluides (Institute of Fluid Mechanics)
IMFL	Institut de Mecanique des Fluides de Lille (Lille Institute of Fluid Mechanics)
in.	inch
ISAS	Institute of Space and Astronautical Science
ISL	Institut de Saint-Louis (Saint-Louis Institute)
JPO	Joint Program Office
k	one thousand
kA	kiloampere
kg	kilogram
kg/cm^2	kilogram per square centimeter
kg/s	kilogram per second
KHI	Kawasaki Heavy Industries
kHz	kilohertz
KKK	Projekt Kyro-Niedergeschwindigkeitskanal Koln-Porz (Koln-Porz Cryo-Low-Velocity Wind Tunnel)
km	kilometer
km/s	kilometer per second
kN	kilo-newton
kN/m^2	kilo-newton per square meter
kPa	kilopascal
KRG	Kryo-Rohr-Windkanal Goettingen (Goettingen Cryogenic Tube Wind Tunnel)
kW	kilowatt
lb	pound
lb/ft	pound per foot
lb/s	pound per second
LDA	laser Doppler anemometry
LICH	Ludwieg isentropic compression heating
LMF	Laboratoire de Chalais-Meudon (Chalais Meudon Laboratory)
LRBA	Laboratoire de Recherches Balistiques et Aerodynamiques (Ballistics and Aerodynamics Research Laboratory)
LS	low speed
LST	Low-Speed Wind Tunnel
m	meter
mbars	millibars
MBB	Messerschmitt-Boelkow-Blohm
MHI	Mitsubishi Heavy Industries
MHz	megahertz
min	minute

RAE	Royal Aerospace Establishment
R_e/ft	Reynolds Number per foot
R_e/m	Reynolds Number per meter
RGG	Ringgitter-Windkanal Goettingen (Goettingen Rotating Cascades Wind Tunnel)
rpm	revolutions per minute
RR	Rolls-Royce
RWG	Rohr-Windkanal Goettingen (Goettingen Tube Wind Tunnel)
RWTH	Rheinisch-Westfalischen Technischen Hochschule (Rheinland-Westfalia Technical University)
s	second
SABCA	Societe Anonyme Belge de Constructions Aeronautiques (Belgian Anonymous Society for Aeronautical Construction)
scramjet	supersonic combustion ramjet
SEP	Societe Europeenne de Propulsion (European Propulsion Society)
SIB	Strahlinduktions-Windkanal Braunschweig (Braunschweig Jet-induction Wind Tunnel)
SNECMA	Societe Nationale d'Etude et de Construction de Moteurs d'Aviation (National Society of Studies and Construction of Aviation Motors)
SNIA-BPD	Societa Nazionale Industria Applicazlone-Bomprini Parodi Delfino (National Society for Industrial Applications-Bomprini Parodi Delfino)
SSB	Strahlsimulations-Windkanal Braunschweig (Braunschweig Jet-simulation Wind Tunnel)
ST	Supersonic Tunnel
STOL	Short Takeoff and Landing
STOVL	Short Takeoff and Vertical Landing
SWT	Supersonic Wind Tunnel
TMK	Trisonikkanal Koln-Porz (Koln-Porz Trisonic Wind Tunnel)
TRDI	Technical Research and Development Institute
TST	Transonic/Supersonic Tunnel
TUG	Turbulenzarmer Windkanal Goettingen (Goettingen Low-Turbulence Wind Tunnel)
TWB	Transsonischer Windkanal Braunschweig (Braunschweig Transonic Wind Tunnel)
TWG	Transsonischer Windkanal Goettingen (Goettingen Transonic Wind Tunnel)
TWT	Transonic Wind Tunnel

Center (AEDC).[4] The facility data sheets are designed to present as much information as possible on the principal features of a facility in a "quick glance" format.

As part of our review, we conducted a literature search of test facilities. We incorporated the technical data and information into the facility data sheets and discussed them with appropriate facility owners or operators for verification. We visited 40 key wind tunnel, shock tunnel, and air-breathing propulsion test cell facilities in Europe, Japan, and Australia to verify, validate, and update the data sheets. We obtained facility handbooks and technical papers in French, German, and Japanese, which were translated by the Department of State, and incorporated technical data and information from these sources into the facility data sheets. We sent copies of each facility data sheet to the appropriate owner or operator for review and editing. These comments have been incorporated into the data sheets as appropriate. Each facility data sheet is structured so that it can stand alone or in a group (e.g., by category or country). The facilities are grouped by country and according to class (i.e., wind tunnels and air-breathing propulsion test cells). Wind tunnels are further grouped according to speed regimes (i.e., subsonic, transonic, trisonic, supersonic, hypersonic, and hypervelocity).[5] Air-breathing propulsion test cells are also grouped according to category (i.e., propulsion wind tunnels; altitude engine test facilities; and propulsion component facilities for engine turbines, compressors, and combustors).

Each facility is presented in a format that contains a photograph, schematic drawing, and/or schematic diagram of the facility's layout, where available, and a facility data sheet with tabular data and narrative information. The facility data sheet contains a summary or quick reference chart of the most pertinent data about the facility and narrative information on the facility's technical capabilities and research or test

[4] Located at Arnold Air Force Base in Tullahoma, Tennessee, Arnold Engineering Development Center was established in 1949 as a highly specialized Air Force Systems Command test center. AEDC's principal mission is to provide environmental test, analysis, and evaluation support to systems development and research and development programs of the Air Force, Department of Defense, other government agencies, and private industry. AEDC has one of the world's largest complex of facilities including wind tunnels, propulsion test cells, space chambers, and hyperballistic ranges specifically designed to provide engineering development support to aerospace systems.

[5] Subsonic is a range of speed below the speed of sound in air (761.5 mph at sea level). Transonic is a range of speed between about 0.8 and 1.2 times the speed of sound in air. Trisonic refers to three ranges of speed (such as subsonic, transonic, and supersonic). Supersonic is a range of speed between about one and five times the speed of sound in air. Hypersonic is a range of speed which is five times or more the speed of sound in air. Hypervelocity is a range of speed which is 12 times or more the speed of sound in air.

Test run times in a wind tunnel may be continuous, intermittent, or last only a few milliseconds.[8] Almost all wind tunnel tests are conducted with scale models, since wind tunnels capable of accommodating full-scale aircraft are too expensive to build and require too much energy to operate, especially for high-speed testing. The airflow pattern over a scale model is the same for the full-scale vehicle if certain full-scale similarity parameters are duplicated in the wind tunnel. For most flight conditions, these similarity parameters are Reynolds Number[9] and Mach number.[10] In very high-speed flows, other aerothermodynamic conditions such as total enthalpy[11] must be matched.

Wind tunnels are divided into the following categories according to their speed: subsonic, transonic, trisonic, supersonic, hypersonic, and hypervelocity.

Subsonic Wind Tunnels

According to NASA, hundreds of U.S. and foreign subsonic wind tunnels have test sections smaller than 6 feet and speeds less than Mach 0.2. Most of these facilities are used for fundamental research and do not represent the principal capabilities in low-speed aeronautical research and development. Thus, most of these facilities have not been included in this report. We have included those subsonic wind tunnels that U.S. and foreign government and industry officials identified as important wind tunnels for conducting aeronautical research and development and/or key facilities for testing future aerospace vehicles in the low-speed range. Subsonic wind tunnels included in this report have a speed range between Mach 0.1 and 0.8.

Transonic Wind Tunnels

Transonic wind tunnels characteristically have ventilated test section walls and a speed range between Mach 0.8 and 1.2 (the transonic region).

Trisonic Wind Tunnels

Trisonic wind tunnels, also known as polysonic and multisonic wind tunnels, have a speed capability over three speed ranges (such as subsonic,

[8] A millisecond is one-thousandth of a second.

[9] A dimensionless number that is used as an indication of scale of fluid flow. It is significant in the design of a model of any system in which the effect of viscosity is important in controlling the velocities or the flow pattern of a fluid. It is equal to the density of a fluid times its velocity times a characteristic length divided by the fluid viscosity.

[10] A number representing the ratio of the speed of an object to the speed of sound in the surrounding atmosphere. An object traveling at the local speed of sound is traveling at Mach 1.

[11] The sum of the internal energy of a system and the product of its volume multiplied by the pressure exerted on the system by its surroundings.

Wind tunnels included under the air-breathing propulsion test cell category are only those that permit real engine testing (i.e., engine burn) while the wind tunnel is in operation. Wind tunnels that provide only propulsion simulation capabilities through the use of compressed air-driven engine simulators (or similar techniques) have not been included in this report. The engine test facilities included in this report are only those providing altitude test capability. Sea level test stands are not included because they are too numerous and do not provide the proper temperature and pressure conditions required for conducting full-range engine research and development. The engine/propulsion component test facilities listed are only those providing research and development or testing capabilities for engine turbines, fans, and combustors.

Propulsion Wind Tunnels

Propulsion testing in wind tunnels allows the engine and its installed inlet to be tested as an integrated system. The wind tunnel provides the propulsion system being tested with an airflow environment similar to that found in actual flight, where the air is directed around the inlet as well as into the inlet. The angle of attack[12] can be varied in the larger wind tunnels, resulting in even more realistic airflow conditions for the engines. According to NASA, the wind tunnel is unsurpassed for complete aerodynamic behavior and propulsion/airframe integration studies. The drawback of wind tunnels for engine testing is their inability to obtain true temperature simulation over a wide operating range. The air in a wind tunnel is generally neither hot enough at high Mach numbers nor cold enough at high altitudes and lower Mach numbers. Conditioning the large volume of air used by the wind tunnel in addition to the air used by the engine itself is a difficult, costly, and inefficient process. Engine test facilities are more economical and generally have better provisions for temperature/altitude simulation.

Altitude Engine Test Facilities

Propulsion testing in altitude engine test facilities is divided into two broad categories: direct-connect and free-jet testing. In direct-connect testing, air is fed directly into the engine, eliminating (or bypassing) the use of an inlet and avoiding any loss of air flowing around the engine. The objective is to provide properly conditioned combustion air to the engine as if an inlet were present, but in a more efficient manner. This air is usually provided in an idealized uniform profile, although it may be possible to distort temperature and pressure profiles. The smaller and more easily controlled volume of air is thereby easier to condition for the hot or cold temperature extremes required for true simulation of

[12] Angle of attack is the acute angle between the direction of the relative airflow and the chord (i.e., the straight line joining the leading and trailing edges of an airfoil) of the test model.

Table I.1: Wind Tunnel Facilities by Country

Installation and facility	Test section size	Mach number	Reynolds Number	Page
		AUSTRALIA		
Hypervelocity Wind Tunnels				
ANU T-3	2 x 2 ft	4 to 11	3 x 10^4/ft to 2 x 10^6/ft	59
University of Queensland T-4	12 in. diameter	5 to 10	2 x 10^6/ft at Mach 6	64
		BELGIUM		
Subsonic Wind Tunnels				
VKI Cold CWT-1	0.1 x 0.3 x 2.2 m	0.73	4 x 10^6/m (maximum)	69
VKI Low-Speed Cascade C-1	12 x 50 cm	Not available	Not available	72
VKI Low-Speed L-1A	3 m diameter	0.17	4 x 10^6/m	76
Transonic Wind Tunnel				
VKI Compression Tube CT-3	850 mm (maximum tip), 600 mm (hub minimum), and 50 to 70 mm (typical blade height)	Not available	Not available	79
Trisonic Wind Tunnel				
VKI High-Speed Cascade C-3	100 x 250 mm^2	0.2 to 2	Not available	81
Supersonic Wind Tunnel				
VKI Supersonic/Transonic S-1	40 x 40 cm (transonic) and 40 x 40 cm (supersonic)	0.4 to 1.05 (transonic), 1.43, and 2 to 2.25 (contoured supersonic)	4 x 10^6/m at Mach 2	84
Hypervelocity Wind Tunnels				
VKI Compression Tube CT-2	250 x 100 mm	Not available	Not available	87
VKI Longshot ST-1	16 m^3	15 (contoured) and 20 (conical)	20 x 10^6/m	90
		FRANCE		
Subsonic Wind Tunnels				
CEPRA 19 Anechoic	2 or 3 m diameter x 11 m long	Greater than 0.29 at 2 m diameter and greater than 0.18 at 3 m diameter	Up to 66 x 10^6/m at 2 m diameter and up to 2.2 x 10^6/m at 3 m diameter	97
ONERA F1	3.5 x 4.5 x 10 m	0.37	10 x 10^6/m	100
ONERA F2	1.8 x 1.4 x 5 m	0.3	6 x 10^6/m	108
ONERA IMFL SV4 Spin	4 m diameter x 36 m high	0.12	Up to 2.7 x 10^6/m	112
ONERA S2Ch Subsonic	3 m diameter x 5 m long	0.29	Not available	117
Transonic Wind Tunnels				
ONERA IMFL Transonic	200 x 42 x 350 mm and 42 x 240 mm	0.3 to 1.1	14 x 10^2/m at Mach 0.8	121
ONERA S1MA	8 m diameter x 14 m long	0.023 to approximately 1	13.5 x 10^6/m	123

(continued)

Installation and facility	Test section size	Mach number	Reynolds Number	Page
ONERA F4 Hotshot	0.4 to 1 m (nozzle exit diameter)	7 to 18	Not available	191
		ITALY		
Subsonic Wind Tunnel				
CIRA Low-Speed	4.5 x 3.5 m (S1) and 6.4 x 5 m (S2)	0.05 (S2) to 0.1 (S1)	2.3 x 10^6/m	207
Transonic Wind Tunnel				
CIRA High Reynolds Transonic	4.5 x 3.5 m	0.24 to 0.4 (continuous mode) and 0.4 to 1.4 (planned blowdown)	14 x 10^6/m	209
Hypersonic Wind Tunnel				
CIRA Plasma	0.6 x 0.6 x 0.6 m^3	4 to 6	Not available	211
		JAPAN		
Subsonic Wind Tunnels				
FHI Low-Speed	6.56 x 6.56 x 9.5 ft	0 to 0.176	0 to 1.5 x 10^6/ft	214
KHI 3.5 m	No. 1: 3.5 x 3.5 x 6.5 m (closed) and No. 2: 2.5 x 3 m (open)	No. 1: 0 to 0.1 (closed) and No. 2: 0 to 0.19 (open)	No. 1: 0 to 0.71 x 10^6/ft (closed) and No. 2: 0 to 1.33 x 10^6/ft (open)	216
MHI 2 m Low-Speed	1.8 x 2 x 2.5 m	0.06 to 0.23	0.4 to 2 x 10^6/m	219
MHI Smoke	0.2 x 1.5 x 2.5 m	0.05 and 0.11	Not available	224
NAL 6 m Low-Speed	No. 1: 6.5 x 5.5 m (closed) and No. 2: 5.6 x 4.6 m (open)	No. 1: 0.18 and No. 2: 0.21	No. 1: 1.2 x 10^6/m and No. 2: 1.4 x 10^6/m	226
TRDI Convertible	No. 1: 10.8 x 10.8 x 14.8 ft, No. 2: 19.7 x 19.7 x 20.5 ft, and No. 3: 13 (octagon) x 14 ft	No. 1: 0.04 to 0.17, No. 2: 0.03 to 0.05, and No. 3: 0.04 to 0.1	0 to 1.4 x 10^6/ft	228
TRDI Low-Speed	8.2 ft diameter x 11.5 ft long	0.04 to 0.17	0 to 1.4 x 10^6/ft	232
Tsukuba Cryogenic	0.5 x 0.5 x 1.2 m	0.09 to 0.19	1 x 10^5/ft to 1 x 10^7/ft	235
Transonic Wind Tunnels				
ISAS Transonic	0.6 x 0.6 x 1 m	0.3 to 1.3	1.1 x 10^6/m	239
KHI 1 m Transonic	1 x 1 m	0.2 to 1.4	22 x 10^6/ft	243
KHI Two-Dimensional	0.4 x 0.1 x 1 m	0.4 to 1.2	5.1 to 23.7 x 10^6/ft	247
NAL 2 m Transonic	2 x 2 x 4.13 m	0.1 to 1.4	1.6 to 6 x 10^6/m	250
NAL Two-Dimensional Transonic	1 x 0.3 m	0.2 to 1.15	49 x 10^6/ft at Mach 0.8	253
Trisonic Wind Tunnels				
FHI 2 x 2 ft High-Speed	2 x 2 ft	0.2 to 4	3.2 to 3.5 x 10^6/ft	255
MHI 60 cm Trisonic	0.6 x 0.6 x 2.8 m	0.4 to 4	15 to 65 x 10^6/m	257
Supersonic Wind Tunnels				
ISAS Supersonic	0.6 x 0.6 x 0.8 m	1.5 to 4	1.08 x 10^6/m	260
NAL 1 m	1 x 1 m	1.4 to 4	0.6 to 1.8 x 10^7/ft	264

(continued)

Installation and facility	Test section size	Mach number	Reynolds Number	Page
RAE Farnborough 5 m Low-Speed	4.2 x 5 m	0 to 0.33	Up to 18 x 10^6/m	364
RAE Farnborough 11.5 x 8.5 ft	3.5 x 2.6 m	0.01 to 0.32	Up to 7.5 x 10^6/m	367
RAE Farnborough 24 ft Anechoic	7.3 m (circumference) x 7 m long	0.01 to 0.15	Up to 3.4 x 10^6/m	369
Transonic Wind Tunnels				
ARA Bedford Transonic	9 x 8 ft	0 to 1.4	1.5 to 5.5 x 10^6/ft	371
RAE Farnborough 8 x 6 ft	1.8 x 2.4 m	0 to 1.25	24 x 10^6/m at Mach 0.3 and 9 x 10^6/m at Mach 1.25	374
Trisonic Wind Tunnels				
BAe Brough 27 x 27 in. Transonic/Supersonic Blowdown	0.68 x 0.68 x 2.1 m	0.1 to 2.5	2.9 to 66 x 10^6/m (transonic) and 2.9 to 148 x 10^6/m (supersonic)	376
BAe Warton 1.2 m High-Speed	1.22 x 1.22 x 3 m	0.4 to 4	80 x 10^6/m	379
Supersonic Wind Tunnels				
ARA Bedford Supersonic	2.25 x 2.5 ft	1.4 to 3	1 to 4.3 x 10^6/ft	381
BAe Woodford 30 x 27 in. Supersonic	0.76 x 0.69 m	1.6 to 3.5	56 x 10^6/m at Mach 1.6 and 30 x 10^6/m at Mach 3.5	383
Cambridge Supersonic	18 x 11.4 cm (nozzle exit diameter)	3.5	8 x 10^6/ft	385
RAE Bedford 3 x 4 ft Supersonic	4 x 3 ft	2.5 to 5 (contoured)	13 x 10^6/ft at Mach 4.5	387
RAE Bedford 8 x 8 ft Subsonic/Supersonic	8 x 8 ft	0.1 to 0.9 (subsonic) and 1.35 to 2.5 (supersonic)	10 x 10^6/ft at Mach 0.9 and 4 x 10^6/ft at Mach 2.5	389
Hypersonic Wind Tunnels				
ARA Bedford M4T Blowdown	1 x 1.33 ft	4 to 5	14 to 23 x 10^6/ft	391
ARA Bedford M7T Blowdown	1 ft diameter	6, 7, and 8 (contoured)	10 to 15 x 10^6/ft	393
BAe Warton Guided Weapons	0.457 x 0.457 x 0.6 m	1.7 to 6 (contoured)	90 x 10^6/m at Mach 1.7, typically 140 x 10^6/m at Mach 3, and 45 x 10^6/m at Mach 6	395
Southampton Hypersonic Gun Tunnel	0.12 m diameter	8.4 (conical) and up to 12	1 to 10 x 10^6/ft and 2 x 10^6/ft at Mach 12	398
Southampton Light Piston Isentropic Compression	0.21 m diameter	6.85 and 9.4 (contoured)	12 x 10^6/ft	401
Hypervelocity Wind Tunnels				
Cranfield Gun	8 in. diameter	8.2 and 12.2	2.8 x 10^6/ft and 0.9 x 10^6/ft	407
Imperial College Heated N_2	20 cm (nozzle exit diameter)	20 to 25 (contoured)	0.006 to 0.1 x 10^6/m	409
Imperial College Hypersonic Gun Tunnel No. 2	45 cm (nozzle exit diameter)	9 (contoured)	14 x 10^6/ft	412
Oxford Gun Tunnel	Not available	6, 8, and 9 (contoured)	12 x 10^6/ft at Mach 6, 6.4 x 10^6/ft at Mach 8, and 2.5 x 10^6/ft at Mach 9	415

(continued)

Installation and facility	Test section size	Mach number	Reynolds Number	Page
DLR Goettingen Plane Cascades (EGG)	125 x 380 mm	0.5 to 1.6 (downstream)	5 to 10 x 10^5/m	493
DLR Goettingen Rotating Cascades (RGG)	0.512 m (mean diameter) and 0.9 m (ratio of casing diameter to hub diameter)	0.5 to 1.8	Up to 1.2 x 10^7/m	497
DLR Koln-Porz Trisonic (TMK)	60 cm x 60 cm^2	0.5 to 4.5	1 to 8 x 10^7/m	501
DLR Koln-Porz Vertical Free-jet Test Chamber (VMK)	18, 27, and 34 cm diameter (subsonic) and 15, 22, and 31 cm diameter (supersonic)	0.2 to 3.2	1.4 x 10^6/m to 2.5 x 10^8/m	504
Supersonic Wind Tunnels				
DLR Goettingen High-Speed (HKG)	0.75 x 0.75 m (subsonic free-jet cross section) and 0.71 x 0.725 m (supersonic adjustable nozzle cross section)	0.4 to 0.95 (subsonic) and 1.22 to 2.5 (supersonic)	0.8 to 1.6 x 10^7/m	507
DLR Koln-Porz Calibrating (EMK)	0.203 m x 0.381 m^2 (subsonic) and 0.203 m x 0.203 m^2 (supersonic)	0.3 to 0.8 (subsonic) and 1.3 to 3.1 (supersonic)	3.9 x 10^6/m to 8.7 x 10^7/m	510
DLR Koln-Porz High-Speed (HMK)	0.3 m x 0.3 m^2 (cross section)	0.4, 0.7, 1.57, 2.25, 2.89, and 4.15	0.6 to 16.3 x 10^7/m	512
Hypersonic Wind Tunnels				
DLR Goettingen Hypersonic Vacuum Tunnel 1 (V1G)	0.25 m diameter x 0.5 m long	7 to 25	5 x 10^4/m to 5 x 10^6/m	515
DLR Goettingen Hypersonic Vacuum Tunnel 2 (V2G)	0.4 m diameter x 0.8 m long	10 to 20 (conical)	5 x 10^4/m to 5 x 10^5/m	519
DLR Goettingen High-Vacuum Tunnel 3 (V3G)	1,300 mm diameter x 3,300 mm long	6 to 25	4 x 10^2/m to 4 x 10^5/m	523
DLR Goettingen Tube (RWG)	0.5 m diameter	3, 4, 5, 6, 7, 9, 10, and 11	3 to 50 x 10^6/m at Mach 5	527
DLR Koln-Porz High-Enthalpy Tunnel 1 (P1K)	Up to 110 mm diameter	5 to 20 (conical)	1 x 10^3/m to 1 x 10^4/m	531
DLR Koln-Porz High-Enthalpy Tunnel 2 (P2K)	About 250 mm diameter	3 to 20 (conical)	0.003 to 0.35 x 10^6/m	534
DLR Koln-Porz High-Enthalpy Tunnel 3 (P3K)	250 mm diameter	3 to 15 (conical)	1 x 10^5/m to 1 x 10^7/m	537
DLR Koln-Porz Hypersonic Tunnel 1 (H1K)	60 x 36 cm for Mach 4.5	4.5, 6, 8.7, and 11.2	3.6 x 10^5/m to 3 x 10^7/m	540
DLR Koln-Porz Hypersonic Tunnel 2 (H2K)	0.6 cm diameter	4.8, 5.3, 6, 8.7, and 11.2	2.4 x 10^5/m to 5.5 x 10^7/m	542
Hypervelocity Wind Tunnels				
DLR Goettingen High-Enthalpy (HEG)	Not available	7	Not available	545
RWTH Aachen Shock Tunnel	500 x 500 mm	6 to 24 (conical)	1.2 x 10^7/m	549
Technical University of Braunschweig Gun	16 cm (nozzle exit diameter)	8 to 16 (conical)	0.8 x 10^6/m at Mach 8	552

Altitude Engine Test Facilities

Installation and facility	Air supply: Mass flow rate	Air supply: Temperature range	Air supply: Pressure range	Mach number	Altitude range	Page
UNITED KINGDOM						
RAE Pyestock ATF Cell 1	450 lb/s	Ambient to 450 degrees Fahrenheit	2 to 100 psia	0 to 3.5	50,000 ft	426
RAE Pyestock ATF Cell 2	450 lb/s	Ambient to 450 degrees Fahrenheit	2 to 100 psia	0 to 2.5	50,000 ft	428
RAE Pyestock ATF Cell 3	600 lb/s	−100 to 400 degrees Fahrenheit	2 to 39 psia	0 to 2.5	65,000 ft	430
RAE Pyestock ATF Cell 4	500 lb/s	Ambient to 880 degrees Fahrenheit	3 to 60 psia	1.5 to 3.5	100,000 ft	433
RAE Pyestock ATF Cell 3W	1,400 lb/s	−50 degrees Fahrenheit to ambient	2 psia to atmospheric	Subsonic	50,000 ft	435
Rolls-Royce ATF C-1	400 lb/s	−113 to 355 degrees Fahrenheit	73 psia	0 to 2.5	70,000 ft	437
Rolls-Royce ATF C-2	400 lb/s	−113 to 355 degrees Fahrenheit	73 psia	0 to 2.5	70,000 ft	439
Rolls-Royce TP 131A	400 lb/s	841 degrees Fahrenheit	165 psia	0 to 4.2	90,000 ft	441
WEST GERMANY						
University of Stuttgart ATF	140 kg/s	−100 to 430 degrees Kelvin	2.4 bars	2.2	65,600 ft	554

Turbine Component Research Facilities

Installation and facility	Maximum flow rate	Maximum power	Temperature range	Pressure level	Speed range	Page
JAPAN						
IHI High-Pressure Turbine Facility	40 lb/s	6,000 hp	2,500 degrees Fahrenheit	3.5 atm	15,000 rpm	278
NAL High Temperature Turbine Cooling Facility	1.5 kg/s	Not available	1,500 degrees Kelvin	900 kPa	Not available	280

Compressor Component Research Facilities

Installation and facility	Maximum flow rate	Maximum power	Temperature range	Pressure level	Speed range	Page
BELGIUM						
VKI High-Speed Compressor R-4	Not available	Not available	Ambient	0.1 to 2.5 atm	25,000 rpm	93

(continued)

use of key foreign facilities by the National Aero-Space Plane (NASP) Program.[13] We did not collect data and information on U.S. government and industry investment in the NASP Program[14] or compare investments and capabilities among countries.

The scope of our review was primarily limited to future air-breathing aerospace vehicles, since they could provide competition to NASP or future NASP-derived operational vehicles. We focused on countries and critical or enabling technologies.[15] Our review included France, West Germany, the United Kingdom, and Japan, since each of these countries are developing technologies for various concepts of operational aerospace vehicles to secure independent access to space and reduce the costs of launching payloads into orbit. In addition, we included facilities (such as wind tunnels) in The Netherlands, Belgium, Italy, and Australia. Although these countries do not have national programs to develop and build air-breathing aerospace vehicles, their test facilities are being used to conduct research and development of such vehicles by other countries and the European Space Agency (ESA).

We collected technical data and information on test facilities, their capabilities, and the number of people working on aerospace vehicle research and development in those countries included in our review. Facilities include (1) wind tunnels and shock tunnels, (2) air-breathing propulsion test cells (engine test facilities for ramjets and scramjets), (3) aerothermal test facilities, (4) aeroballistic and impact ranges, (5) advanced materials research, development, production, and fabrication laboratories, and (6) aerodynamic computation facilities (supercomputers).[16] We also collected cost information on test facilities, including construction, replacement, annual operating, and user costs, where available.

[13]The NASP Program is a $3.3 billion joint Department of Defense/NASA technology development and demonstration program to build and test the X-30 experimental flight vehicle. The X-30 is being designed to take off horizontally from a conventional runway, reach hypersonic speeds of up to 25 times the speed of sound, attain low earth orbit, and return to land on a conventional runway. The NASP Program is expected to provide the technological basis for future hypersonic flight vehicles by developing critical or enabling technologies.

[14]For a detailed and technical description of the NASP Program, including U.S. government and industry investment in the program, see our report, National Aero-Space Plane: A Technology Development and Demonstration Program to Build the X-30 (GAO/NSIAD-88-122, Apr. 27, 1988).

[15]Enabling technologies include high-speed (ramjet/scramjet) air-breathing propulsion, advanced materials, structures, and hypersonic aerodynamics (the use of hypersonic wind tunnels, CFD, and supercomputers).

[16]Technical data and information on aerothermal test facilities; aeroballistic and impact ranges; advanced materials research, development, production, and fabrication laboratories; and supercomputer facilities will be included in our reports on the individual countries.

(SNECMA). We also conducted work in Les Mureaux at Aerospatiale, and in Saint Cloud at Avions Marcel Dassault-Breguet Aviation.

We also visited the S1MA transonic wind tunnel, S2MA transonic and supersonic wind tunnel, S3MA trisonic wind tunnel, S4MA hypersonic wind tunnel, and R4.3 trisonic cascade wind tunnel at ONERA's Modane-Avrieux Center in Modane.

West Germany

We conducted review work in Bonn at the U.S. Embassy, U.S. Air Force Research and Development Liaison Office, and Bundesministerium fuer Forschung und Technologie (BMFT); in Koln-Porz at DLR; in Friedrichshafen at Dornier Systems; in Ottobrunn at Messerschmitt-Boelkow-Blohm (MBB); in Munich at the U.S. Consulate General and Motoren- und Turbinen-Union Munchen (MTU); in Aachen at the Rheinland-Westfalia Technical University of Aachen; and at the University of Stuttgart.

We also visited several DLR hypersonic vacuum tunnel facilities in Goettingen, wind tunnel and shock tunnel facilities at the Rheinland-Westfalia Technical University of Aachen, engine test stands at MTU in Munich, and wind tunnel and altitude engine test facilities at the University of Stuttgart.

United Kingdom

We conducted review work in London at the U.S. Embassy, U.S. Air Force European Office of Aerospace Research and Development (EOARD), U.S. Air Force Research and Development Liaison Office-United Kingdom, British National Space Centre (BNSC), Rolls-Royce, and The Royal Society; in Stevenage at British Aerospace; at The University of Southampton; and at Oxford University.

We also visited the Hypersonic Gun Tunnel, Light Piston Isentropic Compression Facility, and 12.5 cm Diameter Shock Tube at The University of Southampton and the Oxford University Gun Tunnel, Low-Density Wind Tunnel, and Isentropic Light Piston Tunnel at Oxford University.

The Netherlands

We conducted review work in The Hague at the U.S. Embassy and in Amsterdam at the Nederlands Instituut Voor Vliegtuigontwikkeling en Ruimtevaart (NIVR) and Nationaal Lucht-en Ruimtevaartlaboratorium (NLR).

the Masuda Tracking and Data Acquisition Center at NASDA's Tanegashima Space Center in Tanegashima; wind tunnels, materials laboratory, CFD facility, and computer center at NAL in Chofu; sounding rocket launch sites, Mobile Service Tower, balloon launch area for the Highly Maneuverable Experimental Space (HIMES) vehicle, and data tracking and acquisition center at ISAS's Kagoshima Space Center in Uchinoura; wind tunnels under construction and three HIMES gliding flight test vehicles at ISAS in Sagamihara; wind tunnels, materials laboratories, computer centers, and engine test stands at FHI in Utsunomiya, KHI in Gifu, and MHI in Nagoya and Komaki.

In addition, we conducted a 1-day Workshop on Japanese Aerospace Vehicle Investment and Technologies at GAO in Washington, D.C., with representatives from the NASP JPO Fact Finding Group,[18] who also visited Japan to share technical data and information and exchange views based on the results of our visits to Japan.

Australia

We conducted review work in Canberra at the U.S. Embassy; Department of Physics and Theoretical Physics of The Australian National University (ANU); Office of Space Science and Applications of the Commonwealth Science and Industry Research Organization; Australian Space Office of the Department of Industry, Technology, and Commerce; and NASA; in the Australian Capital Territory (ACT) at the Tidbinbilla Space Tracking Station; in Brisbane at the Department of Mechanical Engineering of the University of Queensland; and in Adelaide at British Aerospace Australia.

We also visited the T-1, T-2, and T-3 Shock Tunnels at The Australian National University and T-4 Shock Tunnel at the University of Queensland.

We conducted our review between March 1988 and July 1989 in accordance with generally accepted government auditing standards.

[18] Members of the Fact Finding Group consisted of representatives from NASP JPO, OSTP, McDonnell Douglas Corporation, and Rockwell International Corporation. The group visited Japan in October 1988 to (1) exchange information about the status of and plans for spaceplane development in Japan and the United States, (2) understand the problems and technical barriers to spaceplane development, and (3) explore specific technical areas for possible use on NASP or for possible collaborative development.

(mm) are indicated. When more than one test section is available, the size of each is listed separately.

Test chamber size (air-breathing propulsion test cells): For engine test facilities, the dimensions are given in the following order: diameter and length of the test chamber.

Component size (air-breathing propulsion test cells): For propulsion component facilities, the diameter of the largest article that can be tested is indicated.

Operational status: An indication of the facility's current work load. A backlog indicates an overflow of work beyond normal operations. The following definitions are used where appropriate.

Active: Facility, plant, instrumentation, and computer systems are manned and maintained ready for use. Tests are ongoing or scheduled. Activity can range from heavily scheduled with test backlog to lightly scheduled (one shift as needed).

Standby: Facility, plant, and computer systems are not manned but are maintained ready for use. Some instrumentation may have been removed for storage or use elsewhere. No tests are currently planned, although they can resume with minimum reactivation effort.

Mothballed: Facility and plant are intact but not maintained. Protective measures have been taken. Major components have not been removed (i.e., the basic test capability has been preserved). Minor components and instrumentation may have been removed for storage or use elsewhere. Testing can be resumed only after considerable refurbishment and/or modification.

Decommissioned: Facility and plant are not maintained. Major components have been removed for storage or use elsewhere, so the integrity of facility may not have been preserved. Reactivation is possible but would be a major undertaking and considered only if a unique potential capability exists.

Under construction, Renovation, or Reactivation, as appropriate: Work is underway to construct a new facility, reactivate a decommissioned or mothballed facility, or improve or modernize previously active or standby facilities. These are transitory statuses, leading to

Maximum flow rate: For propulsion component facilities, the maximum rate of air flow to which the particular component is exposed in pounds per second (lb/s).

Altitude range: For propulsion wind tunnels and altitude engine test facilities, the altitude range simulated in the test section or chamber of the facility in feet (ft).

Pressure level: For propulsion component facilities, the maximum air pressure driving the particular components in atmospheres (atm).

Temperature range: The air temperature in the propulsion wind tunnel test section or the inlet temperature for the engine and component test facility in degrees Fahrenheit.

Pressure range: The pressure environment in the propulsion wind tunnel or engine test facility test section or chamber in pounds per square inch absolute (psia).

Speed range: For propulsion wind tunnels and engine test facilities, the air speed in the test section or chamber in Mach number. For propulsion component facilities, the rotational speed of the test component in revolutions per minute (rpm).

Power level: For propulsion component facilities, the maximum horsepower (hp) level generated by the particular test component (turbine or compressor).

Comments: Supplementary information on the performance range or special conditions of the air-breathing propulsion test cell.

Cost information

Date built: Year of construction.

Date placed in operation: Year facility began operations.

Date(s) upgraded: Year(s) of any major modifications.

Construction cost: Amount in then-year dollars to construct the facility.

Photograph/schematic available: Indicates (yes/no) whether a photograph, schematic drawing, and/or schematic diagram of the facility is included in the report.

References: The principal published facility catalogues, technical reports, or brochures that best describe the facility in detail.

Date of information: Date technical data and information were collected or updated.

ANU T-3 Shock Tunnel

Country: Australia

Location: The Australian National University, Canberra, ACT, Australia

Owner(s):
The Australian National University
Shock Tunnel Laboratory
Department of Physics and Theoretical Physics
P.O. Box 4
Canberra, ACT 2601
Australia

Operator(s): The Australian National University

International Cooperation: ESA, France, the United Kingdom, the United States, and West Germany

Point of Contact: Professor John Sandeman, The Australian National University, Tel.: [61]-(62)-49-2747

Test Section Size: 2 x 2 ft (inviscid core flow 8 to 10 in. diameter)

Operational Status: Active

Utilization Rate: 700 tests per year; up to 6 tests per day

Performance
Mach Number: 4 to 11 or 2 to 8 km/s
Reynolds Number: 3×10^4/ft to 2×10^6/ft
Total Pressure: 0.1 to 5.5 atm
Dynamic Pressure: 0.1 to 5.5 atm
Total Temperature: 300 to 3,000 degrees Kelvin
Run Time: 50 microseconds (high enthalpy); 250 microseconds (low enthalpy)
Comments: See General Comments

Cost Information
Date Built: 1966 to 1968
Date Placed in Operation: 1968
Date(s) Upgraded: 1976 (straight-through mode)
Construction Cost: $222,000 to $333,000 (1966)
Replacement Cost: About $820,000 (1989)
Annual Operating Cost: $574,000 to $820,000 (1989)
Unit Cost to User: About $4,500 per test (1989)
Source(s) of Funding: Australian Department of Education, Australian Research Council, NASA, and foreign industry

Number and Type of Staff
Engineers: 0
Scientists: 2
Technicians: 2
Others: 1 research assistant and 1 research fellow
Administrative/Management: 2
Total: 8

Description: The ANU T-3 Shock Tunnel is a hypervelocity short-duration shock tunnel.

Testing Capabilities: The T-3 is capable of conducting scale model tests, heat transfer rates, pressure distribution measurements, schlieren photography and Mach-Zehnder interferometry, mass spectrometry, and coherent anti-Stokes Raman scattering (CARS) to determine rotational and vibrational temperatures and molecular species concentrations. It also uses other optical diagnostic techniques and laser facilities.

Data Acquisition: The T-3 has 24 on-line channels of data at 2.5-microsecond intervals between measurements that are processed on a Macintosh computer.

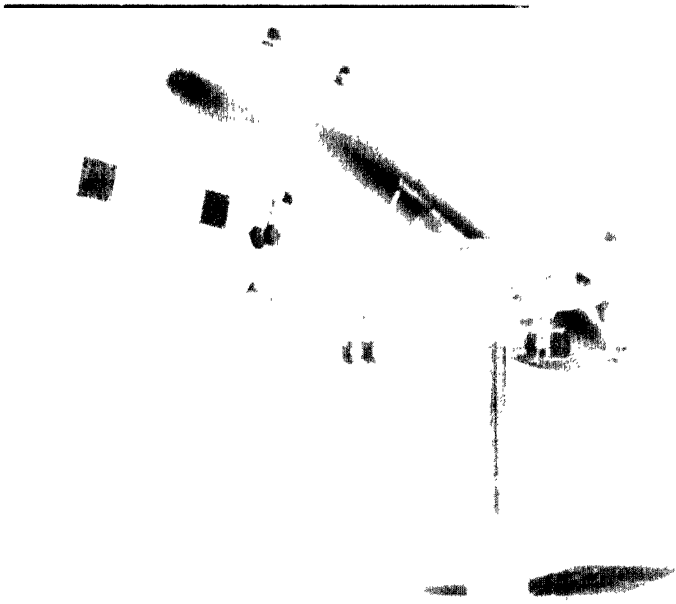
Planned Improvements (Modifications/Upgrades): These include further improvement of laser diagnostic techniques to measure flow velocities.

Unique Characteristics: The T-3 has the capacity to measure equilibrium and non-equilibrium real gas effects at speeds up to 6.5 km/s (Mach 19.1), corresponding to an equivalent flight velocity of 8 km/s (Mach 23.5).

Figure III.2: The Australian National University T-3 Shock Tunnel

Source: GAO

Figure V.26: Ground Effect Test on Airbus A320 Model in Test Section of the ONERA S1MA Wind Tunnel



Source: ONERA

construction of a third door that will be better suited to side wall test setups, the installation of a blowdown generator, and adaptable upper and lower walls.

Unique Characteristics: None

Applications/Current Programs: In 1963, the first in a long series of nozzle tests were conducted for SNECMA's ATAR 9C and 9K engines, including Concorde-related studies which began in 1965. These studies involved weighing of the dynalpy at the nozzle outlet for the adaptation of subsonic flight, measurement of the distortion coefficients, and air intake efficiency. Beginning in 1974, tests gradually oriented toward more general studies for the benefit of industry. Tests were conducted on debugging the D4 dynalpy weighing stand for a high-bypass-ratio engine of the CFM 56 type, which will lead to future studies of nacelle-wing interaction and jet reverser tests. Other activities involve studies of aircraft of new geometry and wing-tail and canard-fuselage interactions for which laser sheet visualization techniques have been developed. The S3Ch conducts various tests on the Ariane launch vehicle. The development of a gust generator with oscillating blown flaps is used for unsteady flow measurements on a fighter aircraft model.

General Comments: None

Photograph/Schematic Available: Yes

References: ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 10-11.

Date of Information: January 1989

ONERA T2 Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Centre d'Etudes et de Recherches de Toulouse, Toulouse, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Centre d'Etudes et de Recherches de Toulouse

International Cooperation: Not available

Point of Contact: Dr. J. Cousteix, Office National d'Etudes et de Recherches Aerospatiales, Centre d'Etudes et de Recherches de Toulouse, Tel.: [33]-(61)-55-70-80

Test Section Size: 0.4 x 0.4 x 1.6 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 1.1 (with adaptive walls)
Reynolds Number: 51 x 10^6/m
Total Pressure: 1.7 to 5 bars
Dynamic Pressure: Not available
Total Temperature: 120 to 300 degrees Kelvin
Run Time: 1 min
Comments: None

Cost Information
Date Built: 1975
Date Placed in Operation: Not available
Date(s) Upgraded: 1983
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

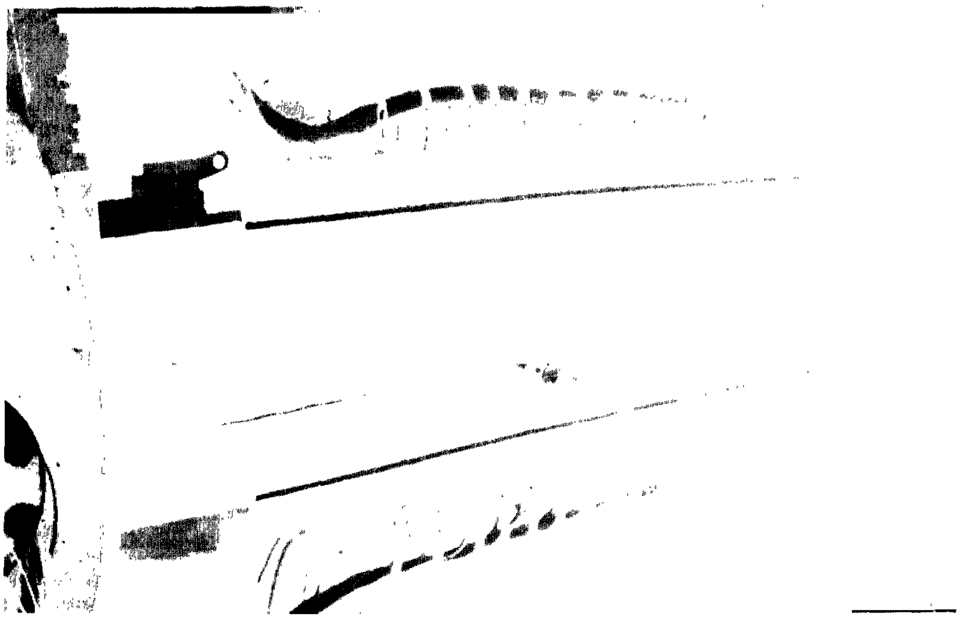
Description: The ONERA T2 Wind Tunnel is a closed, return circuit, ejector-driven blowdown transonic wind tunnel. The T2 is a pressurized, cryogenic, gust wind tunnel in which the flow is produced by induction. The tunnel is pressurized up to 5 bars and speeds of up to Mach 1.1 can be achieved. Operating cryogenically, very high Reynolds Numbers are possible (i.e., approximately 35 x 10^6/m for an airfoil with a chord of 15 cm at Mach 0.8).

Testing Capabilities: The T2 is being used to conduct research on two-dimensional wing sections at high Reynolds Numbers and negligible wall corrections made with cryogenic temperatures and adaptive walls.

Data Acquisition: Two local computers (both Hewlett Packard 1000s) are used for (1) tunnel testing management (precooling of the model, model injection in the test section, and starting and control of the air-driven ejector system and of the liquid nitrogen) and (2) data acquisition.

Planned Improvements (Modifications/Upgrades): These include a nitrogen-driven ejector system and lower ambient humidity.

Figure V.30: Airfoil in Presence of Adaptive Walls of Test Section of the ONERA T2 Wind Tunnel



Source: ONERA

Unique Characteristics: In France, the LRBA C4 is unique in that it is capable of measuring factors related to stability (C_{mq} and C_{lp}). It also has Magnus measurements.

Applications/Current Programs: The C4 is used mainly for development testing on tactical and ballistic missiles. The tunnel is also used for air intake testing for both aircraft and missiles. It is used mainly for supersonic testing.

General Comments: LRBA belongs to the Directorate for Engines, General Delegate for Armament, French Ministry of Defense.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 231. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 96 (EOARD Technical Report).

Date of Information: November 1989

Applications/Current Programs: The R4.3 is used for fundamental tests of compressors and to study composite blades. The tunnel is also used to study the airstream between propeller blades and to measure the coefficient of blades.

General Comments: The ONERA R4.A Wind Tunnel, a small dimension blowdown facility, is located parallel to the R4.3 and is used for special tests, particularly tests of nacelle afterbodies with external flow. The R4.A has recently been used for jet engine exhaust tests for General Electric and SNECMA.

Photograph/Schematic Available: Yes

References: ONERA. Activities 1986: Large Testing Facilities. Chatillon, France: ONERA, 1987, p. 25. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 72-73.

Date of Information: September 1989

Figure V.31: ONERA R4.3 Cascade Wind Tunnel

Source: ONERA

ONERA S2MA Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Modane, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre

International Cooperation: Not available

Point of Contact: Jean Laverre, Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Tel.: [33]-(79)-20-20-00

Test Section Size: 1.75 x 1.77 m (transonic) and 1.75 x 1.93 m (supersonic)

Operational Status: Active

Utilization Rate: 1,500 to 1,700 hours per year (of which 500 to 567 hours are test run times)

Performance
Mach Number: 0.1 to 1.3 (transonic) and 1.5 to 3.1 (supersonic)
Reynolds Number: 5.5 to 29.4 x 10^6/m
Total Pressure: 0.15 to 2.5 bars (maximum)
Dynamic Pressure: 68 kN/m^2
Total Temperature: 0 to 318 degrees Kelvin
Run Time: Continuous
Comments: Test gas used is air.

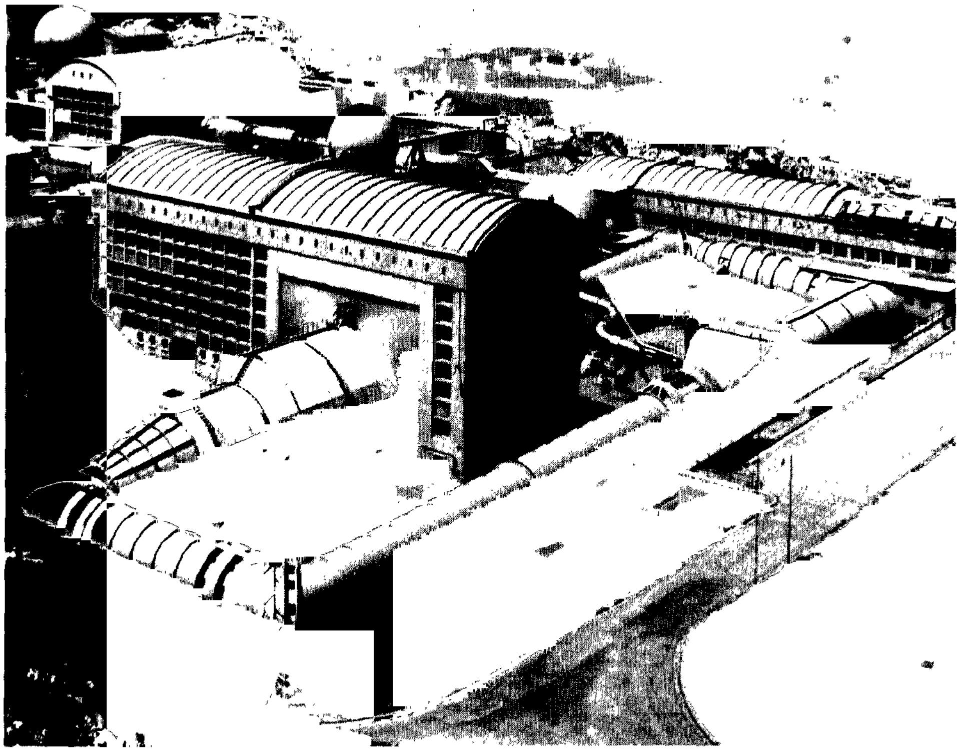
Cost Information
Date Built: 1961
Date Placed in Operation: 1961
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $83.9 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 14

Description: The ONERA S2MA Wind Tunnel is a continuous flow transonic and supersonic wind tunnel. The tunnel is driven by a 57-MW compressor powered by four Pelton turbines. It is cooled by a water exchanger in the aerodynamic circuit just downstream from the compressor. Two rectangular test sections, which can be interchanged by shuttling them sideways in and out of the airflow, are installed in a sealed enclosure. The transonic test section (1.75 × 1.77 m) has solid or perforated walls and is used for tests between Mach 0.1 to 1.3. The supersonic test section (1.75 × 1.93 m) is used for tests between Mach 1.5 to 3.1. The Mach number is varied by longitudinal translation of a block on the floor shaped from an asymmetrical nozzle. The stagnation pressure can be varied from 0.15 bars to a maximum that depends on the Mach number. The circuit is quickly emptied by using the ejectors.

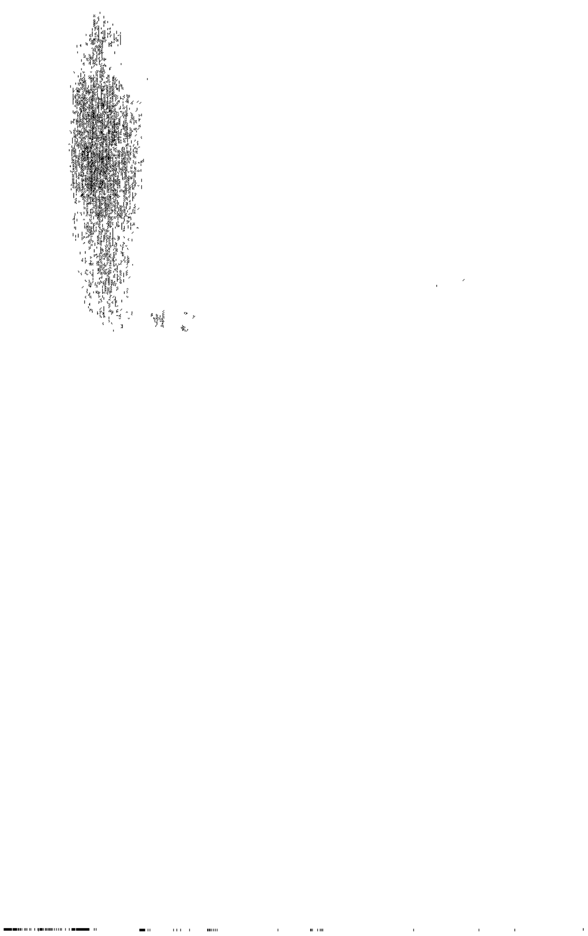
Testing Capabilities: The S2MA is equipped with one stingholder sector and a variety of stings to put together test setups in modular fashion. These stings include a variable-elbow sting; a set of cranked, deflected, and roll-motorized stings; and a wall turret. Several special test devices can also be used in the S2MA. These include a CTS device with six-

Figure V.33: ONERA S2MA Wind Tunnel



Source: ONERA

Figure V.35: Airbus Model on Variable-Elbow Sting in Transonic Test Section of the ONERA S2MA Wind Tunnel



Source: ONERA

Figure V.37: Rafale Model on Sideslip Sting Assembly With Motorized Roll in Transonic Test Section of the ONERA S2MA Wind Tunnel

Source: ONERA

ONERA S3MA Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Modane, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre

International Cooperation: Not available

Point of Contact: Jean Laverre, Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Tel.: [33]-(79)-20-20-00

Test Section Size: 0.78 x 0.56 m (transonic) and 0.80 x 0.76 m (supersonic)

Operational Status: Active

Utilization Rate: 3 to 20 runs per day or about 1,000 runs per year. Tests total almost 1,500 to 1,700 hours per year (of which about 500 to 567 hours are actual test run time).

Performance
Mach Number: 0.1 to 1.1 (subsonic/transonic); 2, 3.4, 4.5, and 5.5 (supersonic fixed nozzle); and 1.7 to 3.8 (supersonic variable nozzle)
Reynolds Number: 64 x 10^6/m
Total Pressure: 0.2 to 4 bars (transonic) and 4 to 7.5 bars (supersonic); minimum varies from 0.2 to 1.4 bars, depending on Mach number
Dynamic Pressure: 3 to 158 kN/m^2
Total Temperature: 530 degrees Kelvin (maximum)
Run Time: 10 s to 50 min
Comments: None

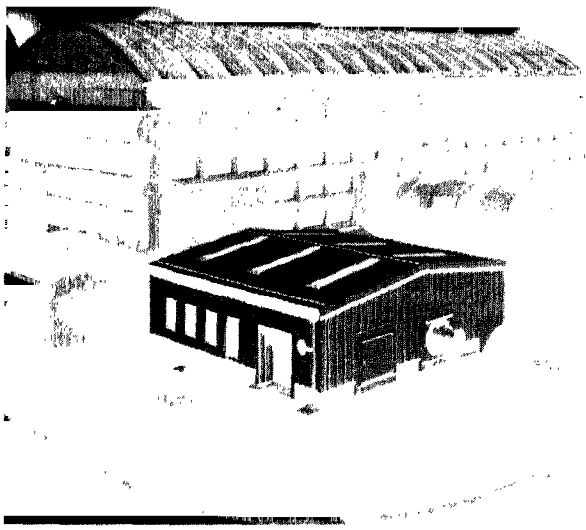
Cost Information
Date Built: 1959
Date Placed in Operation: 1959
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $26.8 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 12

Description: The ONERA S3MA Wind Tunnel is a transonic/supersonic blowdown wind tunnel that has several interchangeable test sections. The subsonic and transonic test section measures 0.78 × 0.56 m with perforated walls. A second subsonic and transonic test section with perforated walls has the same cross section as the first test section and is used for testing airfoils in a two-dimensional flow. The supersonic test section measures 0.80 × 0.76 m. It has symmetrical fixed-blocked nozzles establishing flows at Mach 2, 3.4, 4.5, and 5.5. It also has one variable-Mach nozzle for flows from Mach 1.7 to 3.8. The S3MA is supplied from the Modane-Avrieux Centre's store of compressed air (500 to 5,500 m^3 of air at 90 bar), which, depending on test conditions, is exhausted either into the atmosphere or into vacuum spheres. The usable blowdown time is about 10 s to 50 min. One side of the tunnel completely opens between the settling chamber and quadrant to provide quick access to the model or to remove the nozzle.

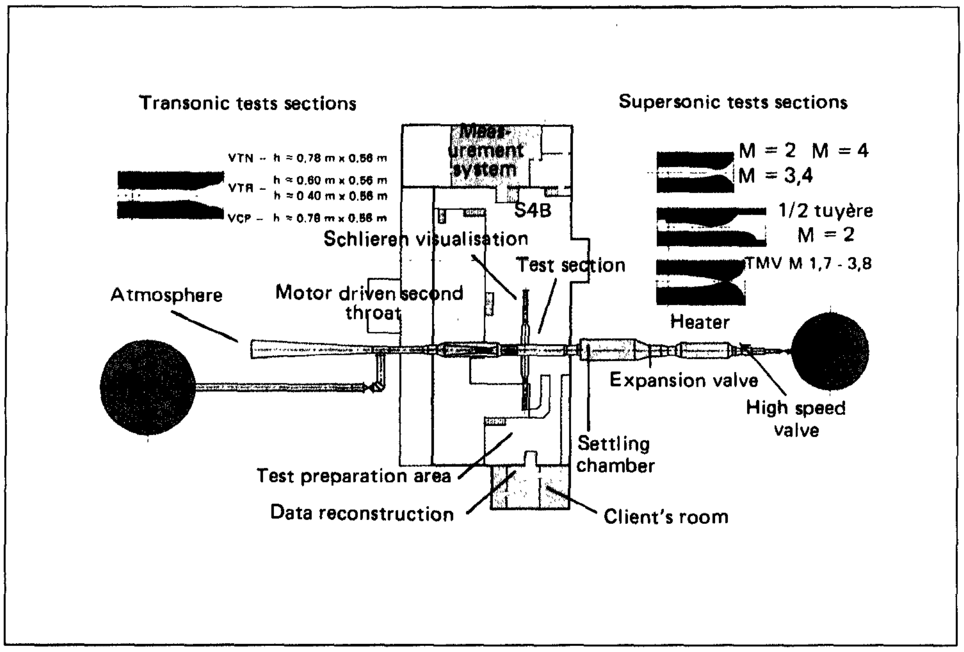
Testing Capabilities: The S3MA is equipped with a remote-controlled stingholder sector that can also be fitted with a roll drive device. A wide

Figure V.39: ONERA S3MA Wind Tunnel



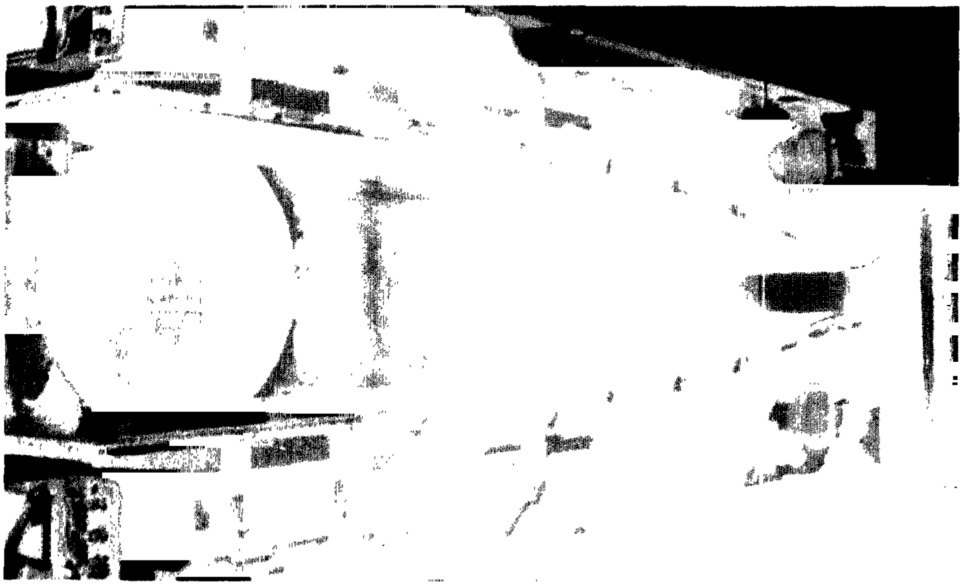
Source: ONERA

Figure V.41: Schematic Diagram of the ONERA S3MA Wind Tunnel



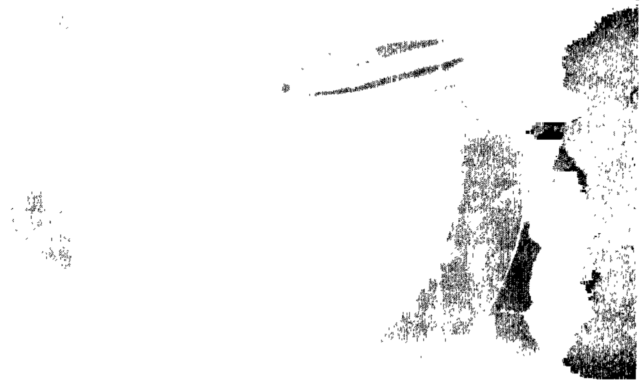
Source: ONERA

Figure V.42: Variable Mach Nozzle of the ONERA S3MA Wind Tunnel



Source: ONERA

Figure V.45: External Aerodynamics Model With Quarter-Circle Air Intake in Test Section of the ONERA S3MA Wind Tunnel



Source: ONERA

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 174.

Date of Information: January 1985

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 80 (EOARD Technical Report).

Date of Information: August 1986

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 85 (EOARD Technical Report).

Date of Information: August 1986

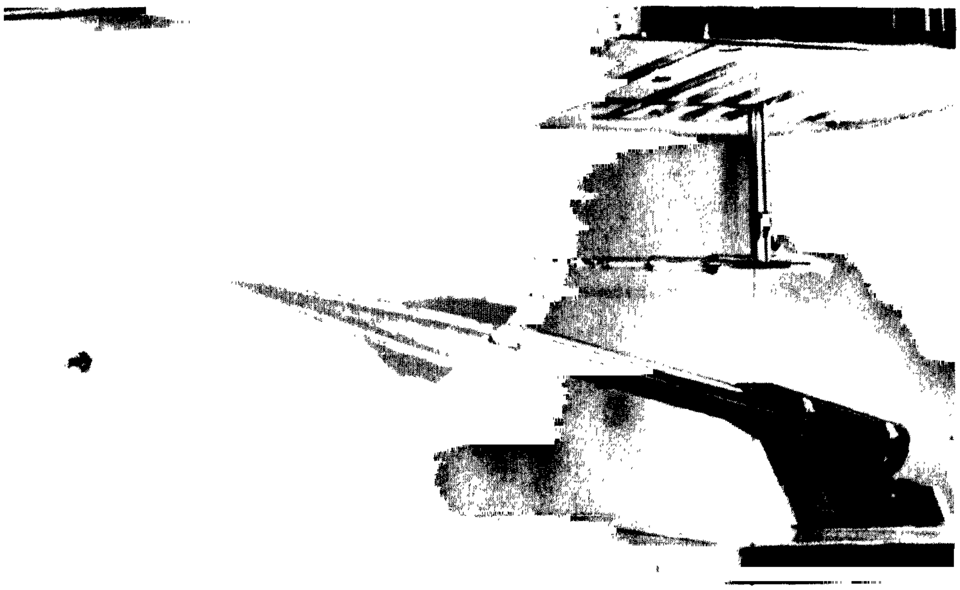
the addition of a second circuit to the tunnel and an adapted test volume (0.45 m x 1.2 m²), studies of cascades were begun, initially in the high subsonic regime over stator blades, then in the supersonic regime through pairs of rotor blade cascades. Currently the S5Ch is used mainly for testing air-breathing missile air intakes and for fundamental research such as the effect of surface temperature on the shock wave boundary layer interaction in supersonic flow. A test section of annular cascades is presently being studied in collaboration with ONERA's Energetics Department.

Photograph/Schematic Available: Yes

References: ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, p. 12.

Date of Information: January 1989

Figure V.46: Probing of the Flow on the Upper Surface of a Dual-Sweep Wing in Supersonic Flow in the ONERA S5Ch Transonic and Supersonic Wind Tunnel



Source: ONERA

References: Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 85 (EOARD Technical Report).

Date of Information: April 1987

as stage separation of launchers and satellite direction control), has been emphasized. Hypersonic reentry aerodynamics is now under study. The SR.3 is being used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation.

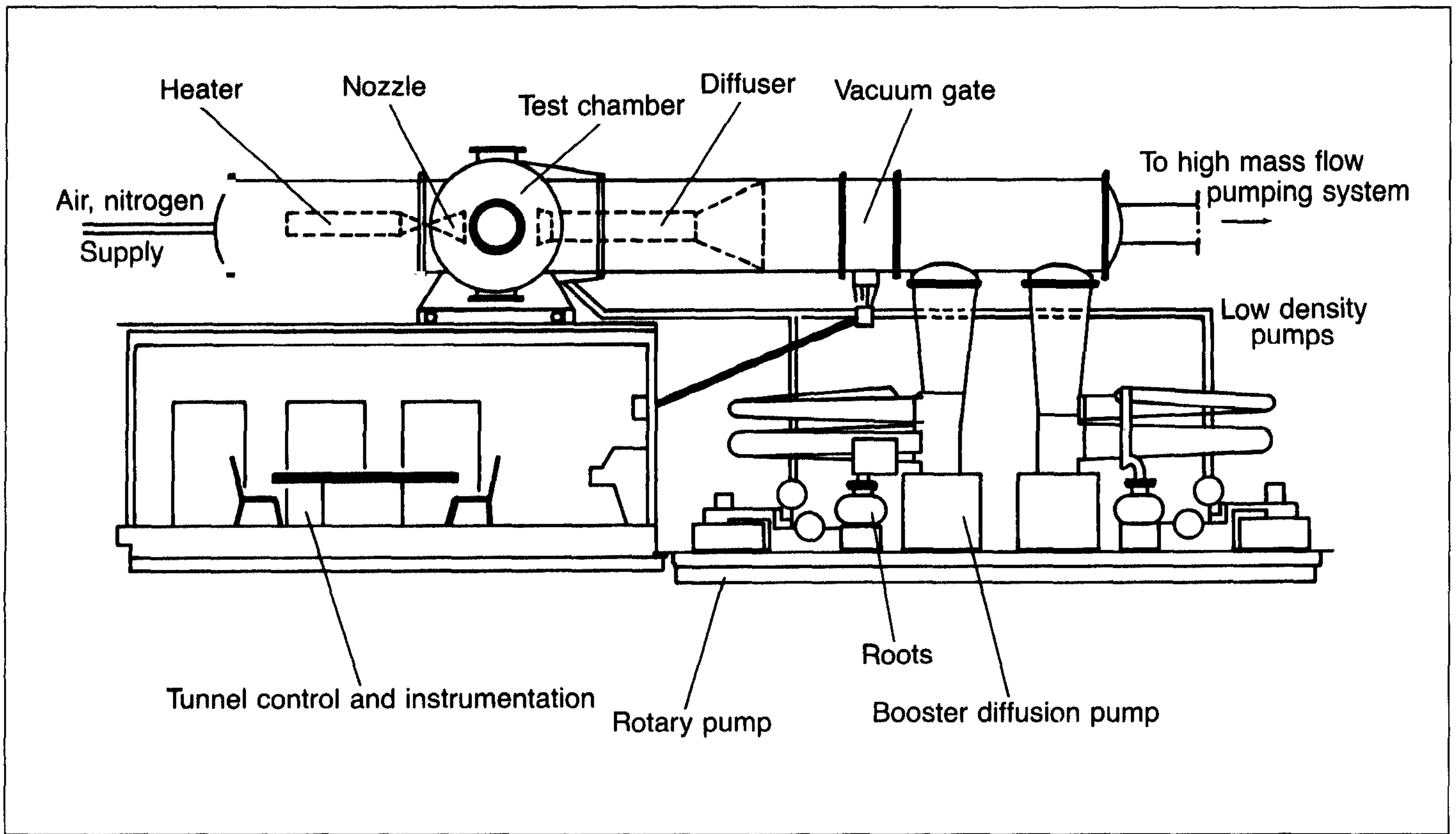
General Comments: The SR.3 is in regular use in the supersonic and hypersonic range, mainly at Mach 15 and 20.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 86 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 34 and 38-40 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). Laboratoire d'Aerothermique. The SR.3 Wind Tunnel. Meudon, France: Laboratoire d'Aerothermique.

Date of Information: October 1989

Figure V.48: Schematic Diagram of the CNRS SR.3 Wind Tunnel



Source: U.S. Air Force EOARD

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 95 (EOARD Technical Report).

Date of Information: August 1986

and model displacement systems and very sensitive balances have been installed. The tunnel is capable of testing missile stage separation with jet simulation by air or solid propellant thruster.

Data Acquisition: The R2Ch has 40 channels of data and uses a SOLAR 16-45 local computer with the R3Ch.

Planned Improvements (Modifications/Upgrades): These include an increase in the Reynolds Number range for Mach 3, 4, and 5 in 1990, an increase in nozzle size for Mach 3 and 6 in 1991, and a new data acquisition system in 1991.

Unique Characteristics: None

Applications/Current Programs: The R2Ch was first used mainly to define the aerodynamic components of most ballistic missile and hypersonic glider projects. The tunnel is used to test boundary layer transition with roughness effects, shock boundary layer interactions on a range of two- and three-dimensional shapes, and aerothermodynamics testing on reentry configurations. It is also used to study hypersonic aircraft or missiles and stage separation. By the end of 1987, the R2Ch had conducted nearly 9,400 tests.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 277. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 98 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 34-36 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, p. 13.

Date of Information: September 1989

ONERA R3Ch Blowdown Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Chalais-Meudon, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre

International Cooperation: Not available

Point of Contact: M.C. Capelier, Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Tel.: [33]-(1)-46-57-11-60

Test Section Size: 0.35 m (nozzle exit diameter at Mach 10)

Operational Status: Active

Utilization Rate: 4 tests per day

Performance
Mach Number: 10 (contoured)
Reynolds Number: 0.6 to 3.5 x 10^6/m
Total Pressure: 15 to 170 bars
Dynamic Pressure: Not available
Total Temperature: 400 to 1,100 degrees Kelvin
Run Time: 10 s at Mach 10
Comments: Starting time is 3 ms and the sweep rate is 50 degrees/10 s. The nozzle exit diameter useful core is 0.23 m.

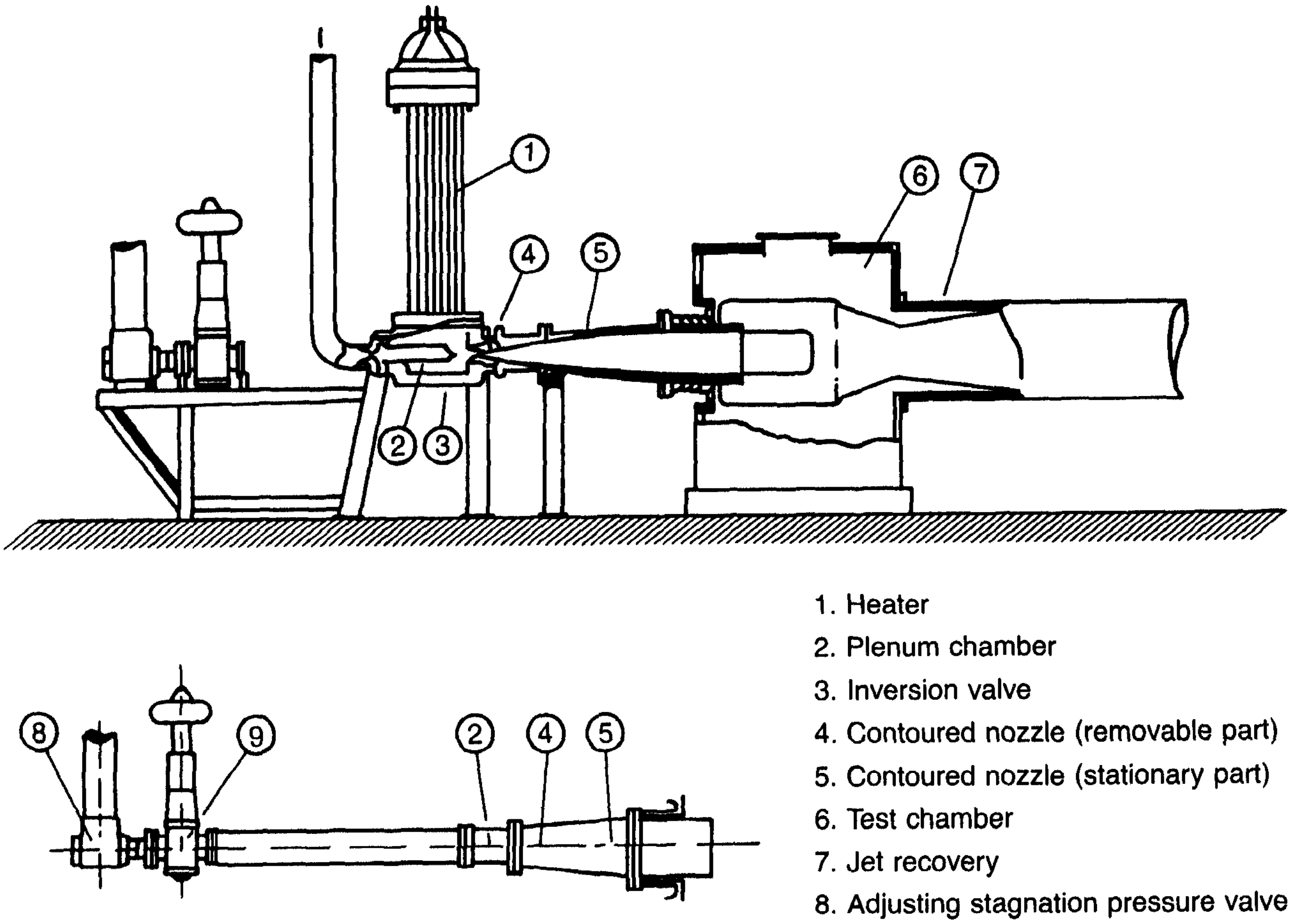
Cost Information
Date Built: 1963
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 5

Description: The ONERA R3Ch Blowdown Wind Tunnel is a blowdown, open-jet hypersonic wind tunnel. It shares some high pressure vacuum equipment with ONERA's R2Ch Blowdown Wind Tunnel. Stagnation pressures up to 2,500 psi are supplied to the R3Ch, and a complex resistance heater is used to generated stagnation temperatures of up to 1,900 degrees Rankine. Run times of approximately 10 s are obtained at Mach 10. It is equipped with a contoured Mach 10 nozzle with an exit plane diameter of 12 in. The R3Ch has a small Reynolds Number range and will give laminar flow over simple aerodynamic configurations and a mixture of laminar and transitional flows on configurations with extensively separated regions. The electrical power of the heater is continuously variable according to the stagnation.

Testing Capabilities: The R3Ch uses conventional and component sting-mounted force balances. It is also used to measure pressure distributions, heat transfer, and local skin friction. The tunnel is capable of schlieren visualization, testing wall streamliness, and measuring the heat flux by thermosensitive paints.

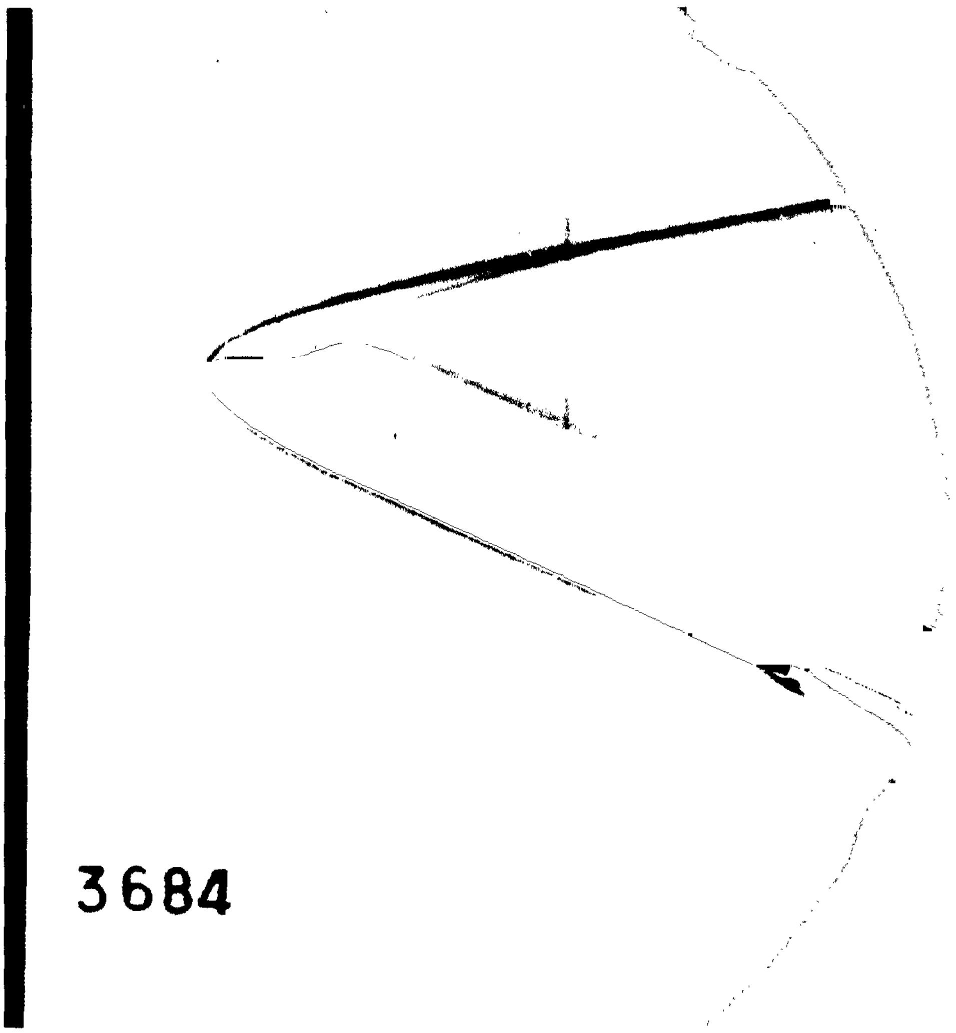
Figure V.50: Schematic Diagram of the ONERA R3Ch Blowdown Wind Tunnel



1. Heater
2. Plenum chamber
3. Inversion valve
4. Contoured nozzle (removable part)
5. Contoured nozzle (stationary part)
6. Test chamber
7. Jet recovery
8. Adjusting stagnation pressure valve
9. Adjusting stagnation pressure valve

Source: U.S. Air Force EOARD

Figure V.52: Schlieren Visualization Photograph of a Model of the Hermes Spaceplane at Mach 10 in the ONERA R3Ch Blowdown Wind Tunnel



Source: ONERA

Data Acquisition: The S4MA has 40 to 48 basic channels that can be expanded if needed. Measurement data is processed in real time by a DEC 6320 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The S4MA is used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation and ramjets.

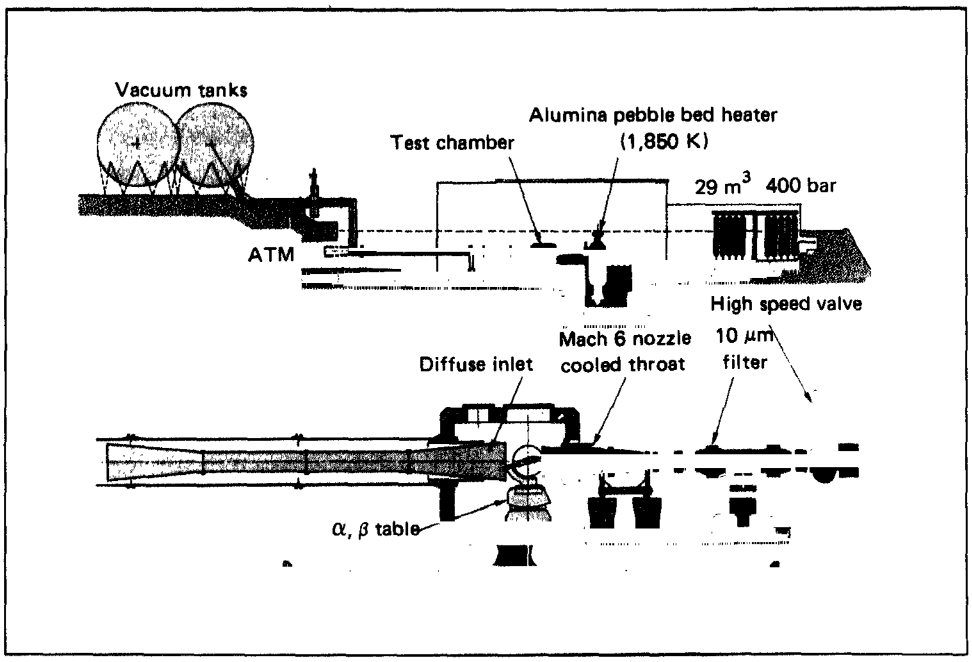
General Comments: The S4MA is the most important hypersonic facility in France, especially for mass flow. For more than 10 years, it was used only as a hot gas generator for air-breathing missile tests. At the request of CNES, the S4MA was reconfigured to its original hypersonic wind tunnel configuration to test ESA's Hermes spaceplane. In fact, the S4MA is the reference wind tunnel for Hermes. The tunnel became operational again in December 1988 after installation of the Mach 10 to 12 nozzle, work on quick-opening valves, an exchange of insulating bricks and cement in the alumina pebble bed heater (due to dust on the models during test runs), and a change of the alumina pebbles.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 264. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 99 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). ONERA. Activities 1986: Large Testing Facilities. Chatillon, France: ONERA, 1987, p. 24. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 58-59 and 70-72.

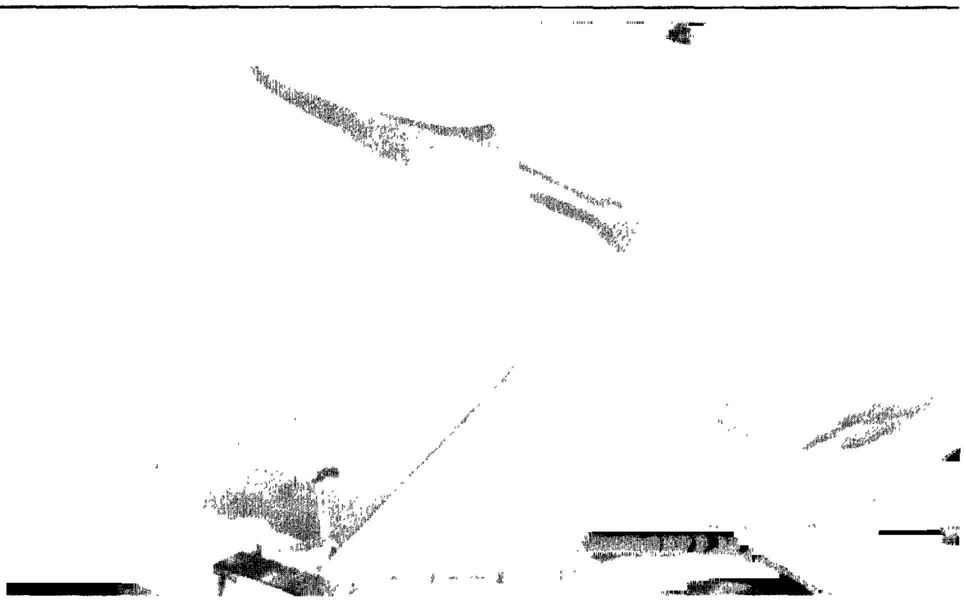
Date of Information: September 1989

Figure V.54: Schematic Diagram of the ONERA S4MA Wind Tunnel



Source: ONERA

Figure V.55: Model of the Hermes Spaceplane on Model Support Table and Mach 6 Nozzle in Test Section of the ONERA S4MA Wind Tunnel



Source: ONERA

Figure V.57: Model Inside Test Chamber of the ONERA S4MA Wind Tunnel

Source: ONERA

References: Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: April 1987

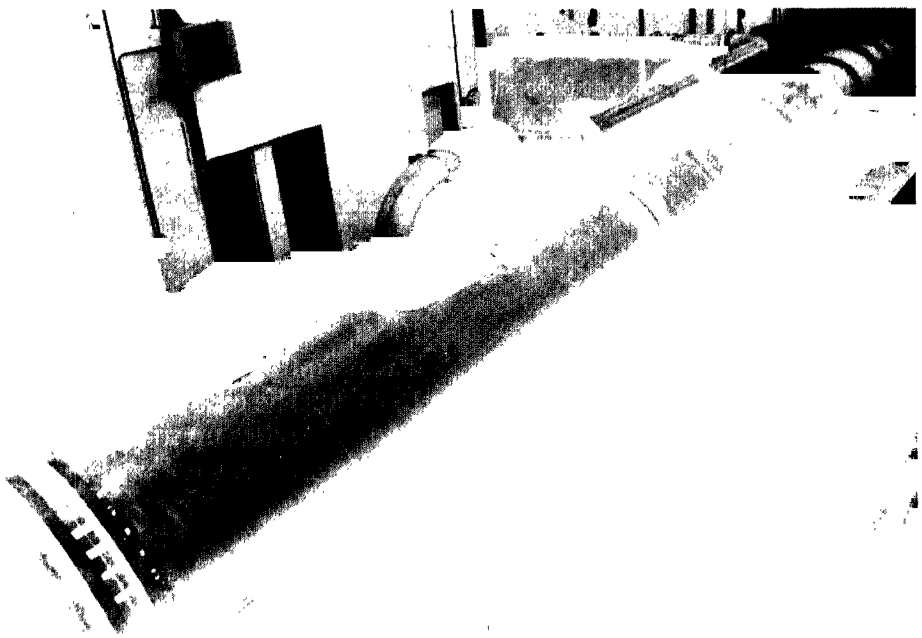
General Comments: The tunnel's nozzle exit diameter is 107 cm with a useful core of 30 to 60 cm. LRBA belongs to the Directorate for Engines, General Delegate for Armament, French Ministry of Defense.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 96 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 257.

Date of Information: November 1989

Figure V.58: LRBA C_2 Reflected Shock Tunnel



Source: LRBA

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: The ONERA ARC 2 Hotshot Wind Tunnel has been dismantled. Elements of the tunnel are being used in the ONERA F4 Wind Tunnel currently under construction at ONERA's Le Fauga-Mauzac Centre near Noe, France. In 1986, the ONERA ARC 2 Hotshot was inoperable because of damage to the energy generator. Although the reservoir temperatures and pressures suggested an impressive performance, the medium in a hotshot facility is not clean and the only two comparable U.S. facilities (AEDC's Tunnel F and Boeing's Hotshot Tunnel) were scrapped because of lack of confidence in test results.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 100 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 34 and 36-38 (EOARD Technical Report).

Date of Information: October 1989

ONERA F4 Hotshot Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre, Noe, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator: Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre

International Cooperation: Not available

Point of Contact: Jean-Marie Carrara, Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre, Tel.: [33]-(61)-56-63-01

Test Section Size: 0.4 to 1 m (nozzle exit diameter)

Operational Status: Under construction

Utilization Rate: Unknown

Performance
Mach Number: 7 to 18
Reynolds Number: Not available
Total Pressure: 2,000 bars (maximum)
Dynamic Pressure: Not available
Total Temperature: Reduced enthalpy less than 200 degrees Kelvin
Run Time: 20 to 100 ms
Comments: None

Cost Information
Date Built: 1989
Date Placed in Operation: Expected in 1990
Date(s) Upgraded: Not applicable
Construction Cost: $10.6 million (1989)
Replacement Cost: Not applicable
Annual Operating Cost: Unknown
Unit Cost to User: Unknown
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ONERA F4 Hotshot Wind Tunnel will be a hotshot hypervelocity wind tunnel. The energy will be stored in an inertial wheel (15,000 kg at 6,000 rpm) connected to an alternator rotor shaft. The electrodes in the arc chamber will be connected to the stator. The excitation of the rotor will produce a reduction of the wheel rpm and an electrical discharge at very high power (maximum 150 MW during about 0.1 s) in the arc chamber, with an increase of pressure and enthalpy of the gas (air or nitrogen).

Testing Capabilities: Various nozzles will be used (with an exit diameter ranging from 0.4 to 1 m), according to the required simulation (Mach number, Reynolds Number, velocity, and kinetics parameter). The F4 Hotshot will be capable of conducting tests of forces and pressures, heat flux measurements and flow diagnostics (validation of CFD codes).

Data Acquisition: The F4 Hotshot will have 70 channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

CEPr C-1 Altitude Engine Test Facility

Country: France

Location: Centre d'Essais des Propulseurs de Saclay, Orsay, France

Owner(s):
Centre d'Essais des Propulseurs de Saclay
F-91406 Orsay Cedex
France

Operator(s): Centre d'Essais des Propulseurs de Saclay

International Cooperation: Not available

Point of Contact: M. Fayot, Centre d'Essais des Propulseurs de Saclay, Tel.: [33]-(6)-941-81-50

Test Cell Size: 11 ft diameter x 26 ft long

Operational Status: Not available

Utilization Rate: Not available

Performance
Mass Flow: 121 lb/s
Altitude Range: 36,000 ft
Temperature Range: −86 to 175 degrees Fahrenheit
Pressure Range: 7 to 17 psia
Speed Range: Mach 0 to 1
Comments: Free-jet and direct-connect turboshaft engines up to 27,000-hp can be tested.

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The CEPr C-1 is an altitude engine test facility with both free-jet and direct-connect testing capability. The capacity of the installed thrust stand is about 2,250 lb/ft.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: These include turboshaft engines.

General Comments: None

Photograph/Schematic Available: No

CEPr R-3 Altitude Engine Test Facility

Country: France

Location: Centre d'Essais des Propulseurs de Saclay, Orsay, France

Owner(s):
Centre d'Essais des Propulseurs de Saclay
F-91406 Orsay Cedex
France

Operator(s): Centre d'Essais des Propulseurs de Saclay

International Cooperation: Not available

Point of Contact: M. Fayot, Centre d'Essais des Propulseurs de Saclay, Tel. [33]-(6)-941-81-50

Test Cell Size: 11.5 ft diameter x 60 ft long

Operational Status: Not available

Utilization Rate: Not available

Performance
Mass Flow: 441 lb/s
Altitude Range: 65,600 ft
Temperature Range: −85 to 390 degrees Fahrenheit
Pressure Range: 30 psia
Speed Range: Mach 0 to 2.4
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The CEPr R-3 is an altitude engine test facility with both free-jet and direct-connect testing capability. The thrust level is 45,000 lb/ft.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: These include testing small turbojets.

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 88.

Date of Information: December 1985

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 88.

Date of Information: December 1985

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 89.

Date of Information: December 1985

ONERA ATD Ramjet Cells Nos. 8 and 9

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Palaiseau Centre, Palaiseau, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Palaiseau Centre

International Cooperation: Not available

Point of Contact: P. Cazin and P. Kuentzmann, Office National d'Etudes et de Recherches Aerospatiales, Chatillon Centre, Tel.: [33]-(1)-4657-11-60

Test Section Size: Up to 430 mm (nozzle exit diameter)

Operational Status: Active

Utilization Rate: Intensive (400 hours per year)

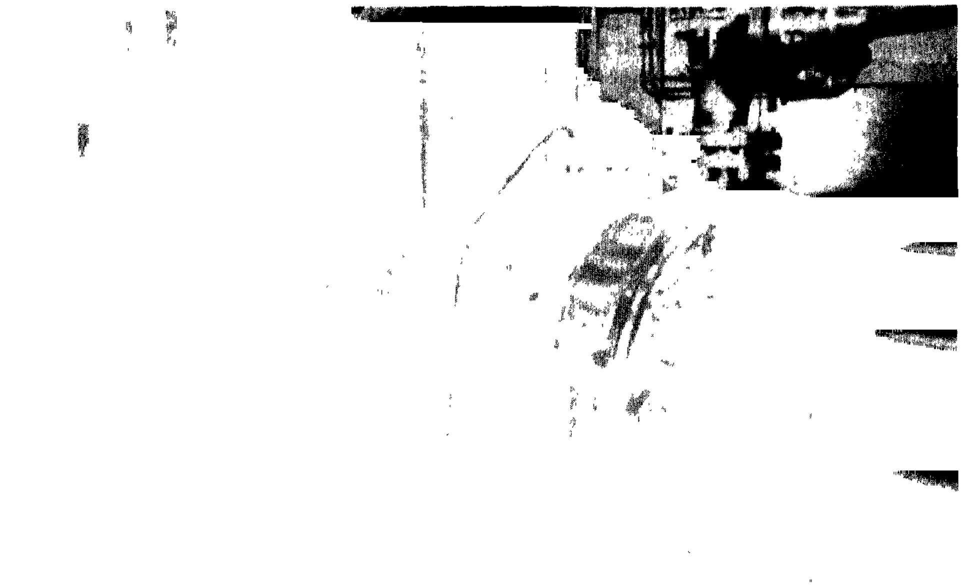
Performance
Mach Number: Up to 4.5
Altitude: Up to 30,000 m
Mass Flow: Up to 50 kg/s
Pressure: Air stored at 250 bars
Temperature Range: Up to 1,200 degrees Kelvin
Thrust Level: Up to 60,000 N
Run Time: Virtually unlimited in stand no. 4
Comments: Air and fuel mass flow rates, stagnation temperature, and pressure are regulated by computer.

Cost Information
Date Built: 1970 to 1979
Date Placed in Operation: 1970 to 1979
Date(s) Upgraded: Permanent upgrading
Construction Cost: $10,395,010 (1979)
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: See General Comments

Number and Type of Staff
Engineers: 4 (engineers and/or scientists)
Scientists: (See engineers)
Technicians: 5
Others: 3
Administrative/Management: 0
Total: 12

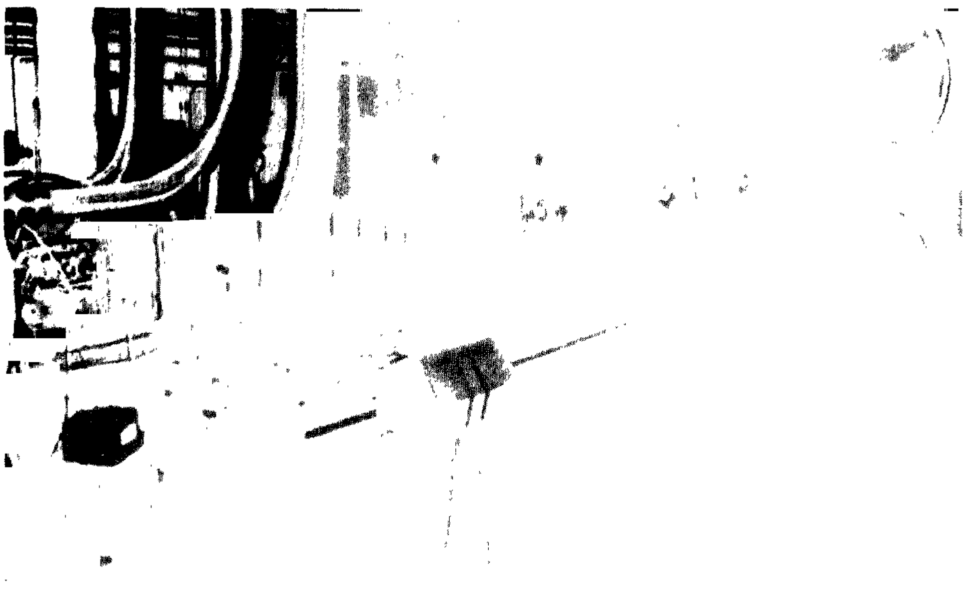
Description: The ONERA Aerothermodynamic (ATD) Ramjet Cells Nos. 8 and 9 are part of the large facilities located at ONERA's Palaiseau Centre needed for research on air-breathing combustors. Of the nine ATD system cells, only numbers 5, 7, 8, and 9 are currently being used for research on air-breathing combustion. Cells Nos. 8 and 9 are equipped for perfecting operational ramjets. This activity requires large facilities, including general support and four test stands. General support equipment includes (1) inlet air heaters, operating by the combustion of hydrogen and the reoxygenation of the effluents, to achieve a temperature of 1,200 degrees Kelvin, (2) a nozzle-effect vacuum generator to lower the ambient pressure to 0.1 bars in the outlet plane of the combustor nozzles, (3) a liquid fuel supply with a controlled temperature ranging from −40 degrees Celsius to 70 degrees Celsius, and (4) numerous measurement devices and automatic systems controlling the operation of the engine and of the test facility. The tests are run either in a forced pipe, in which the combustor caliber may reach 430 mm, or in a semi-free jet where the caliber is limited to 200 mm. The ramjet test cells use water vitiated air feeding. Liquid and solid fuel (or rich fuel solid propellants) are used to test ramjets.

Figure V.61: Kerosene Injection Research Stand in the ONERA ATD Cell No. 7



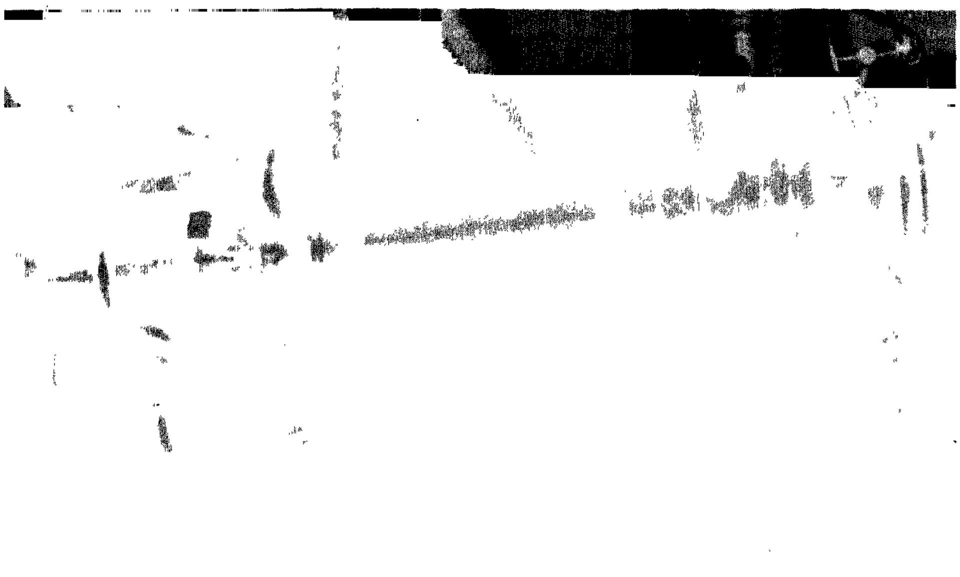
Source: ONERA

Figure V.62: Balance and Dynalpy Decoupling System at Inlet in Test Stand No. 1 of the ONERA ATD Ramjet Cells Nos. 8 and 9



Source: ONERA

Figure V.65: Test of Ceramic Materials on 100-mm Caliber Engine in Test Stand No. 4 of the ONERA ATD Ramjet Cells Nos. 8 and 9



Source: ONERA

CIRA Low-Speed Wind Tunnel

Country: Italy

Location: Centro Italiano Ricerche Aerospaziali, Capua, Italy

Owner(s):
Centro Italiano Ricerche Aerospaziali
Via Filangieri, 21
80100 Naples
Italy

Operator(s): Centro Italiano Ricerche Aerospaziali

International Cooperation: None

Point of Contact: Dott. Ing. Mario Apolloni, Centro Italiano Ricerche Aerospaziali, Tel.: [39]-(81)-42-68-15

Test Section Size: 4.5 x 3.5 m (S1) and 6.4 x 5 m (S2)

Operational Status: Planned

Utilization Rate: Unknown

Performance
- **Mach Number:** 0.05 (S2) to 0.1 (S1)
- **Reynolds Number:** 2.3×10^6/m
- **Total Pressure:** Ambient plus dynamic pressure
- **Dynamic Pressure:** Up to 77 mbars
- **Total Temperature:** Ambient
- **Run Time:** Continuous
- **Comments:** None

Cost Information
- **Date Built:** Planned
- **Date Placed in Operation:** Not available
- **Date(s) Upgraded:** Not applicable
- **Construction Cost:** About $45 million (1988)
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Unknown
- **Unit Cost to User:** Unknown
- **Source(s) of Funding:** Italian government

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The CIRA Low-Speed Wind Tunnel will be a subsonic wind tunnel. It will have two interchangeable closed test sections that will allow tests on both Short Takeoff and Landing (STOL) and Vertical Take-off and Landing (VTOL) helicopter models. An open test section will provided for noise testing and other applications.

Testing Capabilities: Static and dynamic measurements will be made of forces and moments and pressures of both powered and unpowered models. In addition to those usual capabilities, the tunnel will also provide the capability for flow visualization, particle image velocimetry (PIV), and laser Doppler velocimetry by means of a dedicated laser system.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: The flow qualities required in the tunnel specifications will exceed NATO AGARD specifications.

Applications/Current Programs: Not available

CIRA High Reynolds Transonic Wind Tunnel

Country: Italy

Location: Centro Italiano Ricerche Aerospaziali, Capua, Italy

Owner(s):
Centro Italiano Ricerche Aerospaziali
Via Filangieri, 21
80100 Naples
Italy

Operator(s): Centro Italiano Ricerche Aerospaziali

International Cooperation: None

Point of Contact: Dott. Ing. Mario Apolloni, Centro Italiano Ricerche Aerospaziali, Tel. [39]-(81)-42-68-15

Test Section Size: 4.5 x 3.5 m

Operational Status: Planned

Utilization Rate: Unknown

Performance
Mach Number: 0.24 to 0.4 (continuous mode) and 0.4 to 1.4 (planned blowdown)
Reynolds Number: 14 x 10^6/m
Total Pressure: 0.5 to 6.1 bars
Dynamic Pressure: 0.257 bars at Mach 0.24
Total Temperature: 310 degrees Kelvin
Run Time: Continuous (subsonic) and 45 s (transonic with blowdown mode improvement)
Comments: Fan power is about 17 MW (subsonic).

Cost Information
Date Built: Planned
Date Placed in Operation: Expected in 1995
Date(s) Upgraded: Not applicable
Construction Cost: About $120 million (1988)
Replacement Cost: Not available
Annual Operating Cost: Unknown
Unit Cost to User: Unknown
Source(s) of Funding: Italian government

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The CIRA High Reynolds Transonic Wind Tunnel will be a pressurized transonic wind tunnel with interchangeable closed test sections that will provide the capability to test STOL, VTOL, and helicopter models. Four different carts will be provided to perform different types of tests. The planned air storage system will require around 2,000 m^3 tanks at 90 bars pressure. The filling of the tunnel and of the tanks will be by multistage compressors with a flow rate of about 35 kg/s.

Testing Capabilities: The tunnel will be capable of conducting static and dynamic measurements of forces and moments and pressures of both powered and unpowered models and provide the capabilities of flutter testing at high Reynolds Number. Flow visualization, PIV, and laser Doppler velocimetry capabilities will be provided by a dedicated laser system. Air intake functioning test and thrust simulation on both jet and prop model aircraft will be provided through a 90-bar pressure compressed air storage system.

Data Acquisition: Not available

CIRA Plasma Wind Tunnel

Country: Italy

Location: Centro Italiano Ricerche Aerospaziali, Capua, Italy

Owner(s):
Centro Italiano Ricerche Aerospaziali
Via Filangieri, 21
80100 Naples
Italy

Operator(s): Centro Italiano Ricerche Aerospaziali

International Cooperation: ESA, and CNES and Avions Marcel Dassault-Breguet Aviation, France

Point of Contact: Dott. Ing. Mario Apolloni, Centro Italiano Ricerche Aerospaziali, Tel.: [39]-(81)-42-68-15

Test Section Size: 0.6 x 0.6 x 0.6 m^3

Operational Status: Planned

Utilization Rate: Unknown

Performance
Mach Number: 4 to 6
Reynolds Number: Not available
Total Pressure: 1 to 200 mbars
Dynamic Pressure: Not available
Total Temperature: Less than 2,000 degrees Celsius
Run Time: 5 to 25 min
Comments: Maximum flow rate is 0.2 to 2 kg/s.

Cost Information
Date Built: Planned
Date Placed in Operation: Expected by June 1992
Date(s) Upgraded: Not applicable
Construction Cost: About $50 million (1988)
Replacement Cost: Not available
Annual Operating Cost: Unknown
Unit Cost to User: About $1,500 per hour (1989)
Source(s) of Funding: Italian government, ESA, and CNES

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

Description: The CIRA Plasma Wind Tunnel will be an arc-driven hypersonic wind tunnel. Total enthalpy will range Between 5 and 55 MJ/kg. The normal flow rate will be 0.1 to 0.5 kg/s. Initially, two nozzles are planned: a conical nozzle for testing stagnation point region and a semielliptical nozzle for testing flat plate specimens.

Testing Capabilities: The tunnel will have thermocameras, videocameras, and pirometers.

Data Acquisition: Not available

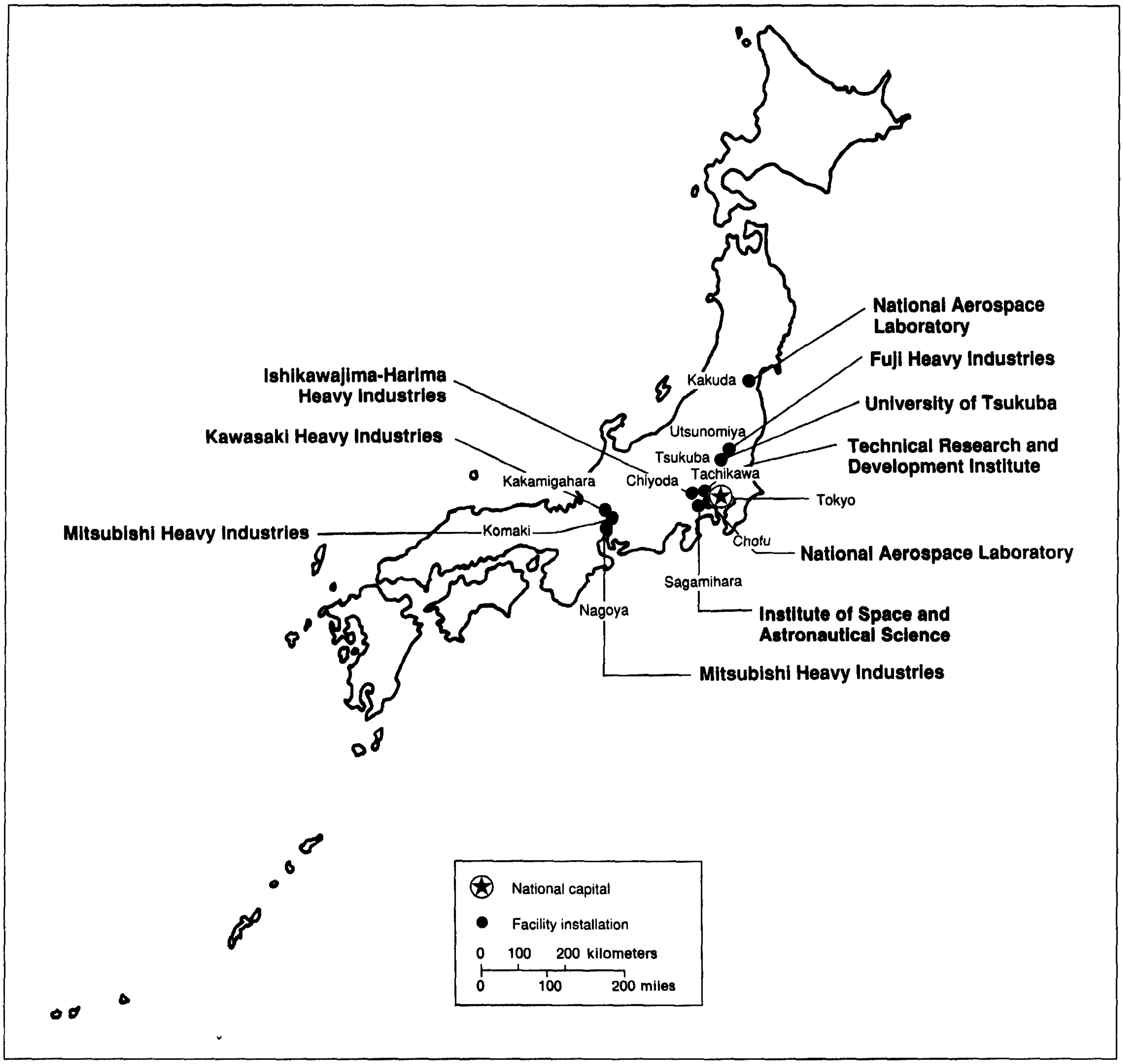
Planned Improvements (Modifications/Upgrades): An extension of test diagnostics to more sophisticated items is planned. Examples of items under consideration are CARS, laser interferometry, and holography.

Unique Characteristics: None

Applications/Current Programs: The primary purpose of the tunnel is to to study and qualify parts of the thermal protection system for the reentry phase of ESA's Hermes spaceplane.

Aerospace Test Facilities in Japan

Figure VII.1: Map of Test Facilities in Japan



Source: GAO

Unique Characteristics: None

Applications/Current Programs: The tunnel is mainly used for the study of low-speed aerodynamics, static and dynamic stability, and control of military and general aviation and transport aircraft configurations. The tunnel is rarely used for the non-aeronautical model tests (such as automobiles or containers).

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 99.

Date of Information: November 1988

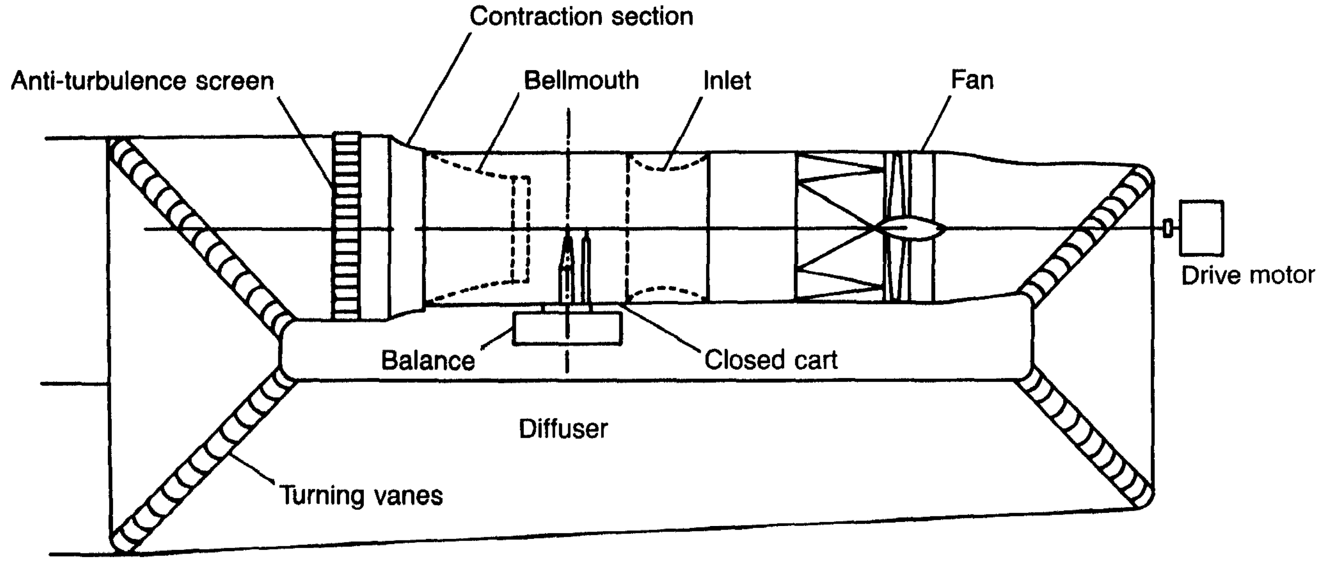
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 67.

Date of Information: October 1989

Figure VII.2: Schematic Diagram of the KHI 3.5 m Wind Tunnel



Source: KHI

MHI 2 m Low-Speed Wind Tunnel

Country: Japan

Location: Mitsubishi Heavy Industries, Nagoya, Aichi Prefecture, Japan

Owner(s):
Mitsubishi Heavy Industries
Nagoya Aerospace SystemsWorks
10 Oye-cho, Minato-ku
Nagoya
Aichi Prefecture 445
Japan

Operator(s): Mitsubishi Heavy Industries, Nagoya Aerospace Systems Works

International Cooperation: None

Point of Contact: Haruhiko Arakawa, Mitsubishi Heavy Industries, Tel.: [81]-(52)-611-8011

Test Section Size: 1.8 x 2 x 2.5 m

Operational Status: Active

Utilization Rate: 10 hours per day

Performance
Mach Number: 0.06 to 0.23 or 20 to 85 m/s
Reynolds Number: 0.4 to 2 x 10^6/m
Total Pressure: Atmospheric
Dynamic Pressure: 0.245 to 4.428 kN/m^2
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1928
Date Placed in Operation: 1928
Date(s) Upgraded: 1957, 1971, 1983, and 1989
Construction Cost: Not available
Replacement Cost: $4.3 million (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

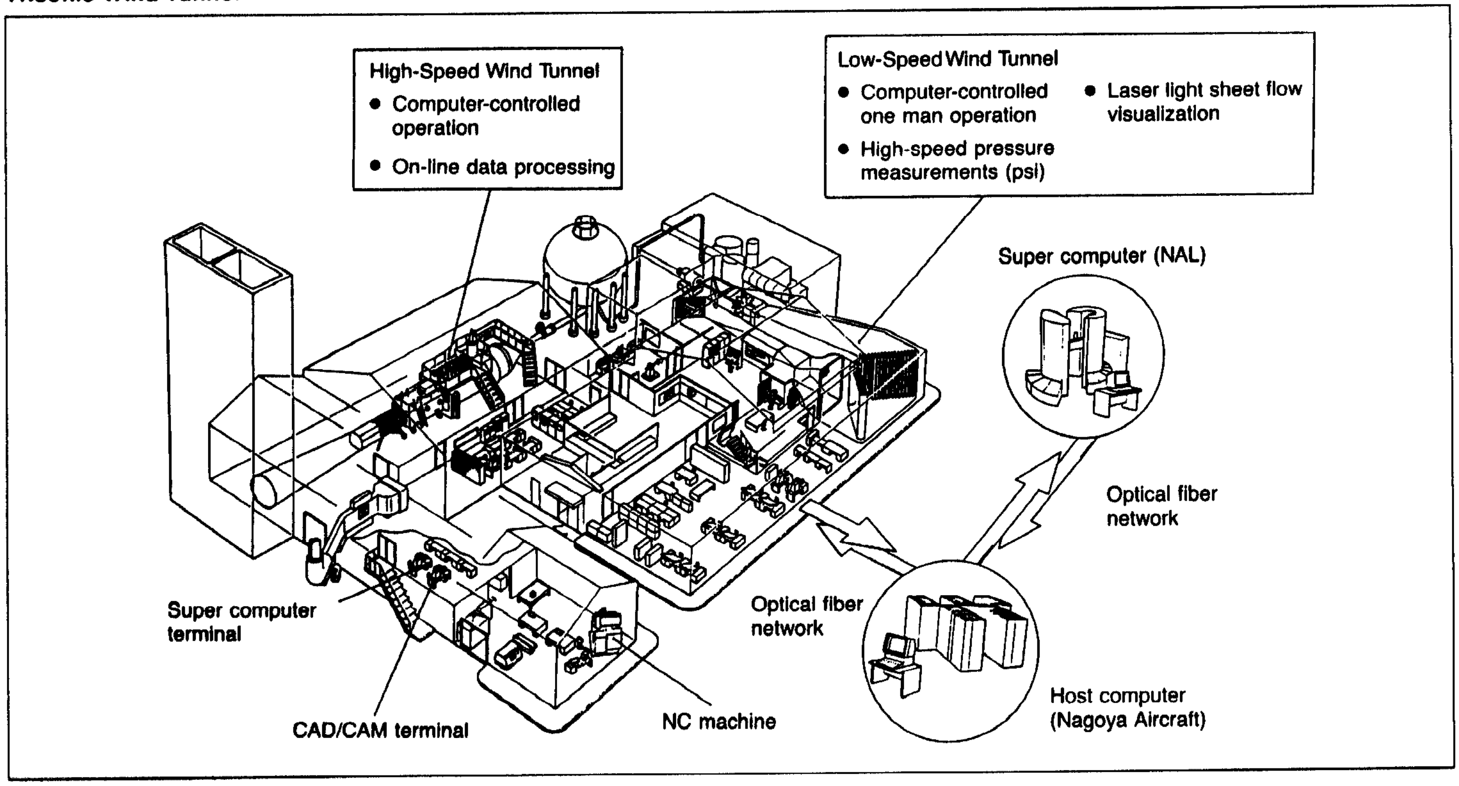
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The MHI 2 m Low-Speed Wind Tunnel is a continuous-flow, closed-circuit, single-return subsonic wind tunnel.

Testing Capabilities: The tunnel is capable of conducting six-component force tests, pressure distribution tests, half-model tests, power effect (air intake or exhaust) tests, wake measurement tests, and flow visualization tests. Two types of supporting models are available: sting support and strut support. Balances include both internal six-component and sidewall. The range of angle of attack is from −30 to 60 degrees and bank angle from −180 to 180 degrees. The strut-support system covers attack angle from −13 to 22 degrees and yaw angle from −90 to 90 degrees. The power effect equipment has a capability to produce pressurized air (cold) up to 8 kg/cm^2 and a weight flow rate of 2 kg/s. The tunnel is powered by a 450-kW DC motor with 8-bladed, 3-m diameter, variable pitch fans. The data acquisition/processing and tunnel control system was upgraded in 1983 to enable automatic model attitude setting, flow velocity control, data acquisition, and data processing. A PSI scanning system is available for pressure measurements.

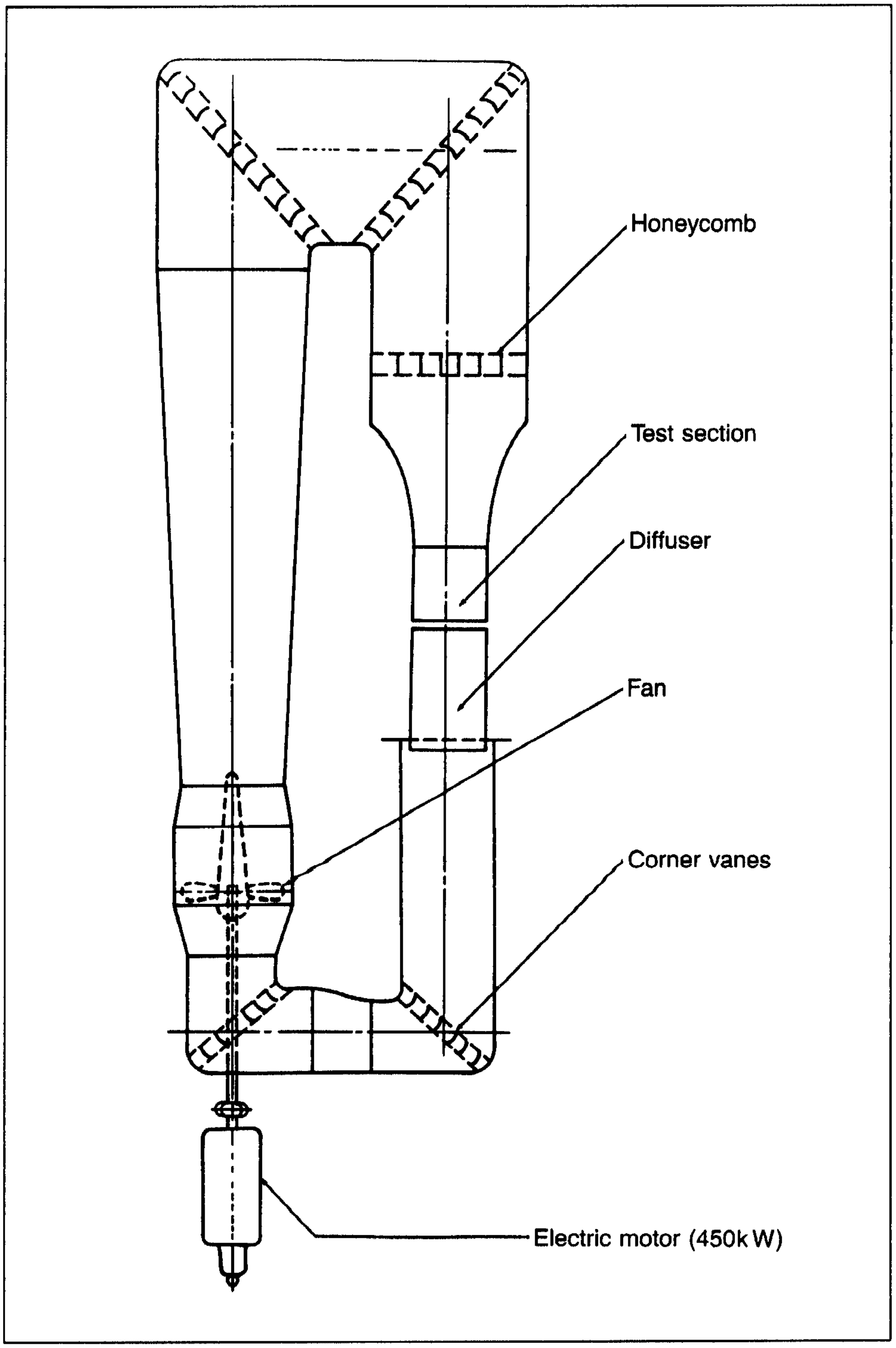
Data Acquisition: The tunnel has the capability to record 18-channel force data and 5-channel pressure data simultaneously. The IBM

Figure VII.4: Schematic Drawing of the MHI Aerodynamics Laboratory With the MHI 2 m Low-Speed Wind Tunnel and MHI 60 cm Trisonic Wind Tunnel



Source: MHI

Figure VII.6: Schematic Diagram of the MHI 2 m Low-Speed Wind Tunnel



Source: MHI

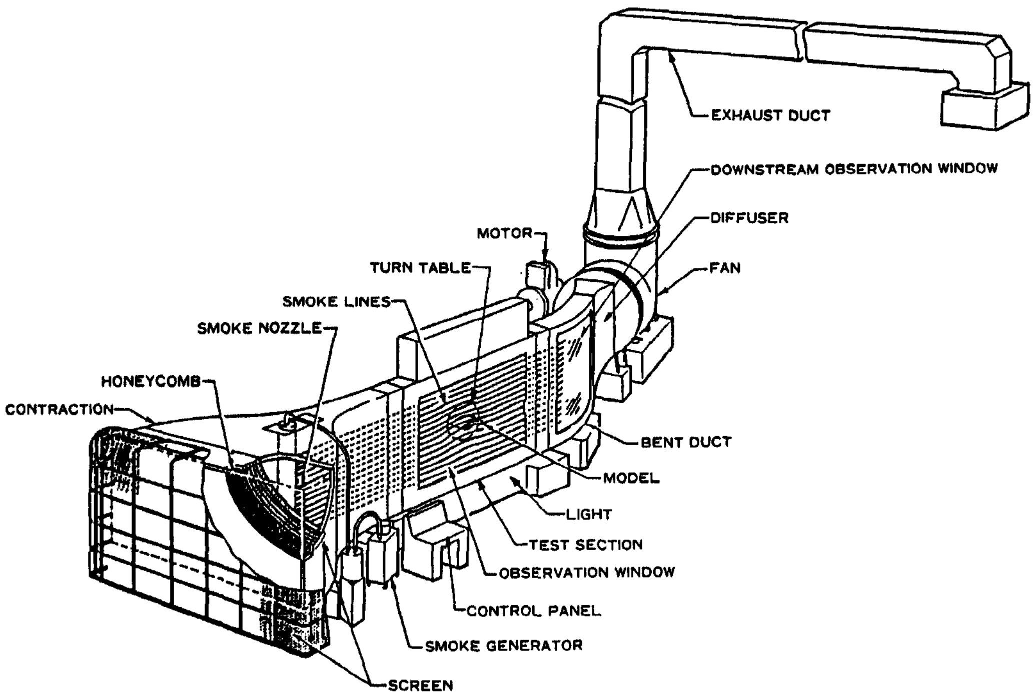
General Comments: None

Photograph/Schematic Available: Yes

References: None available

Date of Information: December 1988

Figure VII.7: Schematic Drawing of the MHI Smoke Tunnel



Source: MHI

Applications/Current Programs: Current applications include studies of the low-speed aerodynamic characteristics (at takeoff and landing) of conventional and V/STOL airplanes, laminar flow control technology, active control technology, and advanced turboprops.

General Comments: An important feature of the NAL 6 m Low-Speed Wind Tunnel LS is its large test section which permits high angle of attack and/or power tests of large, full-component aircraft models.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 50. National Aerospace Laboratory. NAL 1988. Chofu-shi, Tokyo: National Aerospace Laboratory, 1988, p. 16.

Date of Information: October 1989

Unique Characteristics: None

Applications/Current Programs: The horizontal tunnel is used to conduct research on the low-speed aerodynamics of military aircraft and on low-speed wind tunnel testing techniques. The vertical tunnel is used to conduct research on the rotary aerodynamics of military aircraft during spin motions and on spin test techniques.

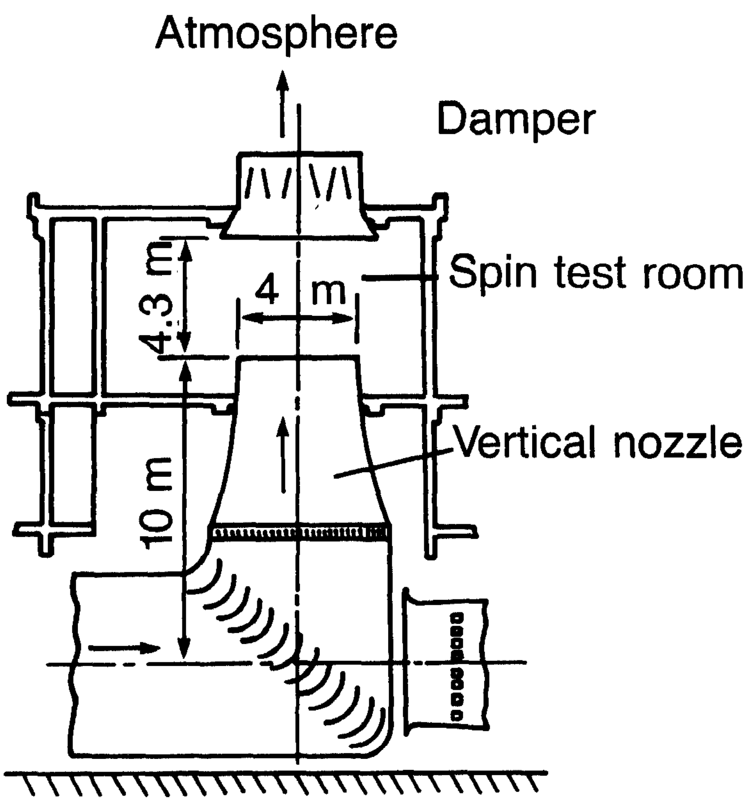
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank. E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 84.

Date of Information: October 1989

Figure VII.9: Sectional View of the Vertical Configuration of the TRDI Convertible Wind Tunnel



Source: TRDI

Applications/Current Programs: These include studying high angle of attack aerodynamic characteristics, low-speed aerodynamics of military aircraft, and low-speed wind tunnel testing techniques. The tunnel is also being used for studying store separation testing techniques.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 86.

Date of Information: October 1989

University of Tsukuba Cryogenic Wind Tunnel

Country: Japan

Location: University of Tsukuba, Institute of Engineering Mechanics, Tsukuba, Ibaraki Prefecture, Japan

Owner(s):
University of Tsukuba
Institute of Engineering Mechanics
1-1-1 Tennodai
Tsukuba
Ibaraki Prefecture 305
Japan

Operator(s): University of Tsukuba, Institute of Engineering Mechanics

International Cooperation: Not available

Point of Contact: Tsutomu Adachi, University of Tsukuba, Institute of Engineering Mechanics, Tel.: [81]-(298)-53-5121

Test Section Size: 0.5 x 0.5 x 1.2 m

Operational Status: Active

Utilization Rate: 100 hours (1988)

Performance
Mach Number: 0.09 to 0.19 or 30 to 65 m/s
Reynolds Number: 1 x 10^5/ft to 1 x 10^7/ft (with a reference length of 50 mm)
Total Pressure: Up to 8 bars
Dynamic Pressure: 0.54 to 60 kN/m^2
Total Temperature: 100 to 300 degrees Kelvin
Run Time: Not available
Comments: Test gas used is nitrogen.

Cost Information
Date Built: 1982
Date Placed in Operation: 1984
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 3
Scientists: 1
Technicians: 0
Others: 0
Administrative/Management: 1
Total: 5

Description: The University of Tsukuba Cryogenic Wind Tunnel is a continuous-flow, closed-circuit subsonic wind tunnel. The inside of the tunnel is thermal-shielded.

Testing Capabilities: Models can be set in the test section. Model angle to the flow can be controlled by a worm and worm wheel mechanism from outside of the tunnel. Temperature and velocity can be measured using a traversing mechanism, which is controlled from outside of the tunnel.

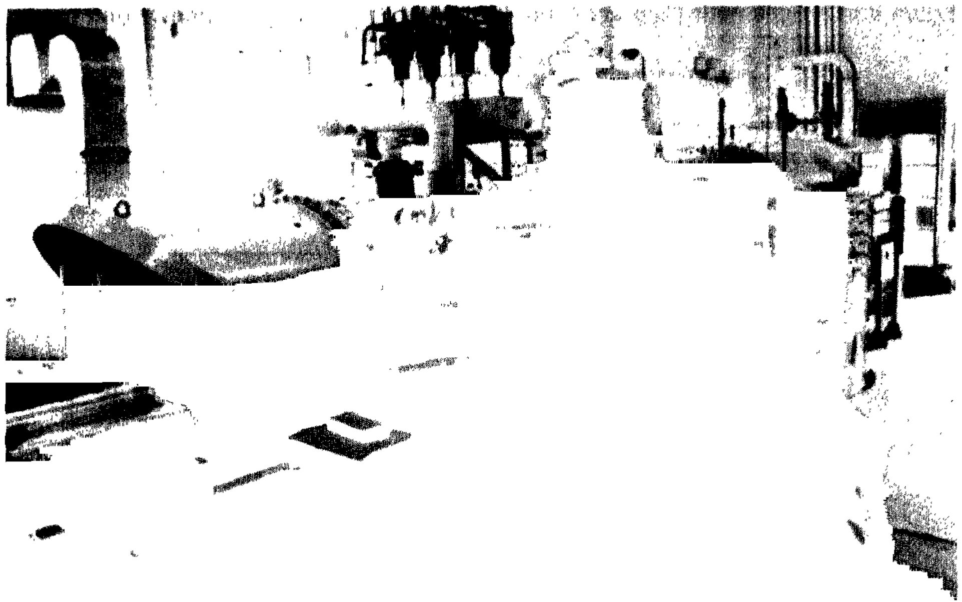
Data Acquisition: The tunnel has 50 temperature outputs and 50 pressure outputs that can be taken and analyzed from outside of the tunnel.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Research is mainly directed to the study of low-speed and high Reynolds Number aerodynamics, especially the study of drag and vortex shedding of two-dimensional bodies (circular and square cylinders).

Figure VII.11: University of Tsukuba Cryogenic Wind Tunnel



Source: University of Tsukuba

ISAS Transonic Wind Tunnel

Country: Japan

Location: Institute of Space and Astronautical Science, Sagamihara-shi, Kanawaga Prefecture, Japan

Owner(s):
Institute of Space and Astronautical Science
3-1-1 Yoshinodai
Sagamihara-shi
Kanagawa Prefecture 229
Japan

Operator(s): Institute of Space and Astronautical Science

International Cooperation: None

Point of Contact: Professor Keiichi Karashima, Institute of Space and Astronautical Science, Tel.: [81]-(427)-57-3911, ext. 2812

Test Section Size: 0.6 x 0.6 x 1 m

Operational Status: Active

Utilization Rate: 6 runs per day

Performance
Mach Number: 0.3 to 1.3 (maximum)
Reynolds Number: 1.1 x 10^6/m
Total Pressure: 5 atm (maximum)
Dynamic Pressure: 216 kN/m^2 (maximum)
Total Temperature: Atmospheric
Run Time: 50 s (minimum)
Comments: None

Cost Information
Date Built: 1988
Date Placed in Operation: 1989
Date(s) Upgraded: None
Construction Cost: $10 million (1988) (See General Comments)
Replacement Cost: Not available
Annual Operating Cost: $220,000 (1990)
Unit Cost to User: $1,000 per hour (1990)
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: 1
Scientists: 0
Technicians: 1
Others: 0
Administrative/Management: 1
Total: 3

Description: The ISAS Transonic Wind Tunnel is a blowdown transonic wind tunnel. It covers the range of Mach numbers from 0.3 to 1.3 continuously where stagnation pressure from 2 to 5 atm is available for conventional operations. Tests can be conducted in two operational modes. These include fixed Mach number operations and sweep Mach number operations.

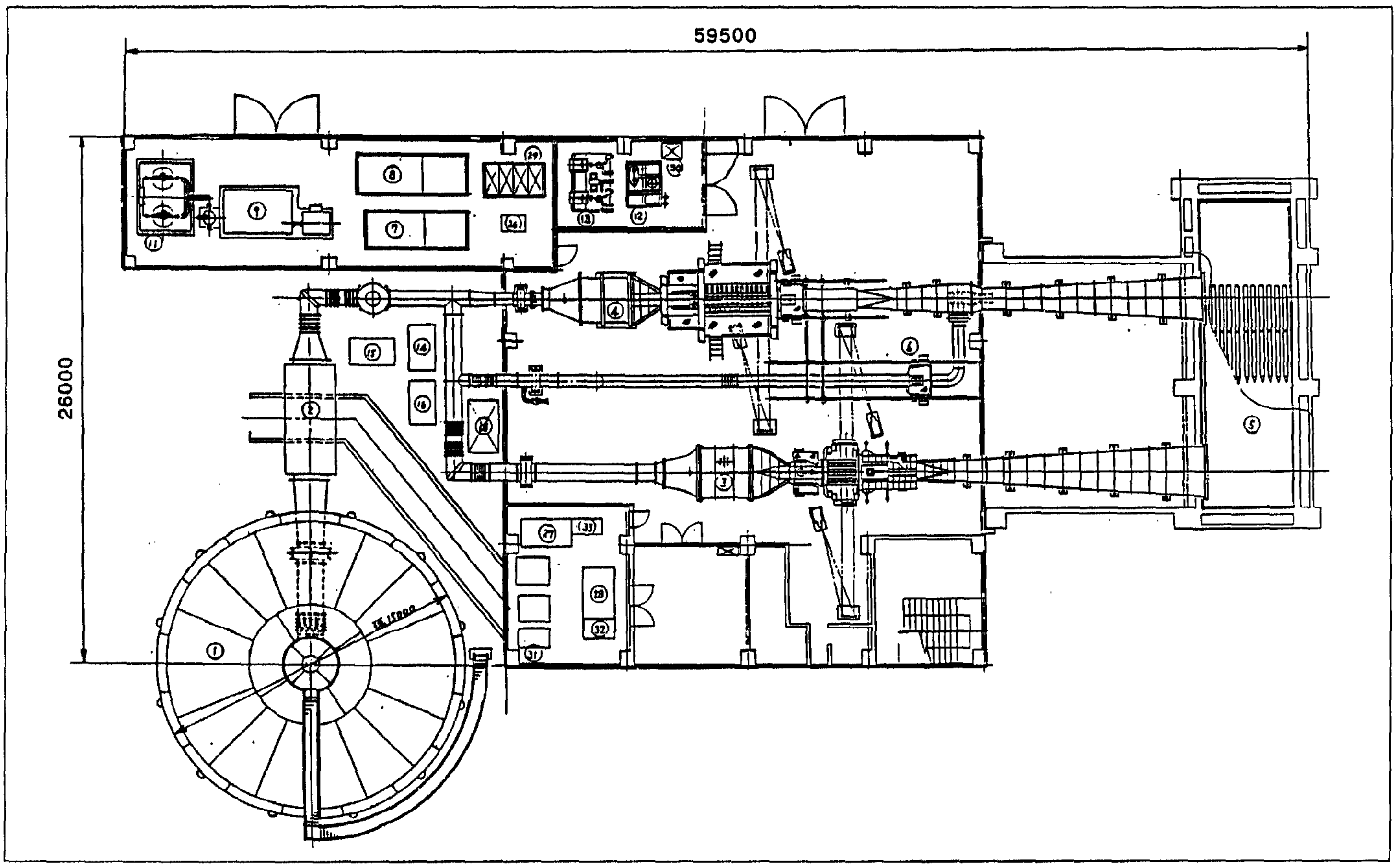
Testing Capabilities: The tunnel has various testing capabilities including six-component force tests, pressure measurement at 120 points, and optical observation using schlieren and laser interferometry as well as a high-speed video system.

Data Acquisition: A high-speed and multi-channel data acquisition system is available, which consists of a computer and the associated measurement devices. Data acquisition is obtained automatically.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Figure VII.13: Schematic Diagram of the ISAS Supersonic and Transonic Wind Tunnels



Source: ISAS

KHI 1 m Transonic Wind Tunnel

Country: Japan

Location: Kawasaki Heavy Industries, Kakamigahara City, Gifu Prefecture, Japan

Owner(s):
Kawasaki Heavy Industries
Gifu Works
1, Kawasaki-cho
Kakamigahara City
Gifu Prefecture 504
Japan

Operator(s): Kawasaki Heavy Industries

International Cooperation: None

Point of Contact: Jun Okumura, Kawasaki Heavy Industries, Tel.: [81]-(583)-82-5346

Test Section Size: 1 x 1 m

Operational Status: Active

Utilization Rate: 10 to 15 tests per day

Performance
Mach Number: 0.2 to 1.4
Reynolds Number: 22 x 10^6/ft
Total Pressure: 5 atm (maximum)
Dynamic Pressure: 2.2 atm (maximum)
Total Temperature: Atmospheric
Run Time: 6 s to 2 min
Comments: Test gas used is air.

Cost Information
Date Built: 1988
Date Placed in Operation: 1988
Date(s) Upgraded: Not available
Construction Cost: $25 million (1988)
Replacement Cost: Not available
Annual Operating Cost: Unknown
Unit Cost to User: Not available
Source(s) of Funding: Kawasaki Heavy Industries

Number and Type of Staff
Engineers: 2
Scientists: 1
Technicians:1
Others: 0
Administrative/Management: 1
Total: 5

Description: The KHI 1 m Transonic Wind Tunnel is a blowdown transonic wind tunnel. The tunnel has a hydraulic nozzle adjustment, porous walls to absorb the shock wave reflection from the walls, and two 1,500-hp compressors.

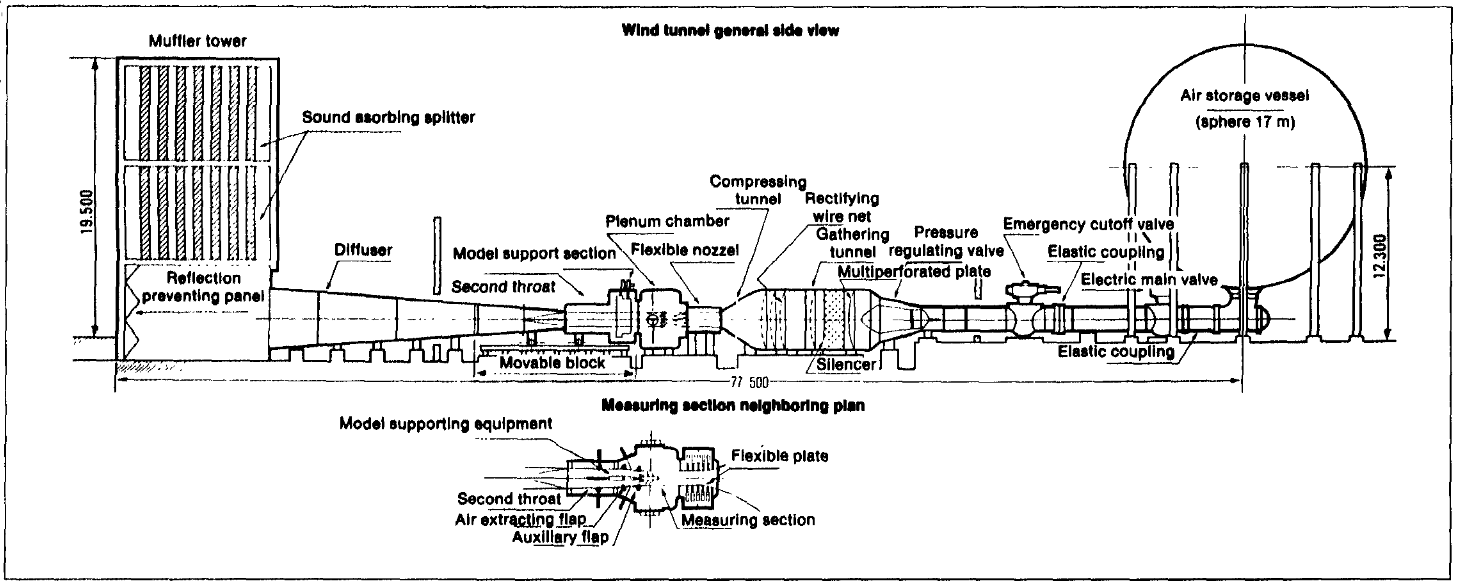
Testing Capabilities: The tunnel is capable of conducting six-component force and moment tests, half-model tests, and pressure tests. It is also capable of exhaust jet simulation, optical tests, schlieren flow visualization, and wake measurements.

Data Acquisition: The tunnel has 80 on-line channels of data. The host computer is a MV-7800.

Planned Improvements (Modifications/Upgrades): None

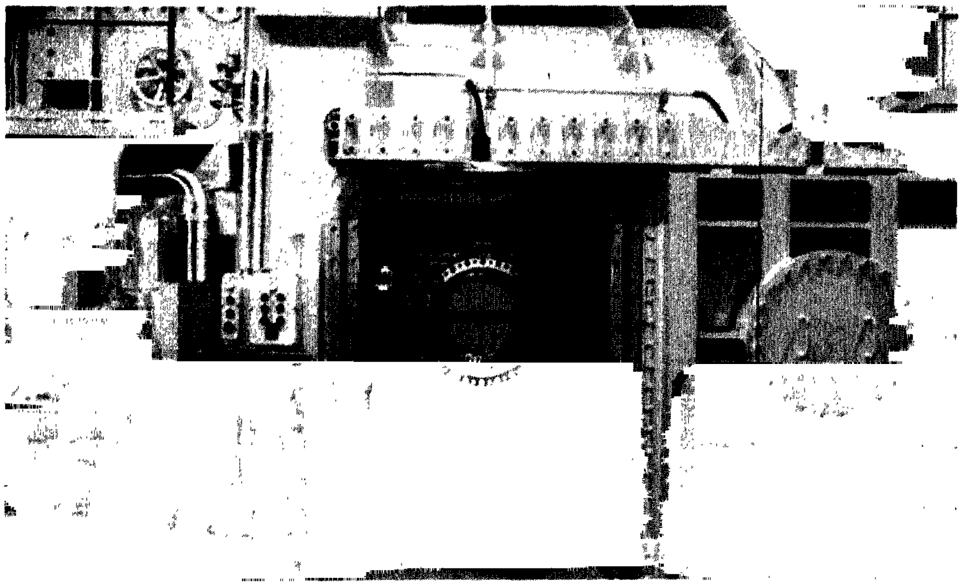
Unique Characteristics: The KHI 1 m Transonic Wind Tunnel is the largest transonic wind tunnel in Japanese industry and has one of the highest Reynolds Number of any wind tunnel in Japan.

Figure VII.16: Schematic Diagram of the KHI 1 m Transonic Wind Tunnel



Source: KHI

Figure VII.17: Plenum Chamber of the KHI 1 m Transonic Wind Tunnel



Source: KHI

KHI Two-Dimensional Wind Tunnel

Country: Japan

Location: Kawasaki Heavy Industries, Kakamigahara City, Gifu Prefecture, Japan

Owner(s):
Kawasaki Heavy Industries
Gifu Works
1, Kawasaki-cho
Kakamigahara City
Gifu Prefecture 504
Japan

Operator(s): Kawasaki Heavy Industries

International Cooperation: Not available

Point of Contact: Jun Okumura, Kawasaki Heavy Industries, Tel.: [81]-(583)-82-5346

Test Section Size: 0.4 x 0.1 x 1 m

Operational Status: Active

Utilization Rate: 10 to 15 tests per day

Performance
Mach Number: 0.4 to 1.2
Reynolds Number: 5.1 to 23.7 x 10^6/ft
Total Pressure: 1.5 to 5 atm
Dynamic Pressure: 0.2 to 2.1 atm
Total Temperature: Ambient
Run Time: 1 to 40 s
Comments: None

Cost Information
Date Built: 1976
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 5

Description: The KHI Two-Dimensional Wind Tunnel is a blowdown transonic wind tunnel.

Testing Capabilities: The tunnel is capable of conducting pressure measurements and schlieren flow visualization tests.

Data Acquisition: The tunnel has 40 on-line channels of data.

Planned Improvements (Modifications/Upgrades): None

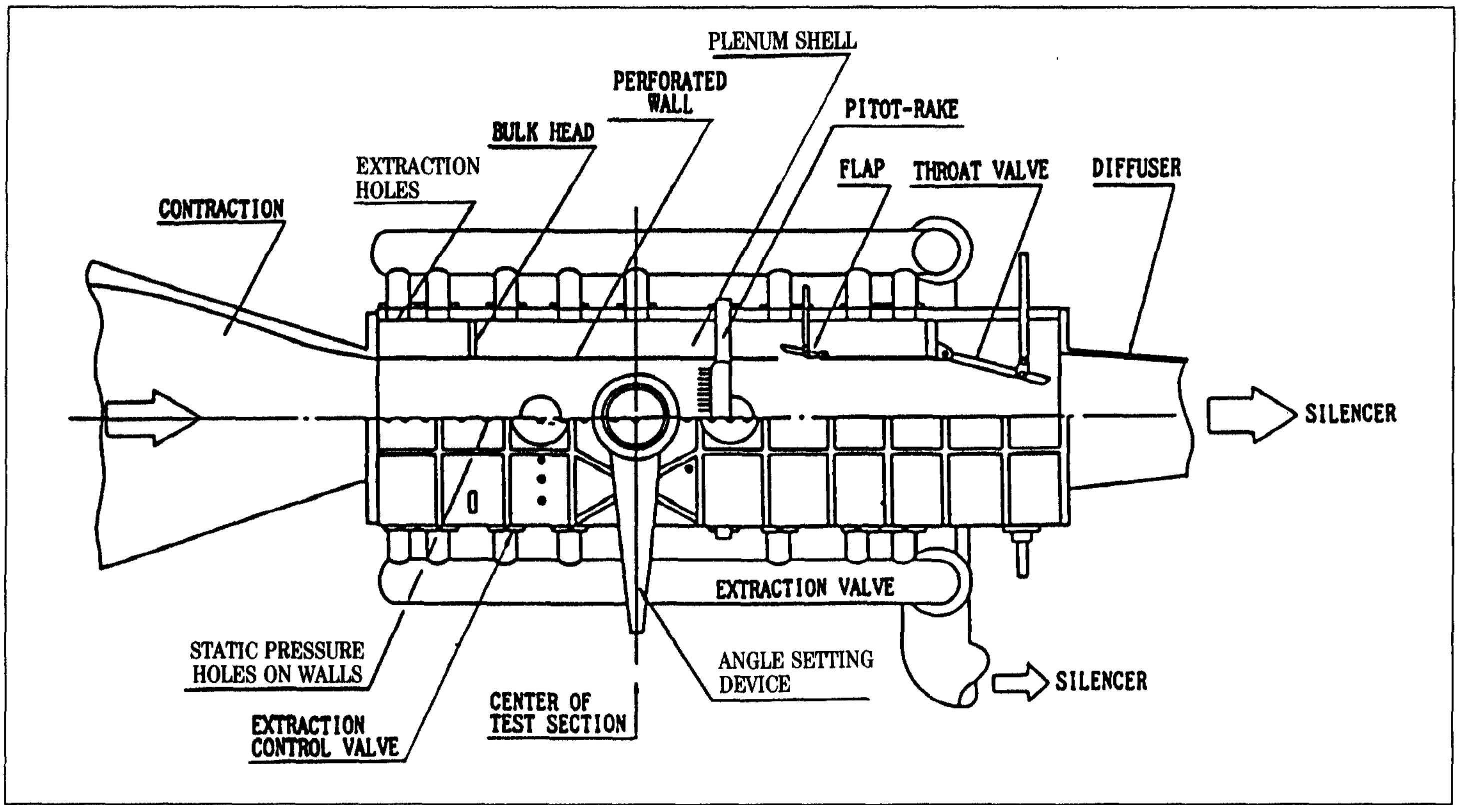
Unique Characteristics: None

Applications/Current Programs: Current applications include fundamental research on airfoils.

General Comments: None

Photograph/Schematic Available: Yes

Figure VII.20: Schematic Diagram of the Test Section Configuration of the KHI Two-Dimensional Wind Tunnel



Source: KHI

for low-speed (1 to about 1,000 Hz variable) acquisition. Test data before balance-drift corrections are processed on-line by a computer system attached to the wind tunnel.

Planned Improvements (Modifications/Upgrades): Step-by-step refurbishment of the major hardware components began in 1985 is still underway.

Unique Characteristics: None

Applications/Current Programs: The major portion of the testing time is devoted to data acquisition for the development of aerospace vehicles. The tunnel is used for both domestic Japanese and international aerospace research and development work.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 162. National Aerospace Laboratory. NAL 1988. Chofu-shi, Tokyo: National Aerospace Laboratory, 1988, pp. 15-16.

Date of Information: October 1989

NAL Two-Dimensional Transonic Wind Tunnel

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: I. Kawamoto, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911

Test Section Size: 1 x 0.3 m

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.2 to 1.15
Reynolds Number: 49 x 10^6/ft at Mach 0.8
Total Pressure: 200 to 1,200 kPa
Dynamic Pressure: 350 kPa
Total Temperature: Ambient
Run Time: 9 to 100 s
Comments: None

Cost Information
Date Built: 1979
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: $6.26 million (1985)
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Japanese government

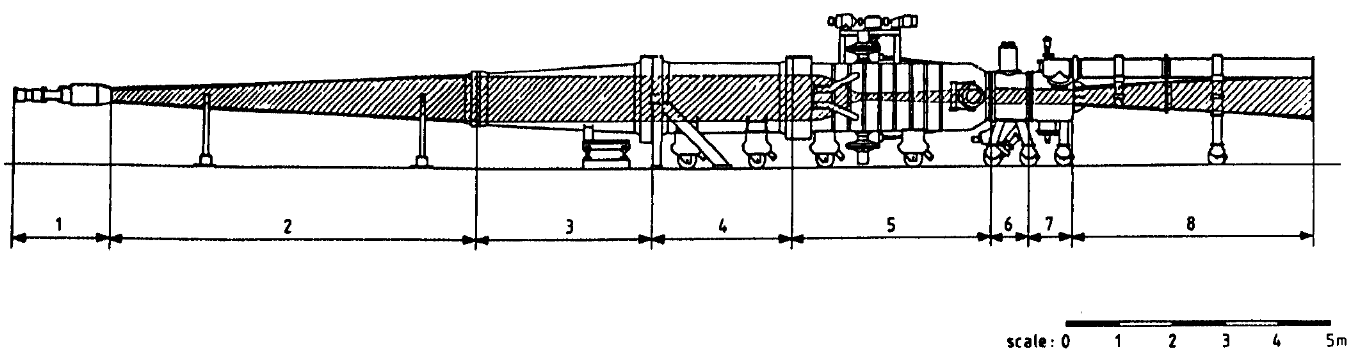
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 5

Description: The NAL Two-Dimensional Transonic Wind Tunnel is an intermittent blowdown transonic wind tunnel. The tunnel has a two-dimensional test section with slotted upper and lower walls and solid sidewalls. It can accommodate models with a chord length of 9.84 in. Tunnel operation is automated and controlled by one person.

Testing Capabilities: The tunnel is capable of testing models with an angle of attack ranging from −15 degrees to 25 degrees. Measurement of pressure distribution on the model and wake surveys are conducted. For wall interference correction, pressure distributions along the upper and lower walls are available. It is equipped with a sidewall boundary layer suction system. A pair of glass windows 25 cm in diameter mounted on sidewalls provide optical observation. The tunnel is capable of conducting schlieren flow visualization tests. Oil flow techniques are available as well.

Data Acquisition: The tunnel has 48 analog channels and 24 digital channels of data that can be recorded on the data acquisition system with a Hewlett Packard 2113B minicomputer. The data can be reduced immediately after the tunnel run.

Figure VIII.9: Schematic Diagram of the Delft University of Technology Blowdown Wind Tunnel B (TST 27)



1 FLOW CONTROL VALVE
2 INLET DIFFUSOR
3 TRANSITION PART
4 SETTLING CHAMBER
5 INLET NOZZLE AND TEST SECTION
6 MODEL SUPPORT SECTION
7 CHOKE SECTION
8 OUTLET DIFFUSOR

Source: Delft University of Technology

Delft University of Technology GLT 20 Boundary Layer Tunnel

Country: The Netherlands

Location: Delft University of Technology, Delft, The Netherlands

Owner(s):
Delft University of Technology
Faculty of Aerospace Engineering
Kluyverweg 1
2629 HS Delft
The Netherlands

Operator(s): Delft University of Technology

International Cooperation: None

Point of Contact: W.J. Bannink, Delft University of Technology, Tel.: [31]-(15)-784500

Test Section Size: 17 x 20 x 132 cm

Operational Status: Planned

Utilization Rate: Unknown

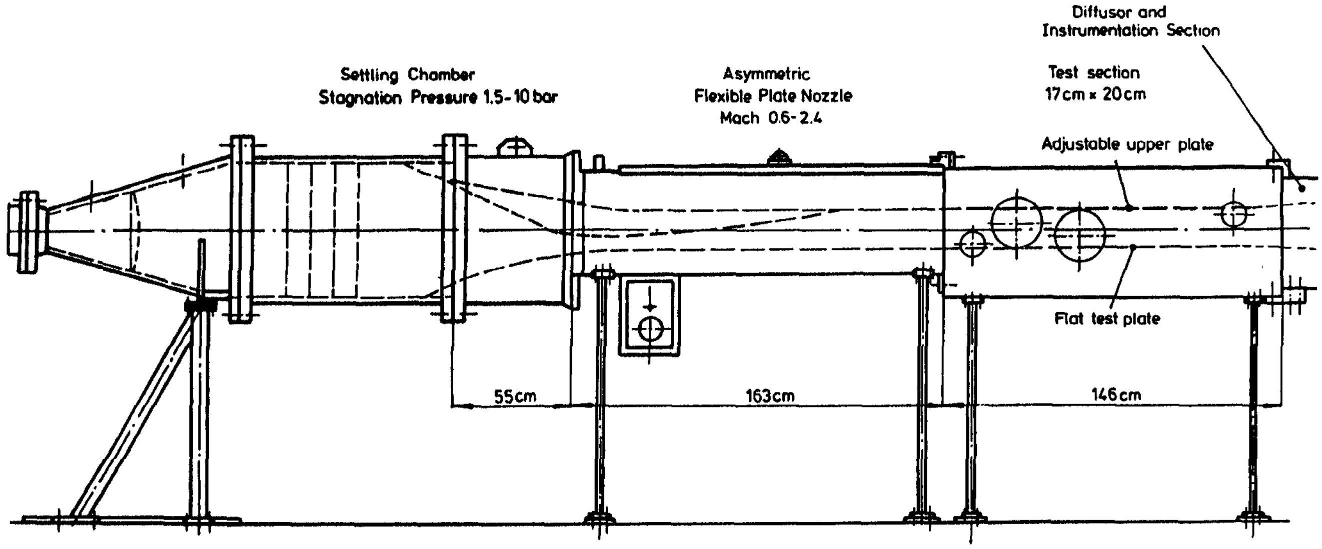
Performance
Mach Number: 0.6 to 2.4 (continuously variable)
Reynolds Number: 27 x 10^6/ft at Mach 2.4
Total Pressure: 4 bars at Mach 1 to 10 bars at Mach 2.4
Dynamic Pressure: 88 to 250 kN/m^2
Total Temperature: 280 degrees Kelvin
Run Time: 12 min
Comments: None

Cost Information
Date Built: Planned
Date Placed in Operation: Expected in 1990
Date(s) Upgraded: Not applicable
Construction Cost: $900,000 (1989 estimate)
Replacement Cost: $900,000 (1989 estimate)
Annual Operating Cost: Unknown
Unit Cost to User: Unknown
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 2 (part-time)
Scientists: 4 (part-time)
Technicians: 2 (part-time)
Others: 0
Administrative/Management: 1 (part-time)
Total: 9 (part-time)

Description: The Delft University of Technology GLT 20 Boundary Layer Tunnel will be a trisonic wind tunnel with continuously variable Mach numbers from 0.6 to 2.4. The tunnel is being built to facilitate measurements in boundary layers and obtain thick boundary layers exposed to controlled pressure gradients. The boundary layer tunnel may be compared to the upper half of a symmetric wind tunnel, the lower half of which has been replaced by a long flat plate extending from upstream of the throat along the length of the nozzle and test section. The upper wall of the long and slender test section may be contoured to generate shock waves or pressure gradients. The sidewalls of the nozzle will diverge slightly in the flow direction to reduce secondary flows in the boundary layer. A separate test plate with a sharp leading edge may be introduced in the test section to study boundary layers not affected by upstream history effects. The Mach number at the exit of the semiflexible nozzle can be continuously adjusted from subsonic speed to Mach 2.4. A simple adjustable second throat at the exit of the test section will control subsonic and transonic flows. Stagnation pressures will be limited by the capacity of the flow control valve to 4 bars at Mach 1 and to 10 bars at Mach 2.4. The GLT 20 will be driven by dry, oil-free air delivered by a 6,000-kW compressor plant and stored at 40 bar pressure in a 300-m^3 storage vessel.

Figure VIII.11: Schematic Diagram of the Delft University of Technology GLT 20 Boundary Layer Wind Tunnel



Source: Delft University of Technology

Data Acquisition: The tunnel has 26 on-line channels of data. Data are collected, stored, and processed in the central data acquisition system DRS of the Laboratory. For extensive numerical calculations, a terminal provides access to the IBM 3083 mainframe and Convex minisupercomputer at the University Computer Center.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: Asymmetric nozzle blocks and test sections are available for tests in curved supercritical flows. In this setup, the lower nozzle block is shaped to generate supercritical flow simulating local flow conditions over an airfoil, while the upper block is contoured according to the calculated shape of a streamline in order not to interfere with the development of the flow field. Automatic control of a downstream sonic throat maintains the desired Mach number and position of the shock wave.

Applications/Current Programs: These include the study of the interaction of embedded shock waves with the boundary layer over a curved surface in a supercritical flow.

General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 88 (EOARD Technical Report). Delft University of Technology. The Laboratory of High Speed Aerodynamics. Delft, The Netherlands: Delft University of Technology, 1989, pp. 1-4.

Date of Information: October 1989

NLR Continuous Supersonic Wind Tunnel

Country: The Netherlands

Location: Nationaal Lucht-en Ruimtevaartlaboratorium, Amsterdam, The Netherlands

Owner(s):
Nationaal Lucht-en Ruimtevaartlaboratorium
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands

Operator(s): Nationaal Lucht-en Ruimtevaartlaboratorium

International Cooperation: Not available

Point of Contact: H. A. Dambrink, Nationaal Lucht-en Ruimtevaartlaboratorium, Tel.: [31]-(20)-5-113-113

Test Section Size: 0.27 x 0.27 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 1.2 to 6 (contoured)
Reynolds Number: 20 to 30 x 10^6/m
Total Pressure: 30 bars (maximum)
Dynamic Pressure: Not available
Total Temperature: 300 to 500 degrees Kelvin
Run Time: Continuous (about 30 min)
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 5

Description: The NLR Continuous Supersonic Wind Tunnel is a continuous blowdown facility fed by an air storage vessel containing 600 m^3 of dry air at a maximum pressure of about 4,000 kPa.

Testing Capabilities: Forces and moments are measured with a six-component internal strain-gauge balance. For pressure measurements, the model is equipped with a number of pressure leads connecting each pressure plotting hole on the model with a pressure transducer. Heat transfer measurements are possible. Other types of measurements include flow direction sensing, mass flow, and temperature measurements. Flow visualization techniques include the oil and naphthalene methods and the schlieren and shadow optical systems.

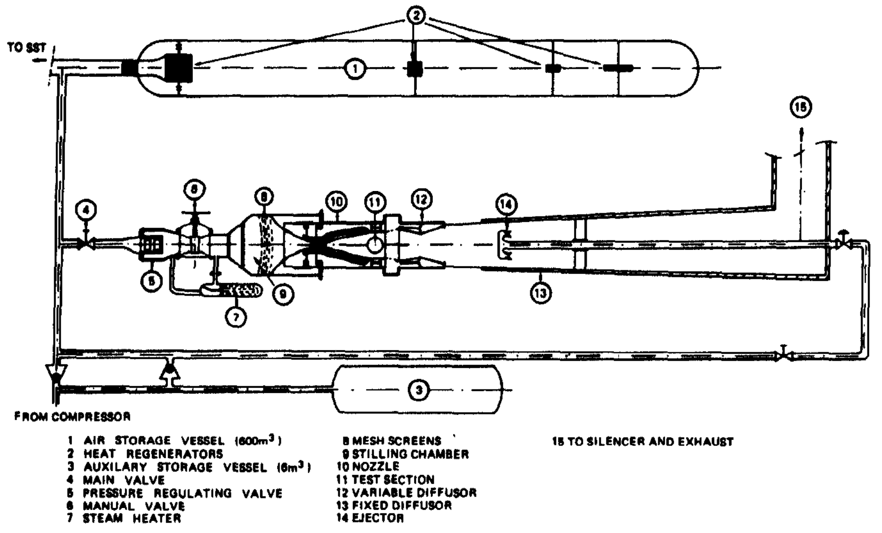
Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: Special features include a cold- and hot-jet simulator.

Applications/Current Programs: Not available

Figure VIII.14: Schematic Diagram of the NLR Continuous Supersonic Wind Tunnel



Source: NLR

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: The tunnel has cold- and hot-jet simulation. An important feature is the ability to exchange the same model between the NLR Supersonic Wind Tunnel and the NLR High-Speed Wind Tunnel. In special cases, it is also possible to test the NLR Supersonic Wind Tunnel and the NLR High-Speed Wind Tunnel models in the NLR Low-Speed Wind Tunnel. This capability enables the user to test one model in different velocity regimes.

Applications/Current Programs: These include forces, moments, pressures, and mass flow. Tests of launchers and shuttles are being conducted for ESA. The NLR Supersonic Wind Tunnel is also being used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 213. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 97 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). National Aerospace Laboratory. Supersonic Wind Tunnel. Amsterdam: National Aerospace Laboratory, 1988.

Date of Information: November 1988

Figure VIII.17: Model of Ariane 5 Launch Vehicle With the Hermes Spaceplane in the NLR Supersonic Wind Tunnel

Source: NLR

ARA Bedford Two-Dimensional Wind Tunnel

Country: United Kingdom

Location: Aircraft Research Association, Bedford, United Kingdom

Owner(s):
Aircraft Research Association
Manton Lane
Bedford, Bedfordshire MK41 7PF
United Kingdom

Operator(s): Aircraft Research Association

International Cooperation: Not available

Point of Contact: Chief Executive, Aircraft Research Association, Tel.: [44]-(234)-50681

Test Section Size: 8 x 18 in.

Operational Status: Active

Utilization Rate: 2,000 runs per year

Performance
Mach Number: 0.3 to 0.86
Reynolds Number: 2 to 7 x 10^6/ft (based on 5 in. chord)
Total Pressure: 20 to 60 psia
Dynamic Pressure: Not available
Total Temperature: 520 degrees Rankine
Run Time: 7 s
Comments: None

Cost Information
Date Built: 1968
Date Placed in Operation: 1969
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $24,750 per typical 200 data point test program (1989)
Source(s) of Funding: Commercial contracts

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ARA Bedford Two-Dimensional Wind Tunnel is a variable pressure, intermittent, blowdown subsonic wind tunnel.

Testing Capabilities: The tunnel has the capability of testing airfoil models in both static and dynamic modes. For static testing, airfoils normally have a total of 44 surface pressures on the upper and lower surfaces and can be tested for an incidence range of −11 to 20 degrees. For dynamic testing, airfoils normally have a total of 39 surface pressures and can be tested for a frequency range of 0 to 200 Hz and for amplitudes of up to about 22 degrees.

Data Acquisition: For static testing, airfoil surface pressures are measured with a scanivalve. For dynamic testing, airfoil surface pressures are measured with Kulite transducers. Lift and pitching moment coefficients are obtainable by the integration of the measured pressures. Drag is measured by means of a rake comb of 48 pitot tubes and 3 static tubes situated downstream of the model.

Planned Improvements (Modifications/Upgrades): None

BAe Brough 7 X 5 ft Low-Speed Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Brough, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
Brough, North Humberside, Cumbria HU15 1EQ
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Alan N. Dewar, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52856

Test Section Size: 2.1 x 1.5 m

Operational Status: Decommissioned (see General Comments)

Utilization Rate: Single shift

Performance
Mach Number: 0 to 0.25 or 0 to 85 m/s
Reynolds Number: 5.4 x 10^6/m
Total Pressure: About 1 bar
Dynamic Pressure: 4.4 kN/m^2
Total Temperature: Ambient to 323 degrees Kelvin
Run Time: Not available
Comments: None

Cost Information
Date Built: 1937
Date Placed in Operation: Not available
Date(s) Upgraded: 1952, 1964, 1975, and 1984
Construction Cost: Not available
Replacement Cost: $1.2 million (1984)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Brough 7 X 5 ft Low-Speed Wind Tunnel is a continuous-flow, closed-circuit subsonic wind tunnel. The tunnel was decommissioned and sold in 1989 to a non-aeronautical company (see General Comments). The working section is vented to atmosphere downstream. The tunnel has an overhead mechanical balance. A floor and roof boundary layer suction system is available for two-dimensional models, and 230 m^3 air at 30 bars is available for blown models.

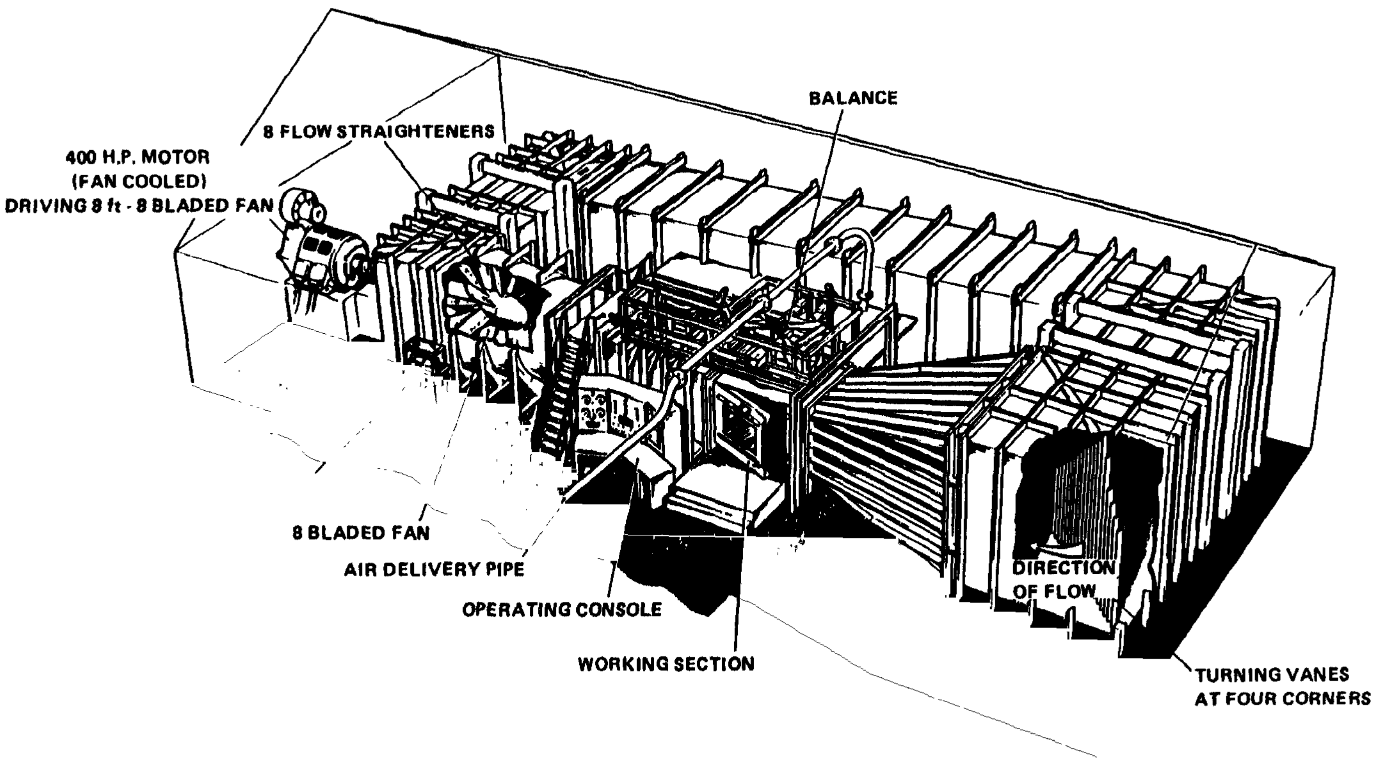
Testing Capabilities: The tunnel had the capability to conduct full- and half-model tests at 76 m/s (Mach 0.22) continuously and at 85 m/s (Mach 0.25) intermittently. Blowing and suction systems for two- and three-dimensional blown wing models were available.

Data Acquisition: The tunnel has a dedicated 16-bit microcomputer for data logging, post-run data reduction, and plotting. It also has multi-scanivalve capability.

Planned Improvements (Modifications/Upgrades): A new operator console and standardized instrumentation database were planned.

Unique Characteristics: Not available

Figure IX.2: Schematic Drawing of the BAe Brough 7 × 5 ft Low-Speed Wind Tunnel



Source: NASA

Unique Characteristics: Not available

Applications/Current Programs: Not available

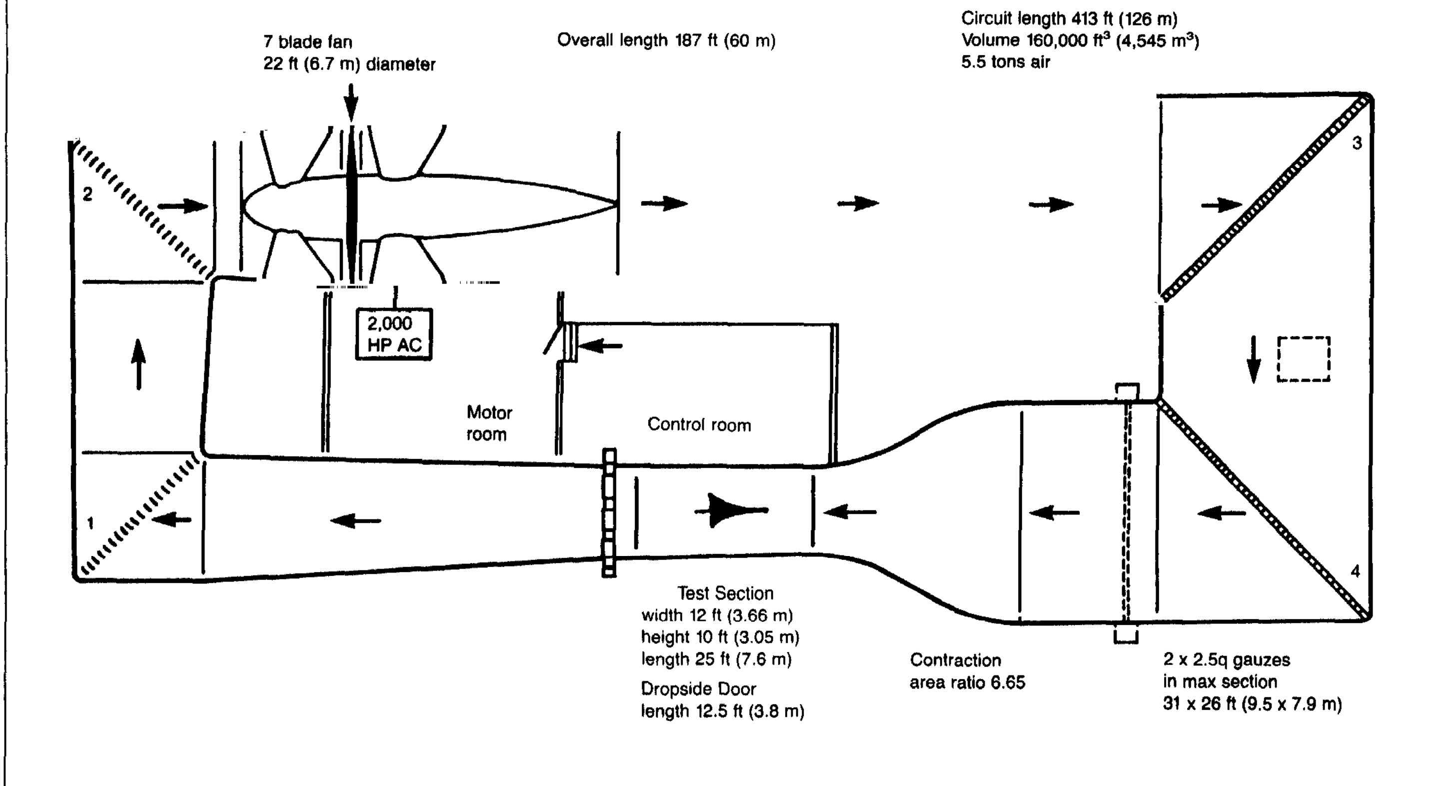
General Comments: The tunnel's overall length is 187 ft and its circuit length is 413 ft. The volume is 160,000 ft³ or 5.5 tons of air.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 68.

Date of Information: January 1990

Figure IX.3: Schematic Diagram of the BAe Filton 12 × 10 ft Wind Tunnel



Source: BAe Filton

Applications/Current Programs: These include conducting low-speed tests in support of current and future British Aerospace, Commercial Aircraft, Ltd., projects as well as conducting research.

General Comments: The tunnel has a good level of turbulence.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 93.

Date of Information: January 1990

BAe Hatfield 15 ft Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Hatfield, United Kingdom

Owner(s):
British Aerospace
Commercial Aircraft, Ltd.
Airlines Division
Wind Tunnel Department
Manor Road
Hatfield, Hertfordshire AL10 9TL
United Kingdom

Operator(s): British Aerospace, Commercial Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Robin G.B. Webb, British Aerospace, Commercial Aircraft, Ltd., Tel.: [44]-(7072)-62345, ext. 52185

Test Section Size: 15 x 15 x 40 ft

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0 to 0.125 or 0 to 140 ft/s
Reynolds Number: 0 to 0.9 x 10^6/ft
Total Pressure: Atmospheric
Dynamic Pressure: 0 to 23 lb/ft^2
Total Temperature: Ambient
Run Time: Continuous
Comments: Normal operating speed is Mach 0.11 or 125 ft/s.

Cost Information
Date Built: 1964
Date Placed in Operation: 1964
Date(s) Upgraded: None
Construction Cost: $250,000 (1964)
Replacement Cost: $8 million (1990)
Annual Operating Cost: $480,000 (1990)
Unit Cost to User: $1,900 per day (1990)
Source(s) of Funding: None

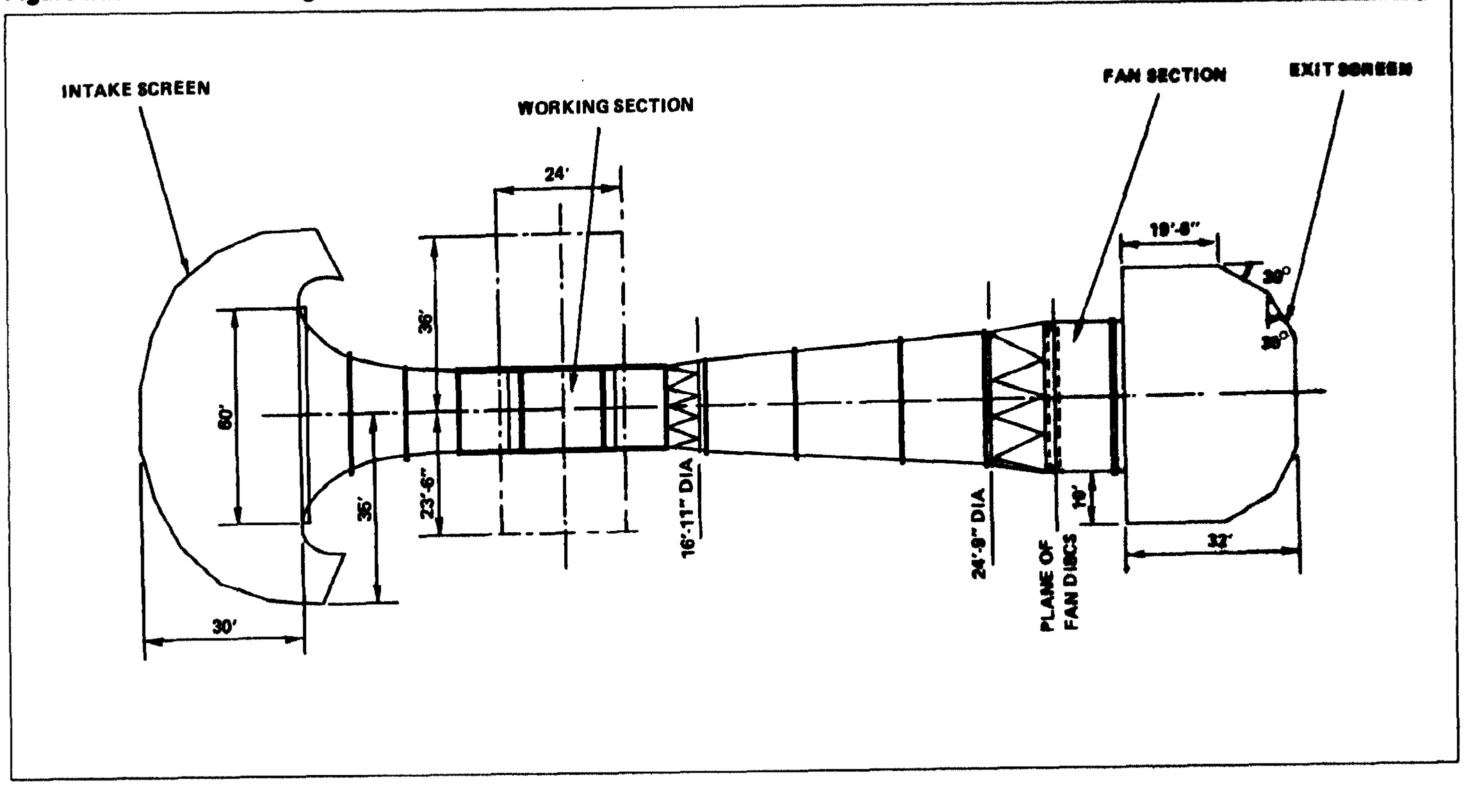
Number and Type of Staff
Engineers: 4
Scientists: 0
Technicians: 2
Others: The support team is shared with the BAe Hatfield 9 x 7 ft Wind Tunnel.
Administrative/Management: 1
Total: At least 7

Description: The BAe Hatfield 15 ft Wind Tunnel is a continuous-flow, open-circuit, closed-throat subsonic wind tunnel. A static test facility duplicating the test section structure is adjacent to the tunnel.

Testing Capabilities: The tunnel is powered by 7 100-hp electric motors driving 10-ft diameter fans at the downstream end. The virtual-center underfloor balance is equipped with a variety of mounting systems for complete models and half-models with the wing in a vertical plane. The tunnel uses a six-component mechanical balance. A variable height ground board/reflection plane is built into the tunnel floor, and another is available for mounting in the vertical or horizontal plane, as required. Compressed air supplies up to 20 lb/s at about 100 psig, and suction of 11,000 ft^3/min at 20 in. mercury are available.

Data Acquisition: Digital signals from the mechanical balance and analog signals from various devices (such as pressure transducers and strain gauges) are processed and fed into the Wind Tunnel Department's own computer for on-line computation and presentation.

Figure IX.5: Schematic Diagram of the BAe Hatfield 15 ft Wind Tunnel



Source: BAe Hatfield

Planned Improvements (Modifications/Upgrades): These include maintenance and replacement of lifted equipment for long-term active operation.

Unique Characteristics: Not available

Applications/Current Programs: The tunnel is currently used for aircraft design and development, flight test support, new project assessment, and aerodynamic research by a major manufacturer of combat aircraft. It is fully active on a flexible program. It is also fully staffed for design and manufacture of models, rigs, and strain-gauge balances, as well as for calibration, testing, and analysis.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 95.

Date of Information: January 1990

BAe Warton 18 ft V/STOL Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Preston, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
Warton Aerodrome
Preston, Lancashire PR4 1AX
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Alan N. Dewar, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52856

Test Section Size: 5 x 5.5 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.035 to 0.065 or 12 to 22 m/s
Reynolds Number: 0.8 to 1.5 x 10^6/m
Total Pressure: Atmospheric
Dynamic Pressure: 0.09 to 0.3 kN/m^2
Total Temperature: Ambient
Run Time: Not available
Comments: None

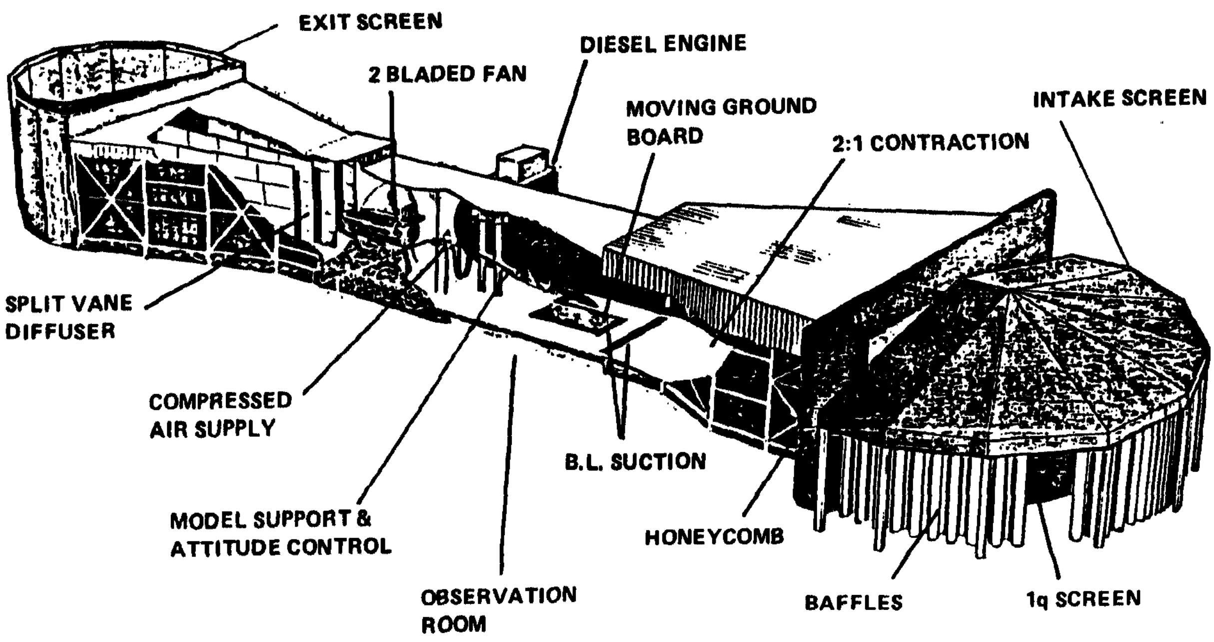
Cost Information
Date Built: 1963
Date Placed in Operation: Not available
Date(s) Upgraded: 1975 and 1980
Construction Cost: Not available
Replacement Cost: $3.2 million (1990)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Warton 18 ft V/STOL Wind Tunnel is a straight-through circuit-to-atmosphere subsonic wind tunnel.

Testing Capabilities: The tunnel is powered by a 220-kW diesel engine and uses a 2-bladed fan. Blade pitch can be varied to give speeds less than 12 m/s (Mach 0.035). Speed is uniform to about 0.5 percent; upwash and sidewash is within 0.3 degrees. The tunnel uses sting mounting with height adjustment from the floor to upper half of the working section. Full-width boundary layer removal is possible. The tunnel has a 1.5-m wide moving ground belt at 25 m/s. It has several internal strain-gauge balances and six components with a normal force of 2 kN (maximum). It has a rolling rig with about 60 rpm about the wind axis. Model mass is limited to 60 kg. Incidence is about 90 degrees. Sideslip is by pitch and roll. A six-component internal strain-gauge balance gives damping due to the rate of roll. Air supplies of 240 m^3 at 40 bars are supplied from the BAe Warton 1.2 m High-Speed Wind Tunnel. Mass flows are limited only by pipework and model design to 4 kg/s. The tunnel is equipped with thrust and mass flow calibration rigs.

Figure IX.7: Schematic Drawing of the BAe Warton 18 ft V/STOL Wind Tunnel



Source: NASA

BAe Weybridge 3 X 2 ft High-Speed Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Weybridge, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
Warton Aerodrome
Preston, Lancashire PR4 1AX
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not applicable

Point of Contact: Alan N. Dewar, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52856

Test Section Size: 2 x 3 x 5 ft

Operational Status: Decommissioned (see General Comments)

Utilization Rate: Not operational

Performance
Mach Number: 0.4 to 0.92 or 447 to 1,027 ft/s
Reynolds Number: 2.6 to 4.5 x 10^6/ft
Total Pressure: Atmospheric
Dynamic Pressure: 200 to 700 lb/ft^2
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1950
Date Placed in Operation: Not available
Date(s) Upgraded: 1970 and 1980
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Weybridge 3 X 2 ft High-Speed Wind Tunnel was a continuous-flow, closed-circuit, single-return subsonic wind tunnel. The tunnel was decommissioned in 1989 and has been dismantled (see General Comments). The tunnel had a closed test section that was cooled by air exchange. It also had an underfloor strain-gauge balance and sting balances.

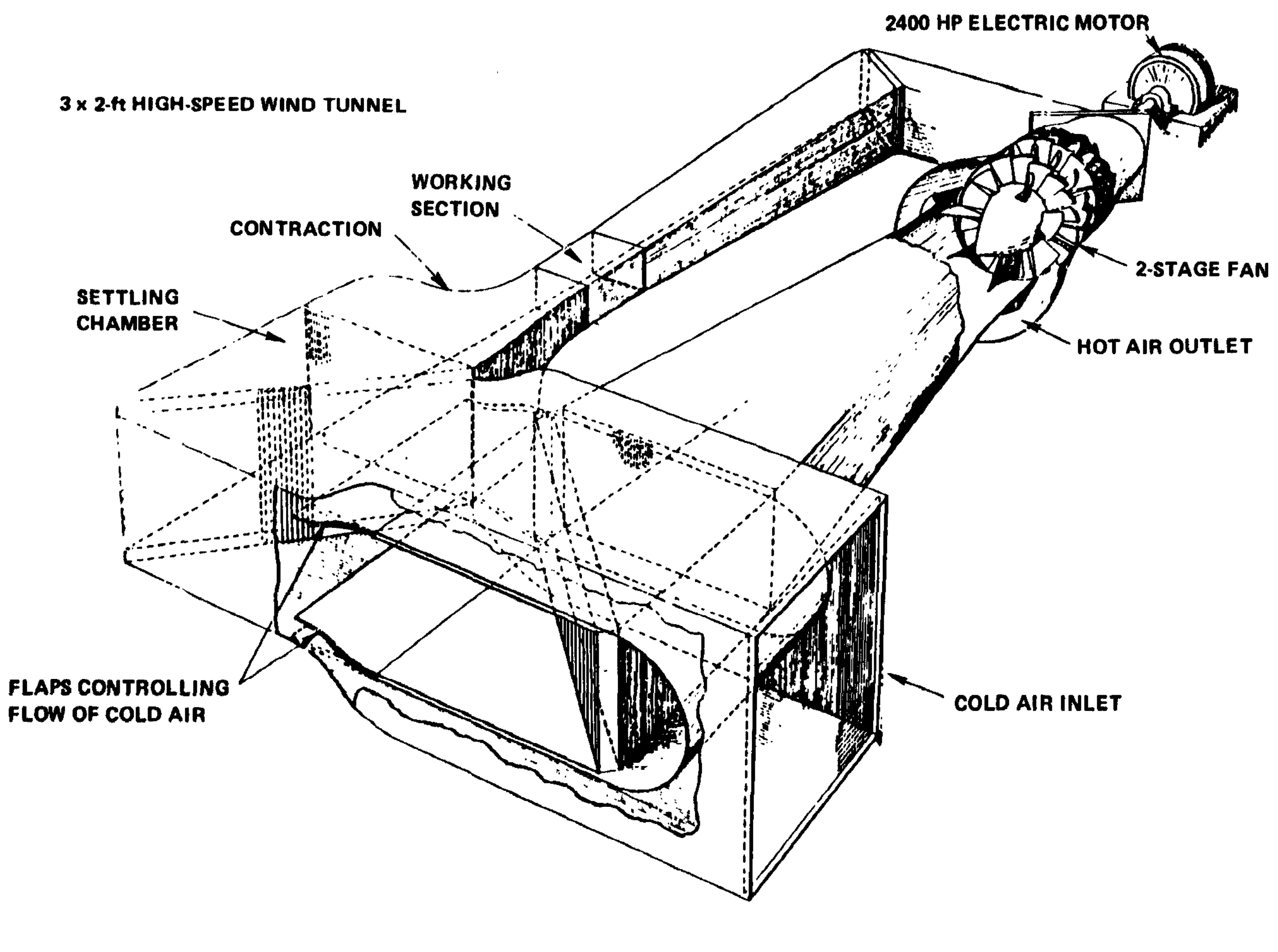
Testing Capabilities: A 2-stage 7-ft (2.1 m) diameter fan was driven through the second corner by a 2,200-hp electric motor. The test section was 2 X 3 ft (0.6 m X 0.9 m) with a floor turntable. The tunnel had underfloor four-component strain-gauge balances for half-models and sting balances for complete-models.

Data Acquisition: The tunnel had a dedicated PDP 11/60 computer for on-line data acquisition and multitasking with graph plotting and background computation roles. Data recording was achieved by 16 digital and/or 16 analog inputs.

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: Not available

Figure IX.9: Schematic Drawing of the BAe Weybridge 3 × 2 ft High-Speed Wind Tunnel



Source: NASA

Planned Improvements (Modifications/Upgrades): A sting-mounting system and high-pressure compressed air supply are to be installed in 1991.

Unique Characteristics: Not available

Applications/Current Programs: The tunnel currently is not used for any applications or programs, since it was dismantled and is currently being relocated and reactivated.

General Comments: The BAe Warton 13 × 9 ft Low-Speed Wind Tunnel was formerly known as the BAe Weybridge 13 × 9 ft Low-Speed Wind Tunnel. The tunnel was dismantled and is currently being relocated from BAe Weybridge to BAe Warton in Preston. The British Aerospace site at Weybridge has been closed and torn down. The tunnel is expected to be rebuilt and reactivated by mid-1991.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 65.

Date of Information: January 1990

BAe Woodford 9 × 7 ft Low-Speed Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Woodford, United Kingdom

Owner(s):
British Aerospace
Commercial Aircraft, Ltd.
Airlines Division
Chester Road
Woodford, Bramhall
Stockport, Cheshire SK7 1QR
United Kingdom

Operator(s): British Aerospace, Commercial Aircraft, Ltd.

International Cooperation: Not applicable

Point of Contact: Robin G.B. Webb, British Aerospace, Commercial Aircraft, Ltd., Tel.: [44]-(7072)-62345, ext. 52185

Test Section Size: 2.74 x 2.13 x 5.5 m

Operational Status: Decommissioned (see General Comments)

Utilization Rate: Not available

Performance
Mach Number: 0 to 0.17 or 0 to 60 m/s
Reynolds Number: 0 to 4.3 x 10^6/m
Total Pressure: Atmospheric
Dynamic Pressure: 0 to 2.2 kN/m^2
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1949
Date Placed in Operation: Not available
Date(s) Upgraded: 1955
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Woodford 9 × 7 ft Low-Speed Wind Tunnel is a continuous-flow, closed-circuit subsonic wind tunnel. The tunnel has been decommissioned and sold to Manchester University where it has been reactivated (see General Comments).

Testing Capabilities: The tunnel is equipped with an overhead semiautomatic six-component mechanical balance. A sting-mounting system with strain-gauge balance is also available. Compressed air supplies of 2.5 lb/s at 100 psi are available. The tunnel is driven by a single 12-ft diameter fan powered by a 500-hp electric motor.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: Not available

Applications/Current Programs: Not available

General Comments: The BAe Woodford 9 × 7 ft Low-Speed Wind Tunnel was decommissioned and sold to Manchester University. The tunnel has

RAE Bedford 13 × 9 ft Low-Speed Wind Tunnel

Country: United Kingdom

Location: Royal Aerospace Establishment Bedford, Bedford, United Kingdom

Owner(s):
Royal Aerospace Establishment Bedford
Bedford, Bedfordshire MK41 6AE
United Kingdom

Operator(s): Royal Aerospace Establishment Bedford

International Cooperation: Not available

Point of Contact: Dr. D.E. Mowbray, Royal Aerospace Establishment Bedford, Tel.: [44]-(234)-225840

Test Section Size: 9 x 13 x 30 ft

Operational Status: Active

Utilization Rate: Not available

Performance
- **Mach Number:** 0.01 to 0.27 or 15 to 300 ft/s
- **Reynolds Number:** 0.1 to 2 x 10^6/ft
- **Total Pressure:** Atmospheric
- **Dynamic Pressure:** 0.3 to 100 lb/ft^2
- **Total Temperature:** Ambient
- **Run Time:** Continuous
- **Comments:** None

Cost Information
- **Date Built:** 1953
- **Date Placed in Operation:** 1953
- **Date(s) Upgraded:** 1968
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

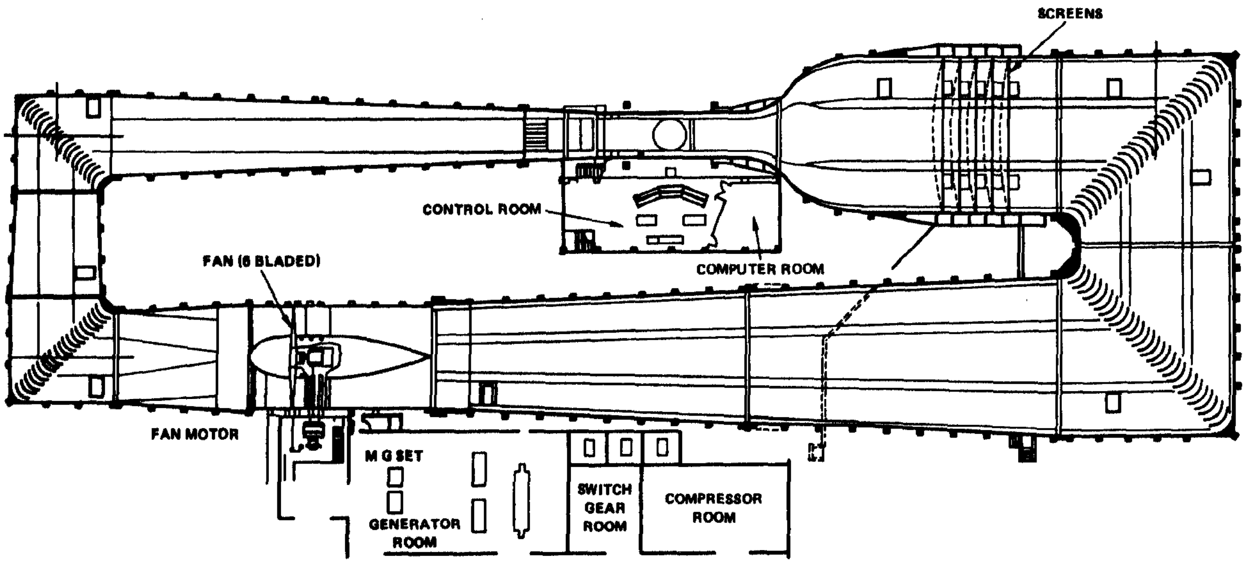
Description: The RAE Bedford 13 × 9 ft Low-Speed Wind Tunnel is a continuous-flow, return-circuit subsonic wind tunnel. The tunnel has both roof and floor balances, a high-incidence sting, and dynamic rigs. The tunnel is powered by a 1.1-MW motor driving a 30-ft diameter fan.

Testing Capabilities: Complete- and half-models can be supported on (1) a six-component overhead mechanical balance, (2) a four-component underfloor mechnical balance, and (3) various sting rigs for internal balance models. Special rigs can be used for dynamic stability tests. Longitudinal turbulence level is better than 0.1 percent. The tunnel can supply auxiliary air to models at 25 atm and at 10 lb/s. Suction at 3 lb/s is also available. The tunnel is well equipped for flow visualization.

Data Acquisition: A dedicated system based on a Hewlett Packard 800 computer records all tunnel and model parameters for force and pressure plotting tests and provides on-line reduction and presentation of data. The tunnel has the capacity for nine low-level analog signals and nine pressure scanning switches.

Planned Improvements (Modifications/Upgrades): None

Figure IX.11: Schematic Diagram of the RAE Bedford 13 × 9 ft Low-Speed Wind Tunnel



Source: NASA

Planned Improvements (Modifications/Upgrades): These include an enhanced blowing system to provide 35 kg/s of air at 200 bars, a new underfloor balance on a new cart, a rotor testing facility, and an enhanced data acquisition system based on networked minicomputers.

Unique Characteristics: None

Applications/Current Programs: These include research on aircraft, helicopters (excluding rotor blades), and weapons.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 105.

Date of Information: November 1989

RAE Farnborough 11.5 × 8.5 ft Wind Tunnel

Country: United Kingdom

Location: Royal Aerospace Establishment Farnborough, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Farnborough
AE2 Division
Aerodynamics Department
Farnborough, Hampshire GU14 6TD
United Kingdom

Operator(s): Royal Aerospace Establishment Farnborough

International Cooperation: Not available

Point of Contact: Superintendent, AE2 Division, Royal Aerospace Establishment Farnborough, Tel.: [44]-(252)-24461, ext. 5377

Test Section Size: 3.5 x 2.6 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.01 to 0.32 or 5 to 110 m/s
Reynolds Number: Up to 7.5 x 10^6/m
Total Pressure: 1 bar
Dynamic Pressure: Up to 7.3 kN/m^2
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1944
Date Placed in Operation: Not available
Date(s) Upgraded: 1968
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Farnborough 11.5 × 8.5 ft Wind Tunnel is a continuous-flow, return-circuit subsonic wind tunnel.

Testing Capabilities: The tunnel has an overhead three-component balance, underfloor six-component virtual-center balance, and sting-support system. Auxiliary air supplies for model blowing are available.

Data Acquisition: The tunnel has a six-channel system for use with balances.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel is being used to conduct general low-speed research on aircraft and weapons.

General Comments: None

Photograph/Schematic Available: Yes

RAE Farnborough 24 ft Anechoic Low-Speed Wind Tunnel

Country: United Kingdom

Location: Royal Aerospace Establishment Farnborough, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Farnborough
AE2 Division
Aerodynamics Department
Farnborough, Hampshire GU14 6TD
United Kingdom

Operator(s): Royal Aerospace Establishment Farnborough

International Cooperation: Not available

Point of Contact: Superintendent, AE2 Division, Royal Aerospace Establishment Farnborough, Tel.: [44]-(252)-24461, ext. 5377

Test Section Size: 7.3 m circumference x 7 m long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.01 to 0.15 or 5 to 50 m/s
Reynolds Number: Up to 3.4 x 10^6/m
Total Pressure: 1 bar
Dynamic Pressure: Up to 1.5 kN/m^2
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1934
Date Placed in Operation: Not available
Date(s) Upgraded: 1970
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Farnborough 24 ft Anechoic Low-Speed Wind Tunnel is an open-jet, single-return circuit, continuous-flow subsonic wind tunnel.

Testing Capabilities: The tunnel has extensive acoustic treatment in the test section and is used to measure propeller, rotor, and jet noise. It has an overhead three-component mechanical balance and heavy-duty floor two-component (lift and drag) balance. It also has auxiliary air supplies for model blowing.

Data Acquisition: The tunnel has portable equipment for acoustic work used in a number of tunnels and laboratories. Outside users of the tunnel bring their own data acquisition systems.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel is being used to test a wide variety of work (such as propeller, rotor, and jet noise).

ARA Bedford Transonic Wind Tunnel (TWT)

Country: United Kingdom

Location: Aircraft Research Association, Bedford, United Kingdom

Owner(s):
Aircraft Research Association
Manton Lane
Bedford, Bedfordshire MK41 7PF
United Kingdom

Operator(s): Aircraft Research Association

International Cooperation: Not available

Point of Contact: Chief Executive, Aircraft Research Association, Tel.: [44]-(234)-50681

Test Section Size: 9 x 8 ft

Operational Status: Active

Utilization Rate: 14 hours per day

Performance
Mach Number: 0 to 1.4
Reynolds Number: 1.5 to 5.5 x 10^6/ft
Total Pressure: 11.8 to 17.6 psia
Dynamic Pressure: 0 to 900 lb/ft^2
Total Temperature: Up to 580 degrees Rankine
Run Time: Continuous
Comments: The tunnel has rapid change model carts.

Cost Information
Date Built: 1953 to 1956
Date Placed in Operation: 1956
Date(s) Upgraded: Continuous
Construction Cost: $4,185,000 (1955)
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $37,950 to $46,200 per day (1989)
Source(s) of Funding: Commercial contracts

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ARA Bedford Transonic Wind Tunnel is a closed-circuit, continuous flow transonic wind tunnel.

Testing Capabilities: The TWT is capable of testing complete models of aircraft and missiles generally using a rear-mounted sting and semispan models with floor mounting. A computer-controlled automatic model movement system is used for most test programs. It has turbine-powered simulators, an isolated cowl rig, afterbody rigs, store trajectory simulators, high-pressure air capability, and a Mach simulation tank ground test facility for model duct flows.

Data Acquisition: The tunnel has 256 channels for strain-gauge balances, scanivalves, electronic pressure scanners, various other transducers, and dynamic transducers to measure mean and unsteady flows, temperatures, and pressures. Force data can be recorded in continuous or "move and pause" modes. Full on-line processing and interactive color graphics are available.

Planned Improvements (Modifications/Upgrades): These include general enhancements.

Unique Characteristics: The TWT has a sting-holder mechanism that is capable of subjecting models to high values of roll rate on a continuous basis, a constant angle of attack and yaw performance curve, and propeller and acoustic testing capability.

Applications/Current Programs: Current programs include industry projects and research.

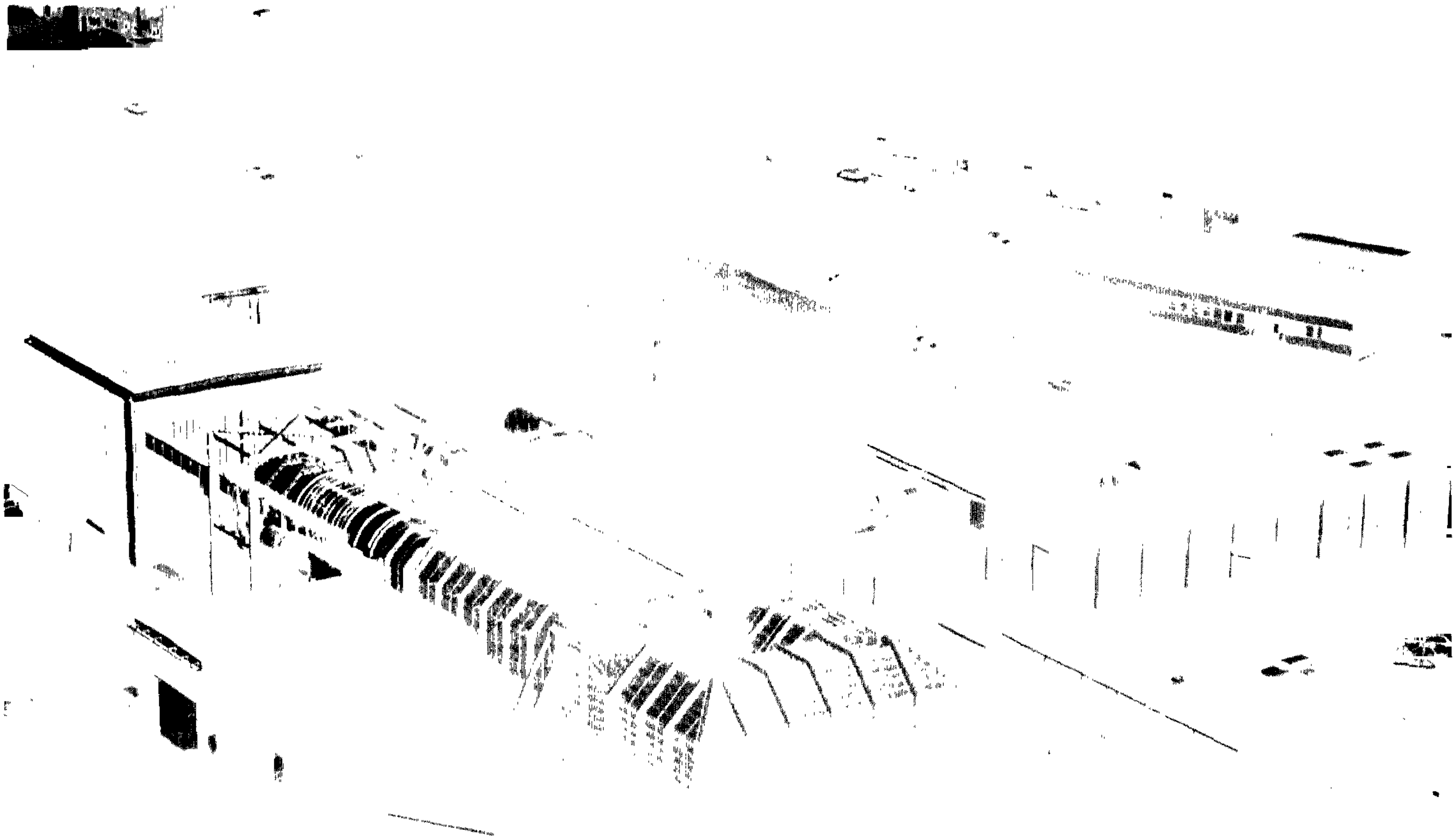
General Comments: The ARA Bedford Transonic Wind tunnel is a highly productive commercial facility with a utilization rate of about 1,700 hours per year. A new brochure is expected to be available in December 1989.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 157.

Date of Information: October 1989

Figure IX.15: ARA Transonic Wind Tunnel (TWT)



Source: ARA

RAE Farnborough 8 × 6 ft Transonic Wind Tunnel

Country: United Kingdom

Location: Royal Aerospace Establishment Farnborough, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Farnborough
AE2 Division
Aerodynamics Department
Farnborough, Hampshire GU14 6TD
United Kingdom

Operator(s): Royal Aerospace Establishment Farnborough

International Cooperation: Not available

Point of Contact: Superintendent, AE2 Division, Royal Aerospace Establishment Farnborough, Tel.: [44]-(252)-24461, ext. 5377

Test Section Size: 1.8 x 2.4 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0 to 1.25
Reynolds Number: 24 x 10^6/m at Mach 0.3 and 9 x 10^6/m at Mach 1.25
Total Pressure: 0.1 to 3.5 bars
Dynamic Pressure: 36 kN/m^2 (maximum)
Total Temperature: 328 degrees Kelvin
Run Time: Not available
Comments: None

Cost Information
Date Built: 1942
Date Placed in Operation: Not available
Date(s) Upgraded: 1955 and 1956
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Farnborough 8 × 6 ft Transonic Wind Tunnel is a continuous-flow, closed-circuit, annular-return transonic wind tunnel. It has a single-stage fan, slotted walls, and a 12,000-hp fan drive with an 8,000-hp plenum chamber suction drive.

Testing Capabilities: The tunnel has sting and half-model balances available as well as a quadrant with straight and cranked stings to cover a high range of angles of attack. Ample compressed air supplies are available at the working section. The tunnel also has a three-phase variable-frequency supply for large electric motors, such as propellers. It contains a sting for weapon trajectories and flow surveys, Midwood manometers, and a scanivalve/transducer system. The 8,000-hp plenum chamber compressor also drives the RAE 2 × 1.5 ft Transonic Wind Tunnel.

Data Acquisition: The tunnel has a computer-based data acquisition system and on-line processing and display strain-gauge balances.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include research on aircraft and weapons including boundary layer surveys and flowfield traverses.

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 159.

Date of Information: November 1989

BAe Brough 27 X 27 in. Transonic/Supersonic Blowdown Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Brough, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
Brough, North Humberside, Cumbria HU15 1EQ
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Alan N. Dewar, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52856

Test Section Size: 0.68 x 0.68 x 2.1 m

Operational Status: Decommissioned (see General Comments)

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.1 to 2.5
Reynolds Number: 2.9 to 66 x 10^6/m (transonic) and 2.9 to 148 x 10^6/m (supersonic)
Total Pressure: 1.2 to 4 bars (transonic) and 1.2 to 9 bars (supersonic)
Dynamic Pressure: 0.8 to 174 kN/m^2 (transonic) and 0.8 to 428 kN/m^2 (supersonic)
Total Temperature: 273 degrees Kelvin
Run Time: Not available
Comments: None

Cost Information
Date Built: 1958
Date Placed in Operation: Not available
Date(s) Upgraded: 1963 and 1984
Construction Cost: Not available
Replacement Cost: $28 million (1990)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Brough 27 X 27 in. Transonic/Supersonic Blowdown Wind Tunnel is a trisonic wind tunnel. The tunnel has been decommissioned and is being sold by British Aerospace (see General Comments).

Testing Capabilities: The tunnel has a 22-percent porosity working section (normal holes) and interchangeable nozzles for Mach 1.4 to 2.5. Tunnel operations (such as Mach number and Reynolds Number) are computer-controlled. The tunnel is used for overall 6-degree force measurements, flutter, weapon jettisons, buffet, and flow visualization on full-, half-, and part-models.

Data Acquisition: The tunnel is capable of computer-controlled data logging of 24 channels with immediate post-run data reduction. It also has multiscanivalve capability.

Planned Improvements (Modifications/Upgrades): In 1985 the tunnel's capability was enhanced to 9 bars at a cost of about $480,000.

Unique Characteristics: Not available

Applications/Current Programs: These included novel methods of weapon release, overall forces on advanced Short Takeoff and Vertical Landing (STOVL) configurations, and other combat aircraft. Other current programs include flutter technique development and in-service weapon clearance/aiming problems.

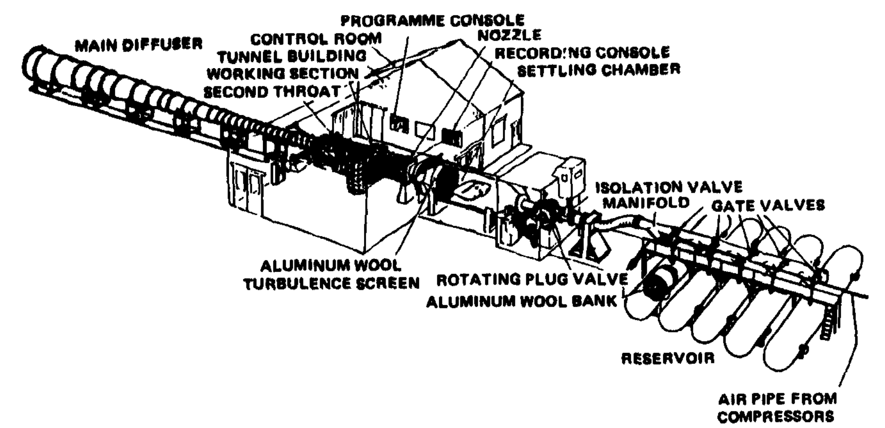
General Comments: The BAe Brough 27 × 27 in. Transonic/Supersonic Blowdown Wind Tunnel has been decommissioned and is being sold by British Aerospace. The tunnel is expected to be reactivated at another facility installation.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 178.

Date of Information: January 1990

Figure IX.16: Schematic Drawing of the BAe Brough 27 × 27 in. Transonic/ Supersonic Blowdown Wind Tunnel



Source: NASA

BAe Warton 1.2 m High-Speed Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Preston, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
Warton Aerodrome
Preston, Lancashire PR4 1AX
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Alan N. Dewar, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52856

Test Section Size: 1.22 x 1.22 x 3 m

Operational Status: Active

Utilization Rate: Double shift; 13 hours per day, 5 days per week

Performance
- **Mach Number:** 0.4 to 4
- **Reynolds Number:** 80 x 10^6/m (maximum)
- **Total Pressure:** 1.38 to 5 bars (transonic)
- **Dynamic Pressure:** Not available
- **Total Temperature:** Ambient
- **Run Time:** 7 to 40 s (depends on Mach number and stagnation pressure)
- **Comments:** Typical recharge time is 40 min.

Cost Information
- **Date Built:** 1959
- **Date Placed in Operation:** Not available
- **Date(s) Upgraded:** 1972, 1980, and 1988
- **Construction Cost:** Not available
- **Replacement Cost:** $35 *million* (1990)
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The BAe Warton 1.2 m High-Speed Wind Tunnel (formerly known as the BAe Warton 4 ft Blowdown Wind Tunnel) is a trisonic wind tunnel.

Testing Capabilities: The tunnel has a supersonic nozzle and flexible roof and floor that can be set to any Mach number. It has a transonic working section with 19-percent perforations, diffuser suction on the plenum chamber, and second throat control of Mach number. The full range of stagnation pressures are used regularly. The tunnel is equipped for (1) six-component tests, two sting-mounting carts, and internal strain-gauge balances, (2) pressure plotting (typically 400 points), (3) afterbody drag measurements and wing tip stings (transonic and supersonic tests), (4) store load and store jettison testing, (5) roll damping derivatives and rolling sting (transonic only at 300 rpm), (6) flutter measurements (damping or destructive), and (7) half-model cart (transonic only) with model mounting from the turret floor.

Data Acquisition: The tunnel has 70 analog, 6 digital, and 6 scanivalve channels on a PDP 11-based data acquisition and control system. The tunnel also has a scanivalve "ZOC Hyscan" solid state system that uses segmented, dual-ported modules, 42-track magnetic tape recording and subsequent digitization, and Fourier analysis for high-frequency data. A dedicated VAX 11/780 computer is used for data reduction, which is fully corrected, plotted, and tabulated in 2 to 10 min after the run. Computer storage of 15-year results with indexed retrieval is also available.

Planned Improvements (Modifications/Upgrades): No improvements are necessary in the near future.

Unique Characteristics: Not available

Applications/Current Programs: The tunnel is used for aircraft design and development, flight test support, new project assessment, and aerodynamic research by a major manufacturer of combat aircraft. The tunnel is fully active on a flexible program, allowing quick reaction to new demands. It is fully staffed for the design and manufacture of models, rigs, and strain-gauge balances and for calibration, testing, and analysis.

General Comments: The BAe Warton 1.2 m High-Speed Wind Tunnel was formerly known as the BAe Warton 4 ft Blowdown Wind Tunnel.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 173.

Date of Information: January 1990

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 230.

Date of Information: October 1989

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 217.

Date of Information: January 1990

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 84 (EOARD Technical Report).

Date of Information: September 1989

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 228. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 103 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: November 1989

balance, and provides on-line reduction and presentation of data. The tunnel has the capacity for 48 low-level analog signals and 24 pressure scanning switches.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 202.

Date of Information: November 1989

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 279. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 81 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: October 1989

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 278. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 81 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: October 1989

second can be recorded and reduced to engineering units locally. An off-line VAX 11/780 computer is used to process the data.

Planned Improvements (Modifications/Upgrades): The working section is to be rebuilt in 1990 with new flexible liner plates to improve the flow quality. All hydraulic and electronic control systems will be replaced between 1990 and 1992.

Unique Characteristics: Not available

Applications/Current Programs: Current programs include project and research force and moment, pressure plotting, and kinetic heating tests on missile shapes for British Aerospace and the British government, aerodynamics of fin-stabilized shells and slender delta platforms, behavior of lateral thrusters, and tests on lifting reentry shapes. The open-jet facility is used for live firings of rocket motors and jettison trials on production or development hardware.

General Comments: The BAe Warton Guided Weapons Wind Tunnel was recommissioned during 1984 after operating for a number of years in a secondary role as a high-speed open-jet test facility with a speed range of Mach 0.1 to 1.8. The tunnel was not used between 1979 and 1984.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 271. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 83 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: January 1990

The University of Southampton Hypersonic Gun Tunnel

Country: United Kingdom

Location: The University of Southampton, Southampton, United Kingdom

Owner(s):
The University of Southampton
Department of Aeronautics and Astronautics
The University, Highfield
Southampton, Hampshire S09 5NH
United Kingdom

Operator(s): The University of Southampton

International Cooperation: Not available

Point of Contact: Professor Robin A. East, The University of Southampton, Tel.: [44]-(703)-592324

Test Section Size: 0.12 m diameter (open-jet)

Operational Status: Active

Utilization Rate: 5 tests per day

Performance
Mach Number: 8.4 (conical) and up to 12
Reynolds Number: 1 to 10 x 10^6/ft and 2 x 10^6/ft at Mach 12
Total Pressure: Up to 600 bars
Dynamic Pressure: Up to 2.2 bars at Mach 8.4 and 0.4 bar at Mach 12
Total Temperature: Up to 1,100 degrees Kelvin
Run Time: 20 ms
Comments: Nozzle exit diameter is 12 cm.

Cost Information
Date Built: 1959
Date Placed in Operation: 1960
Date(s) Upgraded: Continuous process
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: $66,000 (1989)
Unit Cost to User: Not available
Source(s) of Funding: British government, British industry, and The University of Southampton.

Number and Type of Staff
Engineers: 1
Scientists: 0
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 2

Description: The University of Southampton Hypersonic Gun Tunnel is an intermittent hypersonic wind tunnel. The tunnel is a hypersonic flow facility in which nitrogen is compressed and heated by a supersonic light piston. An open-jet test section provides flow durations of approximately 20 ms at Mach numbers up to 12.

Testing Capabilities: The facility is equipped for flow visualization, heat transfer, and force measurements.

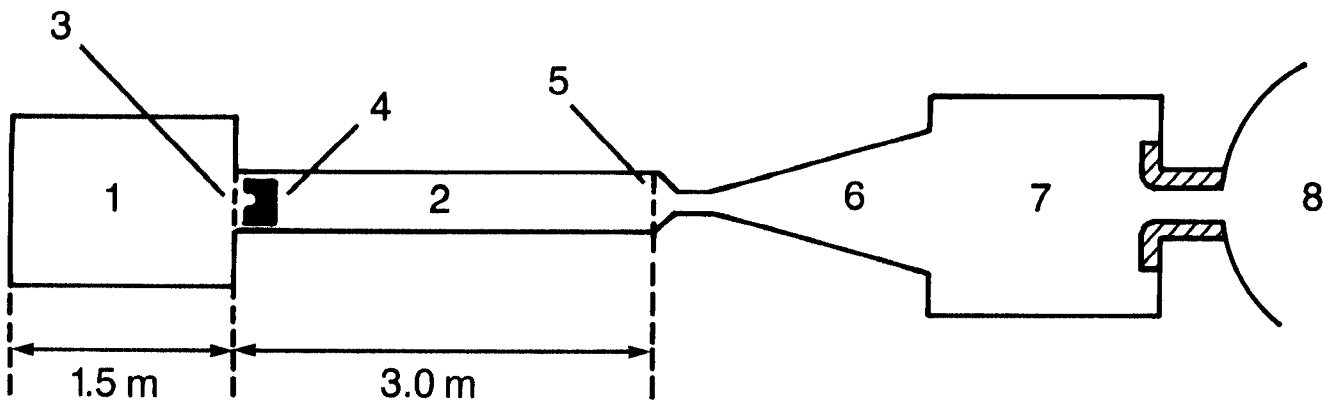
Data Acquisition: The facility has six on-line channels of data.

Planned Improvements (Modifications/Upgrades): Development of equipment to continually record the motion of models in free flight is taking place.

Unique Characteristics: None

Applications/Current Programs: Recent work carried out in this facility has been concerned with force measurements on various slender lifting hypersonic configurations over a range of angles of attack up to 70

Figure IX.18: Schematic Diagram of The University of Southampton Hypersonic Gun Tunnel



1. High pressure vessel ($V = 0.1m^3$, $p = 600$ bar)
2. Barrel ($V = 0.0023m^3$)
3. First diaphragm
4. Piston (0.015 by mass)
5. Second diaphragm
6. Nozzle (0.12m exit diameter, Mach 8.4)
7. Test section (open jet)
8. Dump chamber ($2m^3$ volume)

Source: The University of Southampton

Unique Characteristics: This facility, which possesses an unusually long and steady flow period (1 s) for a short duration facility, retains the economy of intermittent operation but with flow quality typical of continuous flow facilities.

Applications/Current Programs: Current programs include experiments and semi-empirical predictions of dynamic stability of simple axisymmetric shapes and hyperballistic vehicles; free-oscillation and experimental techniques for studying large amplitude non-linear effects on hypersonic dynamic stability; dynamic effects of hypersonic separated flow, for example, a rapidly deployed control surface; development of a continuous recording technique for free-flight studies in short duration hypersonic facilities using optical position sensors; aerodynamic characteristics of a range of basic vehicle configurations with lower surface flow containment; development of liquid crystal thermography for heat transfer investigations; and a study of interference effects on kinetic heating of slender finned bodies. The facility is currently being used for aerodynamic heating tests for HOTOL and unsteadiness of flap-induced separations for ESA's Hermes spaceplane.

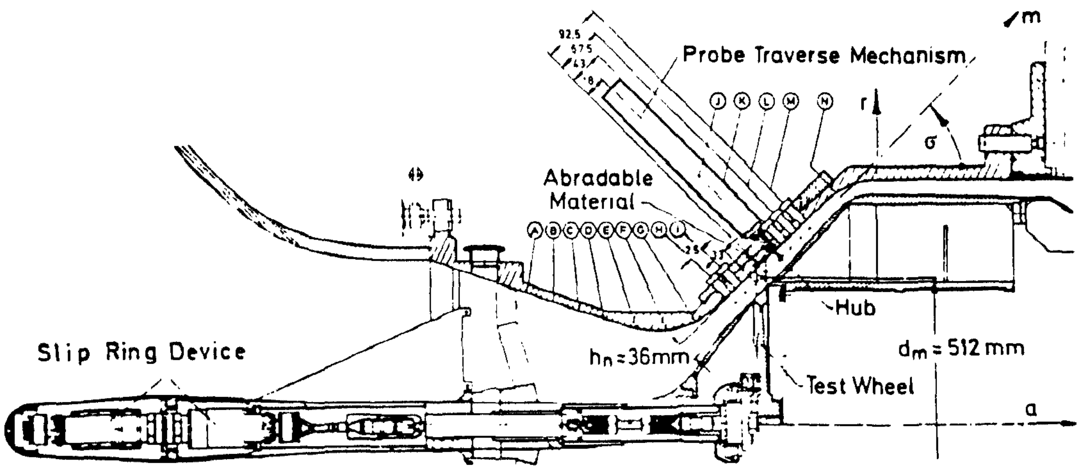
General Comments: The facility has been principally used for hypersonic aerodynamic work. It has also been used as a high-pressure combustion facility. Various liquid/gaseous fuels have been used, including hydrogen. The range and conditions are unusually large for a combustion facility. Operational safety is achieved by short test periods and the limited quantities of fuel used.

Photograph/Schematic Available: Yes

References: Department of Aeronautics and Astronautics, The University of Southampton. Departmental Research Report 1986. Southampton: The University of Southampton, October 1986, pp. 69-70. Hoyt, Capt. Anthony R. European Hypersonic Technology London: European Office of Aerospace Research and Development, 1986, p. 104 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 21-25 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: September 1989

Figure X.28: Schematic Diagram of the Test Section of the DLR Goettingen Rotating Cascades Wind Tunnel (RGG)



Source: DLR

Data Acquisition: The tunnel has a 90-channel A/D converter input and on-line data processing performed by Hewlett Packard A900/A600 computers.

Planned Improvements (Modifications/Upgrades): These include an ejector for variation of dynamic pressure.

Unique Characteristics: None

Applications/Current Programs: Primary research is directed at the investigation of the aerodynamics of missiles and missile components. Basic and concept-oriented fluid mechanical investigations on flying objects and space vehicles are also performed. The tunnel can accommodate models with a wingspan up to 20 cm, length up to 50 cm, and fuselage diameter up to 6 cm. Other programs include the dynamic stability of wings and bodies at high angles of attack.

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-6 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 220. Esch, Helmut. Die 0,6 m × 0,6 m Trisonische Messtrecke (TMK) der DFVLR in Koln-Porz (Stand 1986) (The 0.6 × 0.6 m Trisonic Test Section (TMK) of DFVLR in Koln-Porz (Status 1986). Koln, West Germany: DFVLR, 1986 (DFVLR-Mitteilung 86-21) (in German and translated in ESA-TT-1052, 1987).

Date of Information: October 1989

DLR Koln-Porz Vertical Free-jet Test Chamber (VMK)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanatalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: E.O. Krohn, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2278

Test Section Size: 18, 27, and 34 cm diameter (subsonic) and 15, 22, and 31 cm diameter (supersonic) free-jet exchangeable nozzles

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.2 to 3.2
Reynolds Number: 1.4 x 10^6/m to 2.5 x 10^8/m
Total Pressure: 2 to 35 bars
Dynamic Pressure: Not available
Total Temperature: 300 to 800 degrees Kelvin
Run Time: 60 s
Comments: The test cycle is 10 min (unheated) and 60 min (heated).

Cost Information
Date Built: 1957
Date Placed in Operation: 1964
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $145 per test and $1,668 per day (1989)
Source(s) of Funding: Not available

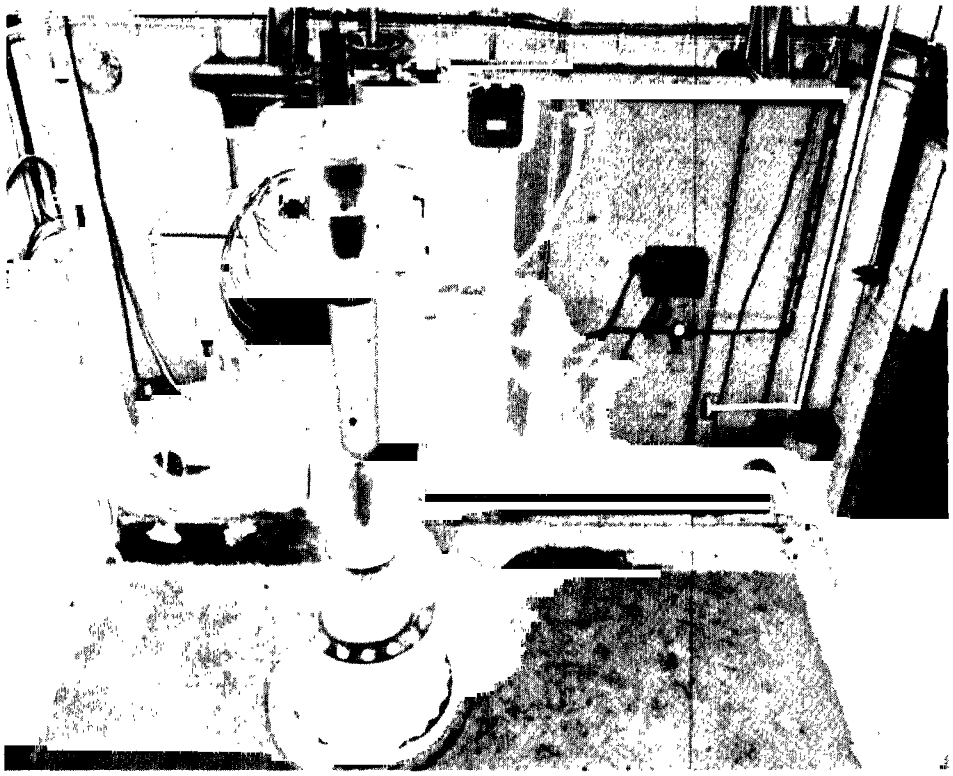
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Koln-Porz Vertical Free-jet Test Chamber is an intermittent operating blowdown subsonic and supersonic wind tunnel. For the subsonic range, three axially symmetrical nozzles of different cross sections can be used. For the supersonic range, 14 nozzles cover a range from Mach 1.57 to 3.2. The static temperature of the wind tunnel flow can be varied between 300 and 800 degrees Kelvin by a storage heater. With a maximum static pressure of 35 bars, ground conditions up to Mach 3 can be simulated. The tunnel is designed for the testing of ramjet engines and is installed in an explosion-proof building. A hydrogen supply for combustion tests is available. The special features of the facility permit heavy utilization.

Testing Capabilities: The tunnel has a thrust balance, internal balances, a multi-channel pressure scanning device, and a high-speed camera. It can conduct flow visualization tests using schlieren optics and jet simulation with cold air (at 300 bars). The tunnel is also capable of injecting models into the flow.

Data Acquisition: The tunnel has on-line data processing performed by Hewlett Packard A900/A600 computers.

Figure X.30: DLR Koln-Porz Vertical Free-jet Test Chamber (VMK)



Source: DLR

Unique Characteristics: None

Applications/Current Programs: The tunnel is used for aerodynamic standard investigations for industry and research on flying objects or airplane models and their components. The tunnel's special construction and the easy accessibility of the test chambers allow special investigations of models' variable configurations, flow visualization, the separation of outside loads in free flight, burning engines, and jet simulation.

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-2 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 183.

Date of Information: October 1989

Planned Improvements (Modifications/Upgrades): Not applicable

Unique Characteristics: None

Applications/Current Programs: These included probes for aerodynamic tests, components of engine inlets, and boundary layers on plane and curved plates.

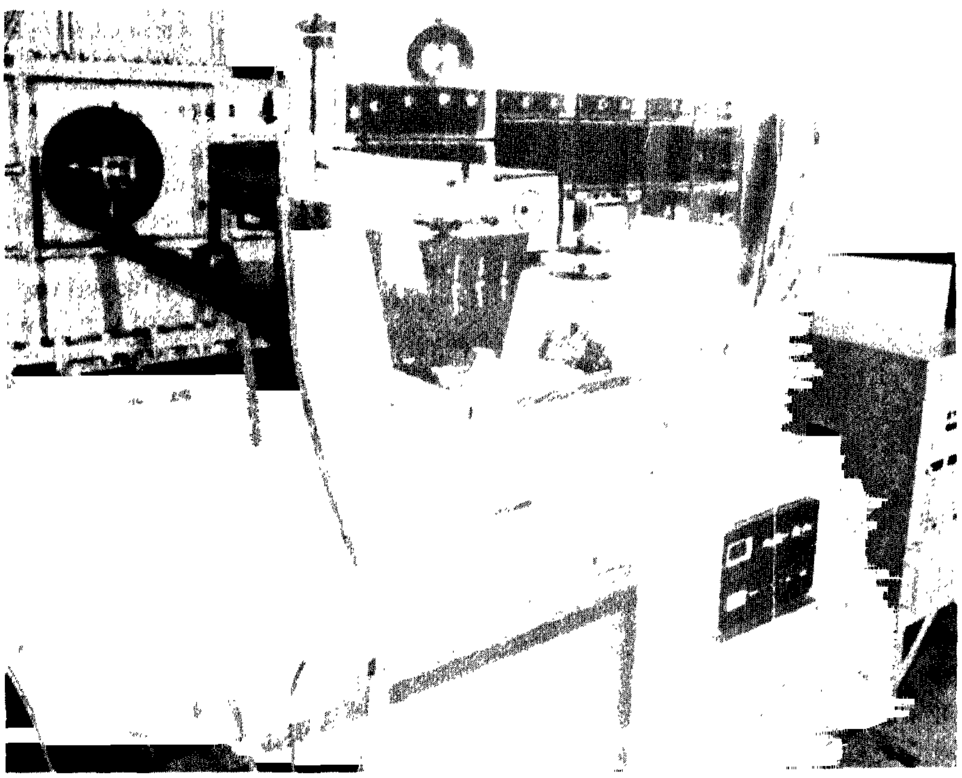
General Comments: The tunnel was decommissioned and has been disassembled.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-9 (in German).

Date of Information: October 1989

Figure X.32: DLR Koln-Porz Calibrating Tunnel (EMK)



Source: DLR

DLR Koln-Porz Calibrating Wind Tunnel (EMK)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-60-11

Test Section Size: 0.203 m x 0.381 m^2 (subsonic) and 0.203 m x 0.203 m^2 (supersonic)

Operational Status: Dismantled (see General Comments)

Utilization Rate: Not applicable

Performance
Mach Number: 0.3 to 0.8 (subsonic) and 1.3 to 3.1 (supersonic)
Reynolds Number: 3.9 x 10^6/m to 8.7 x 10^7/m
Total Pressure: 0.5 to 6 bars
Dynamic Pressure: Not available
Total Temperature: Less than 300 degrees Kelvin
Run Time: Up to 10 min
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Koln-Porz Calibrating Wind Tunnel was an intermittently working supersonic wind tunnel primarily used in blowdown operations. The tunnel was decommissioned and has been disassembled. By attaching a vacuum sphere, it could also be used for suction or combined blowdown-suction operation. It had a closed test section cross section measuring 0.203 × 0.381 m for subsonic velocities and a closed test section measuring 0.203 × 0.203 m for supersonic velocities. An asymmetrical nozzle block system permitted continuous variation of the Mach number between Mach 1.3 and 2.7. Temperature control was absent. Blow times depended on the kinds of operation and lasted up to several minutes. The calibrating tunnel was used for calibrating probes, testing new test methods, and conducting tests on single components of models (such as inlet diffusers).

Testing Capabilities: The tunnel was capable of conducting pressure tests with a measuring position switch and flow observation with schlieren optics. The tunnel was also equipped with three-component outside balances and a laser Doppler anemometer.

Data Acquisition: On-line data collection and evaluation was performed with a Hewlett Packard 2100 computer with drum plotter.

Unique Characteristics: None

Applications/Current Programs: The tunnel is used for basic and concept-oriented fluid mechanical investigations for missiles and space vehicles. The tunnel can accommodate models with a length of 25 cm, a wingspan of 15 cm, and a fuselage diameter of 3 cm.

General Comments: The tunnel shares a common storage heater and pressure regulation with the DLR Koln-Porz Vertical Free-jet Test Chamber (VMK).

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-7 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 226.

Date of Information: October 1989

DLR Koln-Porz High-Speed Wind Tunnel (HMK)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Helmut Esch, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2345

Test Section Size: 0.3 m x 0.3 m^2 (cross section)

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.4, 0.7, 1.57, 2.25, 2.89, and 4.15
Reynolds Number: 0.6 to 16.3 x 10^7/m
Total Pressure: 2 to 35 bars
Dynamic Pressure: Not available
Total Temperature: 300 to 600 degrees Kelvin
Run Time: 60 s
Comments: Test frequency is 5 min.

Cost Information
Date Built: 1959
Date Placed in Operation: 1964
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $145 per test and $1,668 per day (1989)
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Koln-Porz High-Speed Wind Tunnel is an intermittent, blowdown, subsonic and supersonic wind tunnel. In the subsonic range, the Mach number can be varied continuously. In the supersonic range, the Mach number can be varied by exchangeable nozzles. The supersonic tunnel has a closed test chamber measuring 30 cm × 30 cm^2. The static temperature of the flow, which can be varied between ambient and 600 degrees Kelvin, can be kept constant during a test by a heat exchanger. The tunnel is used primarily for fundamental research. The special features of the central air supply plant and the tunnel permit its heavy utilization.

Testing Capabilities: The tunnel has six-component internal balances, a multi-channel pressure scanning device, and a high-speed camera. It can conduct flow visualization tests using schlieren and oil film pictures and jet simulation with cold air (at 300 bars).

Data Acquisition: The tunnel has on-line data processing performed by Hewlett Packard A900/A600 computers. The tunnel also has a laser Doppler velocimeter.

Planned Improvements (Modifications/Upgrades): None

DLR Goettingen Hypersonic Vacuum Tunnel 1 (V1G)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: Tohoku University, Sendai, Japan; and ONERA, CNES, and Avions Marcel Dassault-Breguet Aviation, France

Point of Contact: Dr. H. Legge, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2326

Test Section Size: 0.25 m diameter x 0.5 m long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 7 to 25
Reynolds Number: 5×10^4/m to 5×10^6/m
Total Pressure: 0.1 to 250 bars
Dynamic Pressure: 2×10^2 Pa to 2×10^3 Pa
Total Temperature: 300 to 2,600 degrees Kelvin
Run Time: Continuous (several hours)
Comments: None

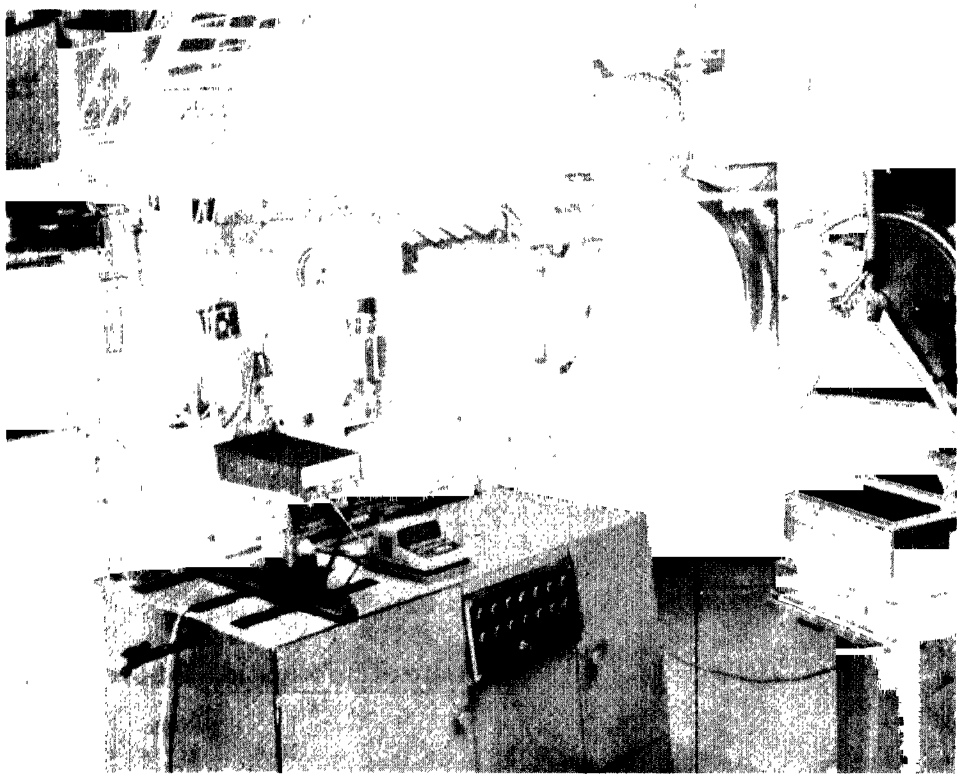
Cost Information
Date Built: 1965
Date Placed in Operation: 1966
Date(s) Upgraded: 1987 to 1992
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

Description: The DLR Goettingen Hypersonic Vacuum Tunnel 1 is a hypersonic wind tunnel. It simulates high Mach numbers in high altitudes. Due to extreme expansion, the gas must be heated in advance to avoid condensation. The requirements of different altitudes or gas densities require wider pressure variation on the high- and low-pressure side. The tunnel is mainly used for testing flow problems on flying objects, sounding devices, and space vehicles in altitudes from 70 to 120 km. It is also used for conducting basic research in the field of rarefied and real gas flows of high Mach numbers.

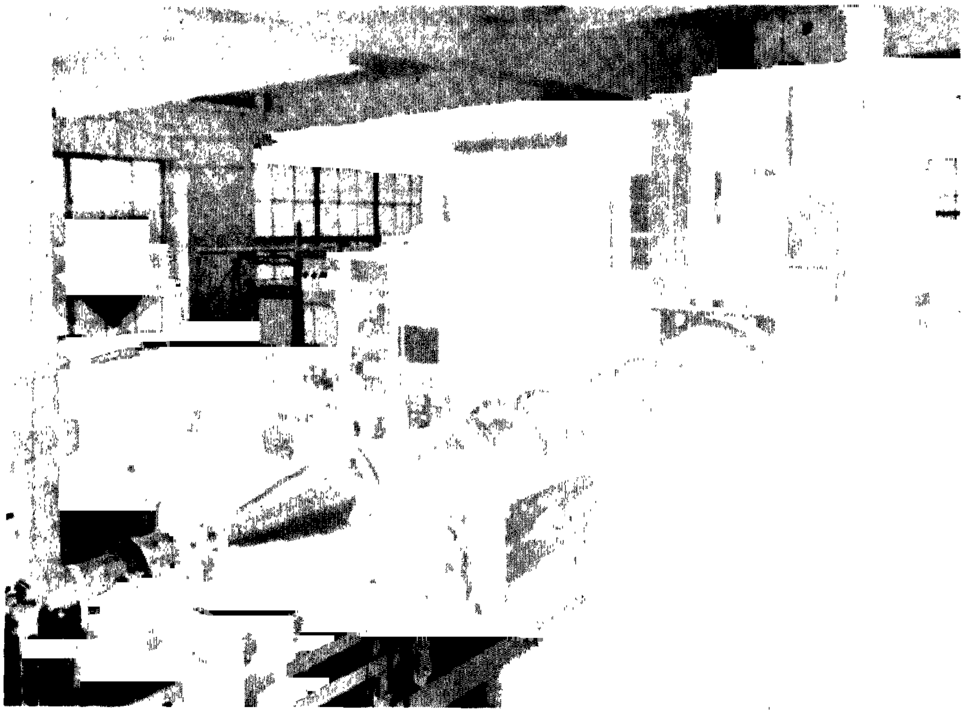
Testing Capabilities: The tunnel is capable of conducting force, pressure, and heat transfer measurements on models. It can also conduct pitot pressure, temperature, velocity, and concentration measurements in the flow field. Test time is practically unlimited. The tunnel has three- and six-component strain-gauge balances, pressure test boxes with switches for eight positions, a test chamber for the thin skin and thick wall technique to determine heat transfer, an electron beam test chamber for determining the state of energy and the absolute velocity of molecules, flow visualization by glow discharge or electron beam excitation, and an

Figure X.33: DLR Koln-Porz High-Speed Wind Tunnel (HMK)



Source: DLR

Figure X.34: DLR Goettingen Hypersonic Vacuum Tunnel 1 (V1G)



Source: GAO

installation for producing models by the galvanoplastic method. The tunnel also uses the liquid crystal technique for heat transfer studies.

Data Acquisition: The tunnel has on-line data processing by personal computers.

Planned Improvements (Modifications/Upgrades): These include higher Reynolds Numbers, larger test sections, contoured nozzles, a laser technique, and improved balances.

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to test flying objects reentry vehicles (such as ESA's Hermes spaceplane and MBB's Sanger II), basic shapes, reaction control, gas and fluid jets, nozzle jets, and processes of condensation.

General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 90 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 29 and 31-33 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-3 (in German).

Date of Information: October 1989

DLR Goettingen Hypersonic Vacuum Tunnel 2 (V2G)

Country: West Germany

Location: Deutsche Forshungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: None

Point of Contact: Dr. H. Legge, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2326

Test Section Size: 0.4 m diameter x 0.8 m long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 10 to 20 (conical)
Reynolds Number: 5 x 10^4/m to 5 x 10^5/m
Total Pressure: 0.25 to 40 bars
Dynamic Pressure: 30 Pa to 1.3 Pa x 10^2
Total Temperature: 300 to 1,800 degrees Kelvin
Run Time: Continuous (several hours)
Comments: None

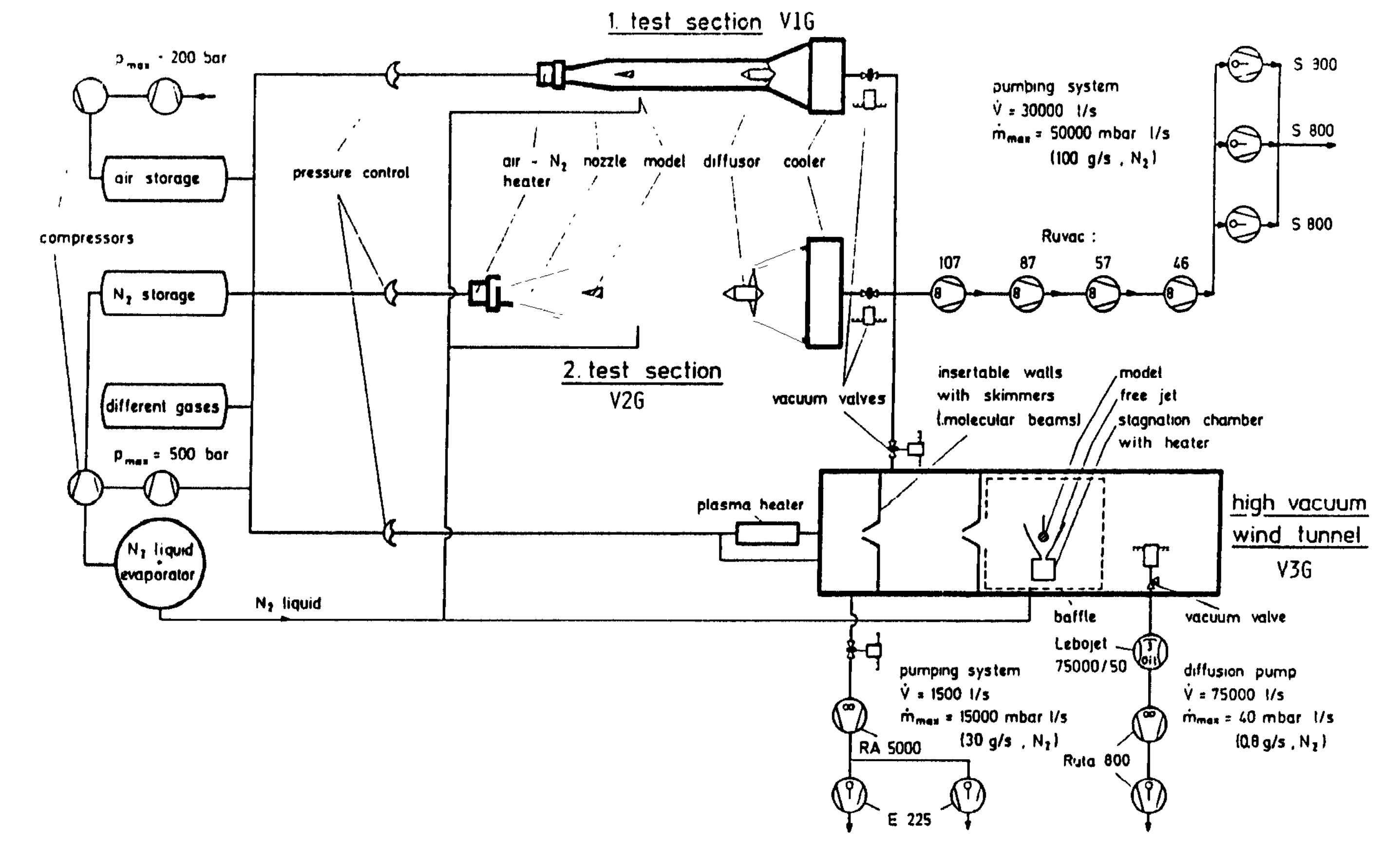
Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

Description: The DLR Goettingen Hypersonic Vacuum Tunnel 2 is a hypersonic wind tunnel. It simulates high Mach numbers in high high altitudes. Due to extreme expansion, the gas must be heated in advance to avoid condensation. The requirements of different altitudes or gas densities require wider pressure variation on the high- and low-pressure side. The tunnel is mainly used for testing flow problems on flying objects, sounding devices, and space vehicles in altitudes from 70 to 120 km. It is also used for conducting basic research in the field of rarefied and real gas flows of high Mach numbers.

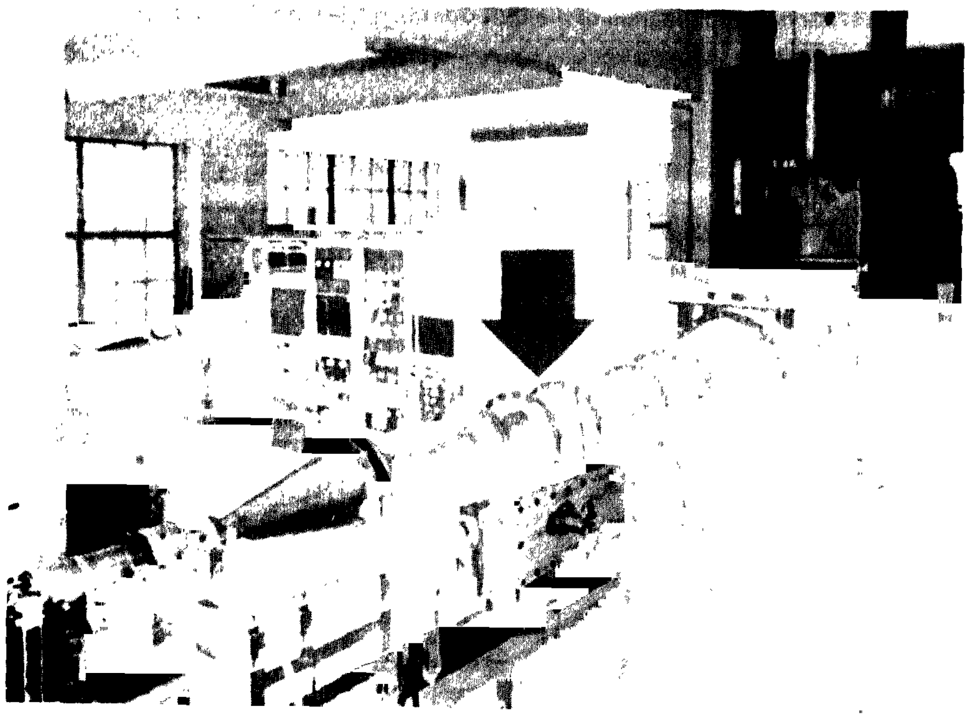
Testing Capabilities: The tunnel is capable of conducting force, pressure, and heat transfer measurements on models. It can also conduct pitot pressure, temperature, velocity and concentration measurements in the flow field. Test time is practically unlimited. The tunnel has three- and six-component strain-gauge balances, pressure test boxes with switch for eight positions, a test chamber for the thin skin and thick wall technique to determine heat transfer, an electron beam test chamber for determining the state of energy and the absolute velocity of molecules, flow visualization by glow discharge or electron beam excitation, and an

Figure X.35: Schematic Diagram of the DLR Goettingen Hypersonic Vacuum Tunnel 1 (V1G)



Source: DLR

Figure X.36: DLR Goettingen Hypersonic Vacuum Tunnel 2 (V2G)



Source: GAO

installation for producing models by the galvanoplastic method. The tunnel also uses the liquid crystal technique for heat transfer studies.

Data Acquisition: The tunnel has on-line data processing by personal computers.

Planned Improvements (Modifications/Upgrades): These include larger test sections, contoured nozzles, and a laser technique for flow diagnostics.

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to test flying objects, reentry vehicles (such as ESA's Hermes spaceplane and MBB's Sanger II), basic shapes, separation, reaction control, gas and fluid jets, nozzle jets, and processes of condensation.

General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 91 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 29 and 31-33 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-3 (in German).

Date of Information: October 1989

DLR Goettingen High-Vacuum Tunnel 3 (V3G)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: ESTEC, The Netherlands; and Avions Marcel Dassault-Breguet Aviation, France

Point of Contact: Dr. H. Legge, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2326

Test Section Size: 1,300 mm diameter x 3,300 mm long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 6 to 25 (sonic orifice free-jet)
Reynolds Number: 4×10^2/m to 4×10^5/m
Total Pressure: 0.005 to 15 bars
Dynamic Pressure: Not available
Total Temperature: 300 to 850 degrees Kelvin
Run Time: Continuous
Comments: None

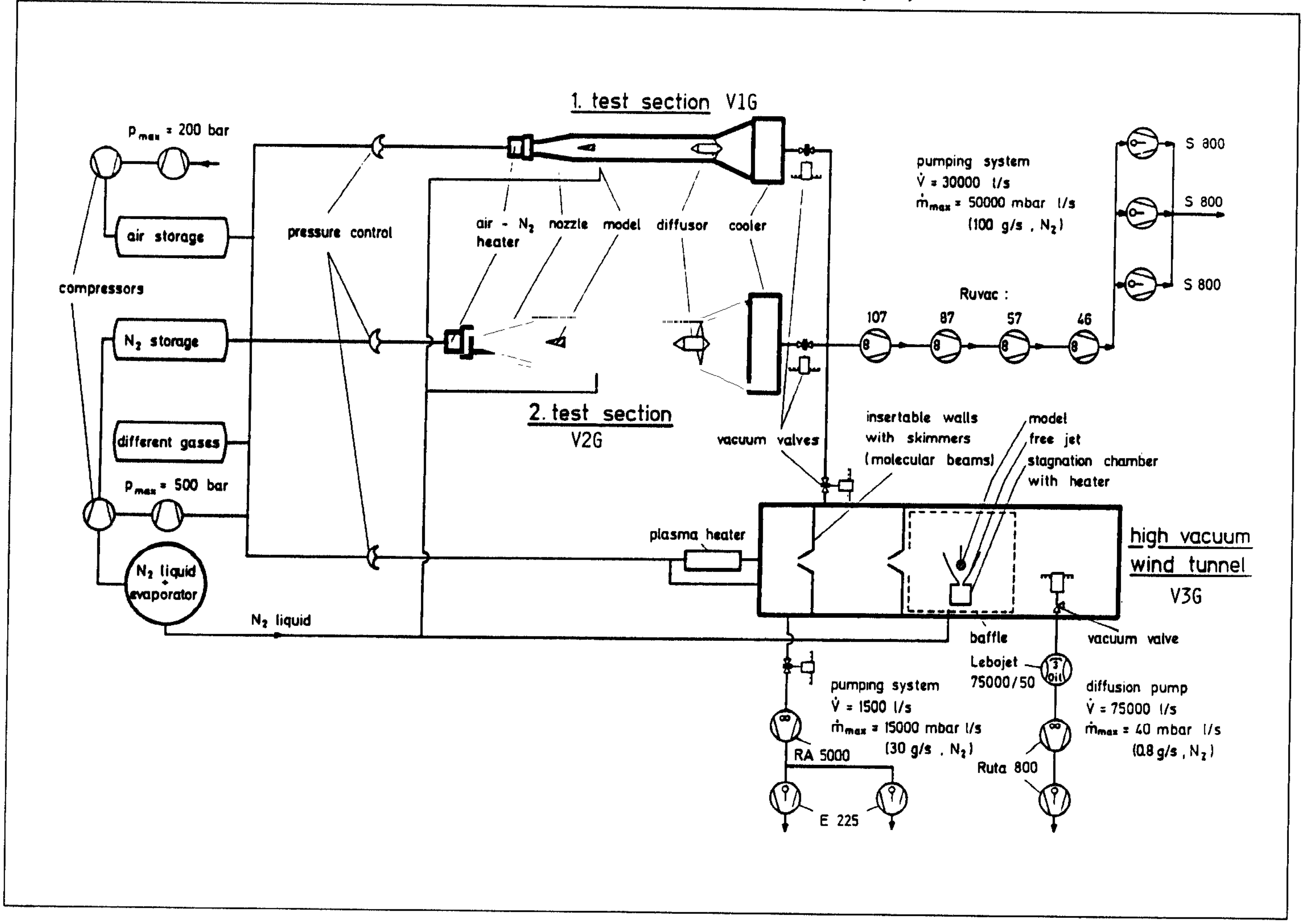
Cost Information
Date Built: 1968
Date Placed in Operation: 1969
Date(s) Upgraded: 1975
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

Description: The DLR Goettingen High-Vacuum Tunnel 3 is a hypersonic wind tunnel. It broadens the operating range of the two test chambers of the vacuum tunnel toward higher altitudes and lower densities. Due to the prevailing influence of viscosity, a sonic orifice free-jet expansion must be used. With the aid of a second pump system, a molecular beam can be produced. The tunnel is especially suited for investigating satellite aerodynamics, studying gas surface interactions, and for simulating flow processes in a high-vacuum environment. This includes plume flow from satellite thrusters and the flow impingement on satellite surfaces.

Testing Capabilities: The tunnel is capable of conducting force, pressure, and heat transfer tests. It can also conduct measurement of the recovery temperature and flow visualization by glow discharge. The tunnel uses the molecular beam technique and has electrodynamic one- and two-component balances, Patterson pressure probes, temperature probes, cryogenic liquid-nitrogen cooling of the test chamber walls, cryo-pumping, and a separate Auger spectrometer.

Figure X.37: Schematic Diagram of the DLR Goettingen Hypersonic Vacuum Tunnel 2 (V2G)



Source: DLR

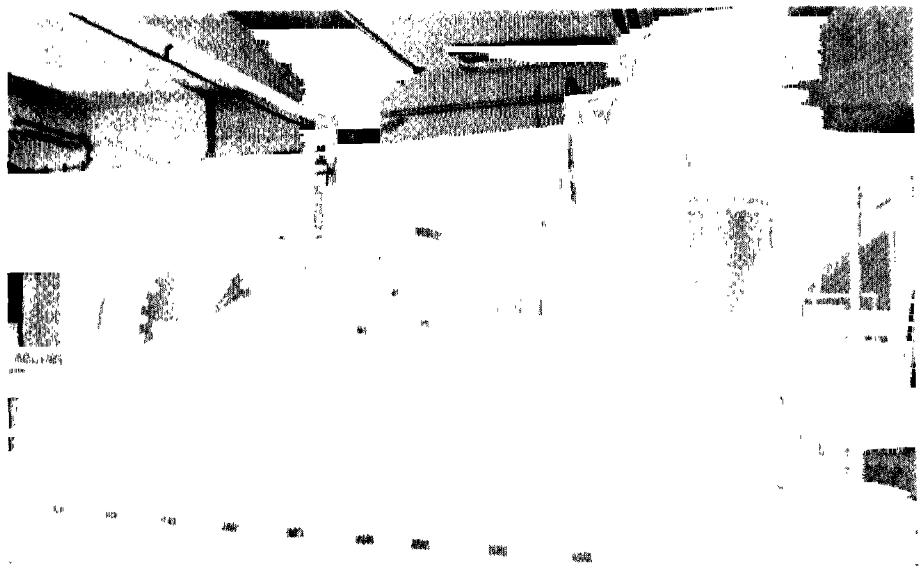


Figure X.38: DLR Goettingen High-Vacuum Tunnel 3 (V3G)

Source: DLR

Data Acquisition: The tunnel has on-line data processing by personal computers.

Planned Improvements (Modifications/Upgrades): These include seeded beam technique for orbital speeds at speeds greater than 5 km/s.

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to test free molecular and rarefied flow, space flying objects, satellites, gas jets, gas surface interaction, and impingement of spacecraft surfaces from control thrusters.

General Comments: Model size in the free-jet is less than 10 mm.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 91 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 29 and 31-33 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-4 (in German).

Date of Information: October 1989

DLR Goettingen Tube Wind Tunnel (RWG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: None

Point of Contact: Dr. G. Hefer, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2323

Test Section Size: 0.5 m diameter

Operational Status: Active

Utilization Rate: About 4 test per hour

Performance
Mach Number: 3, 4, 5, 6, 7, 9, 10, and 11
Reynolds Number: 3 to 50 x 10^6/m at Mach 5
Total Pressure: Greater than 2 bars at Mach 3 and less than 100 bars at Mach 11
Dynamic Pressure: Not available
Total Temperature: See General Comments
Run Time: 0.4 s
Comments: None

Cost Information
Date Built: 1967 to 1968
Date Placed in Operation: 1968
Date(s) Upgraded: Not available
Construction Cost: $505,178 (1967)
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

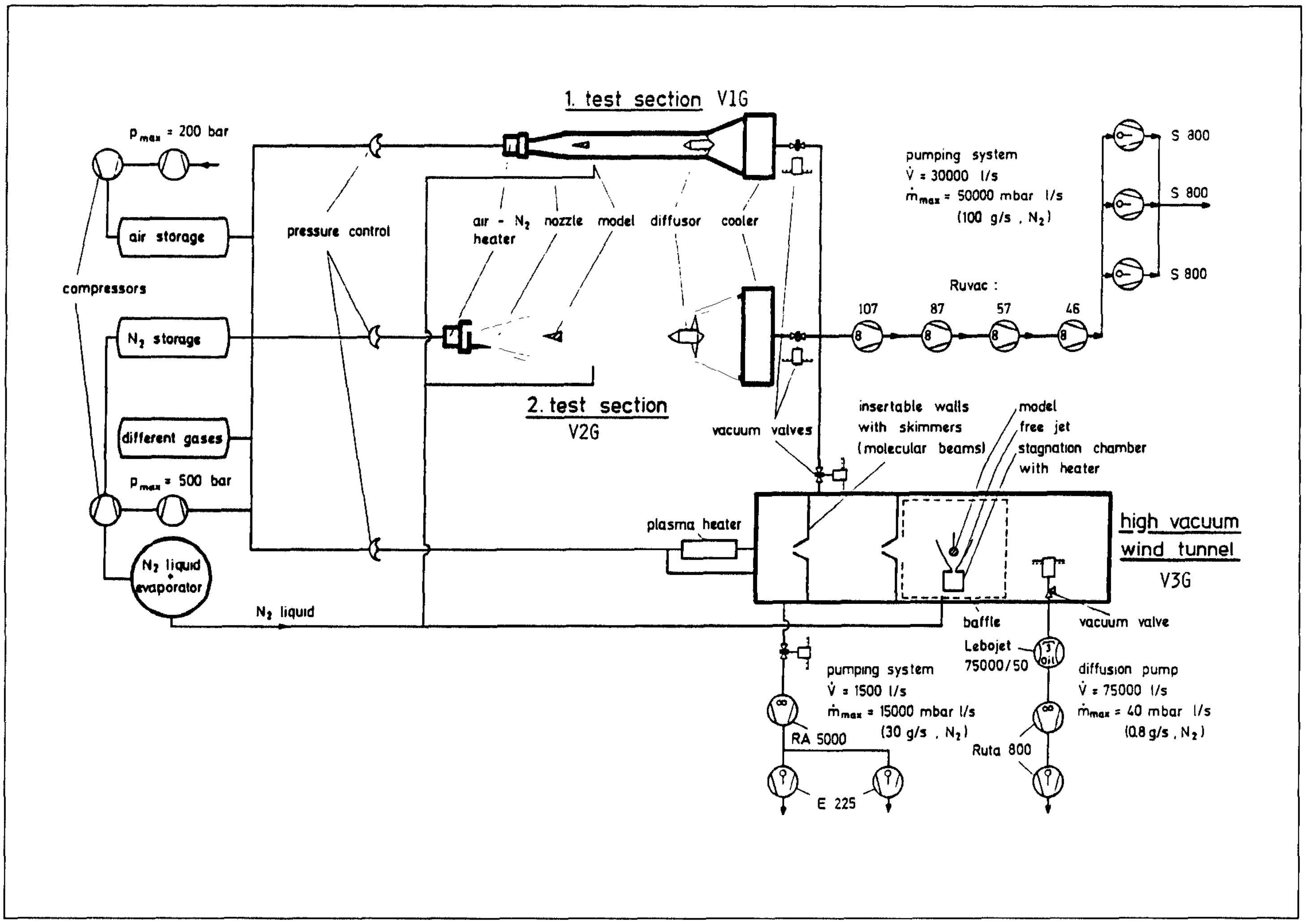
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Goettingen Tube Wind Tunnel is an intermittently operating hypersonic wind tunnel. Simple construction and good flow quality are guaranteed by applying the Ludwieg system, which ensures that constant flow parameters are maintained during the entire test period without special control devices. The tunnel has three separate reservoir tubes for low, medium, and high Mach numbers. It has exchangeable nozzles for Mach numbers 3, 4, 5, 6, 7, 9, 10, and 11.

Testing Capabilities: The tunnel is capable of conducting six-component force and moment measurements using the strain-gauge technique, pressure measurements using strain-gauge or piezoelectric transducers, heat transfer tests using the thin-skin technique, thermal mapping using thermochronic liquid crystals, and flow visualization tests using oil flow and schlieren methods. The test section can accommodate models with a platform area less than 100 cm^2 and a length less than 20 cm for high angle of attack models (cranked sting-supports) and less than 50 cm for small angle of attack models.

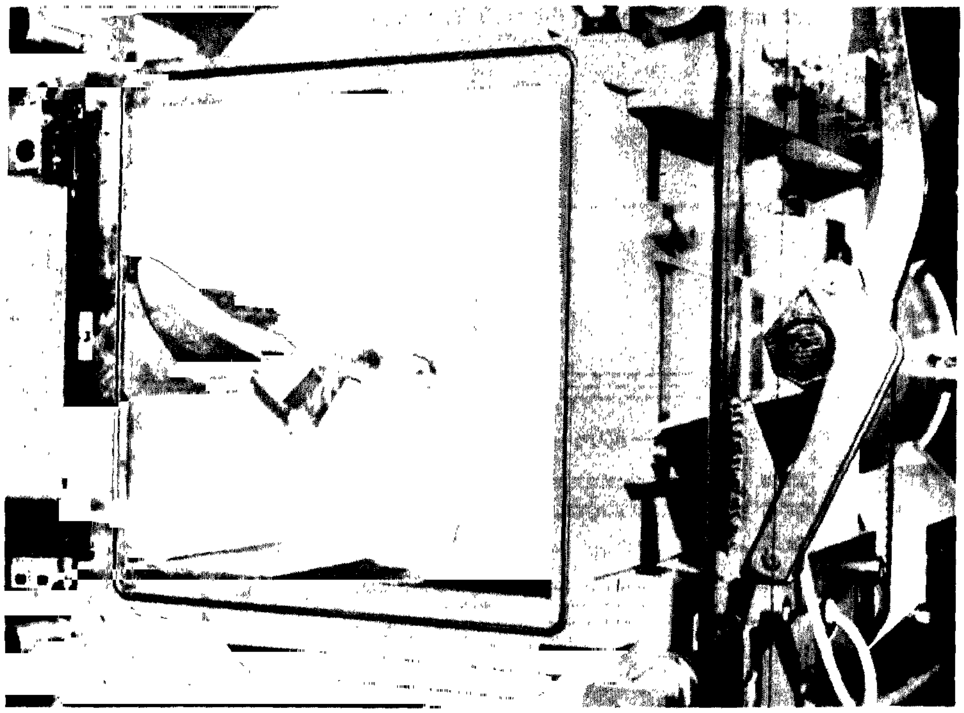
Data Acquisition: The tunnel has 16 channels and digital recording of test data. It also has off-line data reduction.

Figure X.39: Schematic Diagram of the DLR Goettingen High-Vacuum Tunnel 3 (V3G)



Source: DLR

Figure X.40: DLR Goettingen Tube Wind Tunnel (RWG)



Source: DLR

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to conduct basic research on transition, flow separation, and heat transfer. It is also used to conduct contract work for aerospace projects. On request, the tunnel is used for investigating special problems of wind tunnel testing technology and for developing new testing techniques.

General Comments: Total temperature is less than 130 degrees Celsius at Mach 3 to 4, less than 450 degrees Celsius at Mach 5, and less than 850 degrees Celsius at Mach 9 to 11.

Photograph/Schematic Available: Yes

References: DFVLR. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 89-90 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 29-31 and 33 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-3 (in German).

Date of Information: October 1989

)LR Koln-Porz High-Enthalpy Wind Tunnel 1 (P1K)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: K. Kindler, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2484

Test Section Size: Up to 110 mm diameter

Operational Status: Mothballed (see General Comments)

Utilization Rate: Not operational

Performance
Mach Number: 5 to 20 (conical)
Reynolds Number: 1×10^3/m to 1×10^4/m
Total Pressure: 0.1 to 4 bars
Dynamic Pressure: Not available
Total Temperature: 1,000 to 4,000 degrees Kelvin
Run Time: Continuous
Comments: None

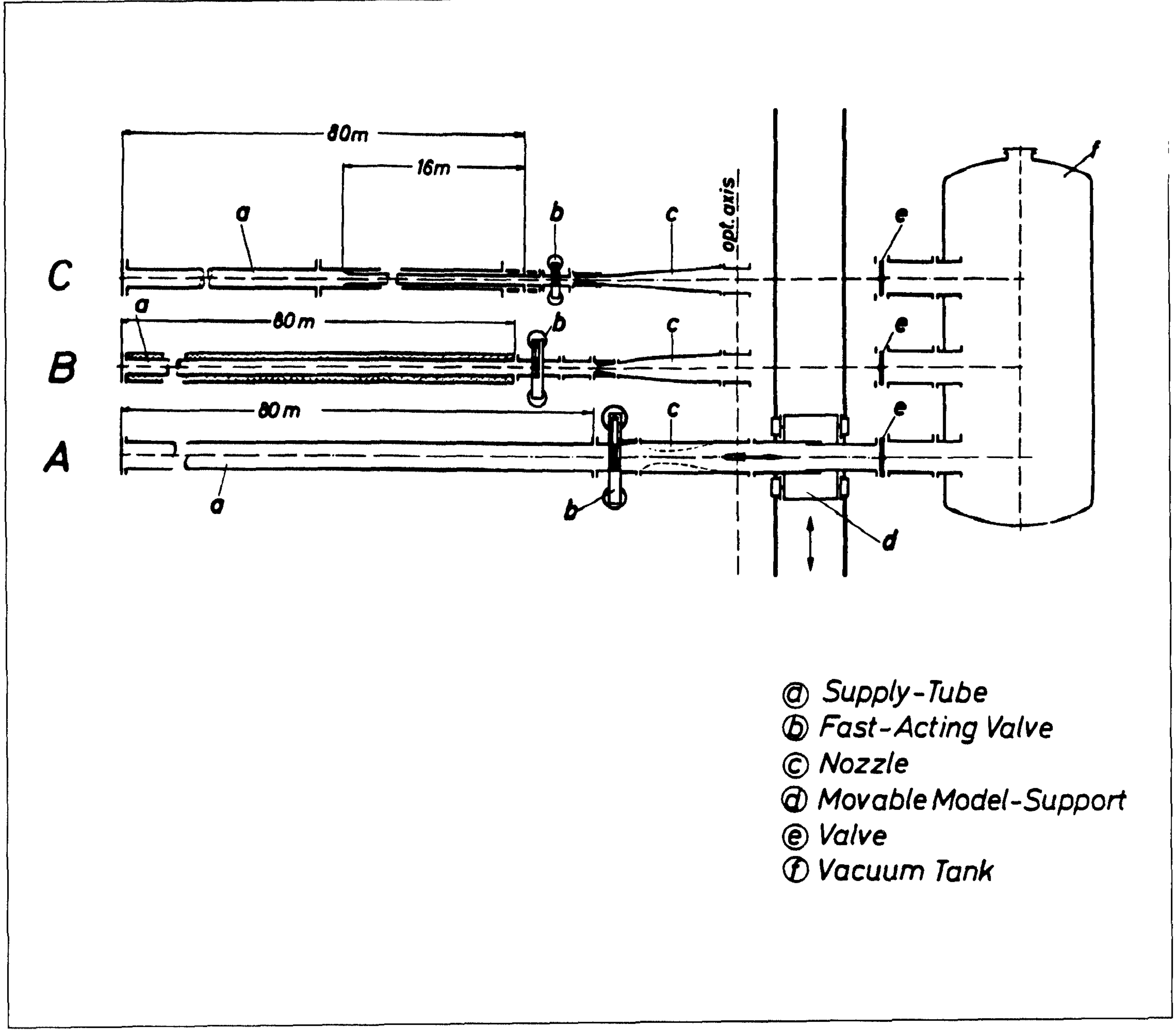
Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 0
Scientists: 0
Technicians: 4
Others: 0
Administrative/Management: 0
Total: 4

Description: The DLR Koln-Porz High-Enthalpy Wind Tunnel 1 is a hypersonic wind tunnel. It operates continuously and has a test chamber 0.8 m in diameter and a vacuum pump set. The gas is heated by a 20- to 200-kW electric arc heater. Operating gases are nitrogen, argon, helium, and dry air. Setting and adjustment of the desired flow condition occur by exchange of the nozzle configurations and infinite variation of the mass flux and the energy feed-in. The nozzle throat diameter is between 2 and 6 mm, conical nozzles have half-angles between 8 and 20 degrees, and the exit diameter is between 190 and 400 mm. The test chamber is an open cylinder and is perpendicular to the flow. The tunnel is used for pressure, temperature, force, and heat transfer tests in high-velocity flows. Although currently out of service, the tunnel can be made available, on short notice, for heavy utilization.

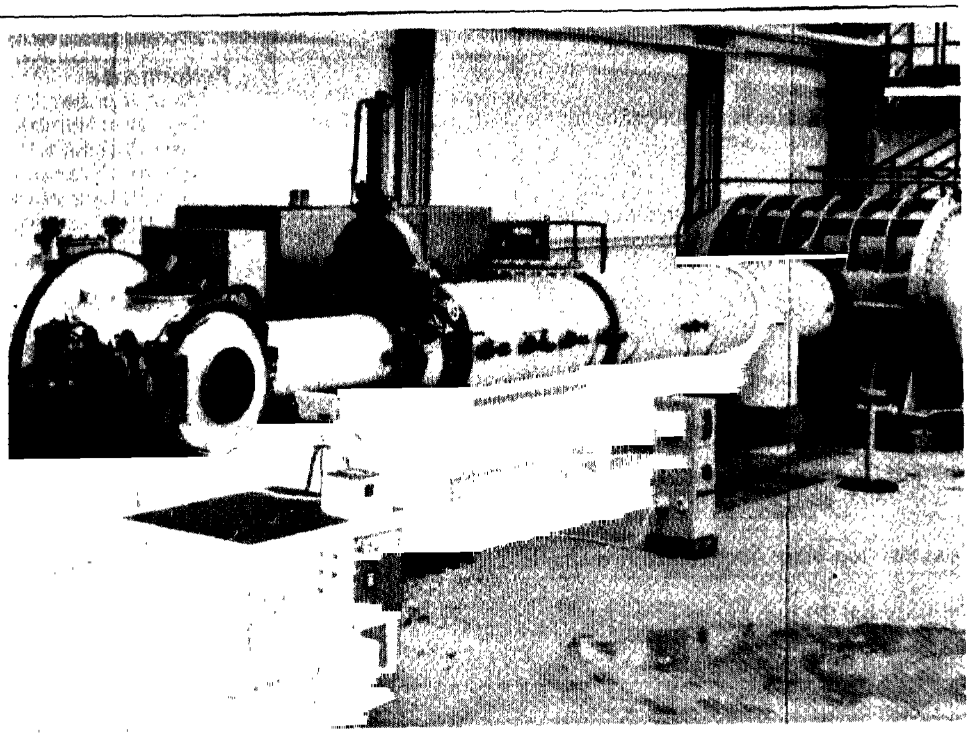
Testing Capabilities: The tunnel is capable of conducting pressure tests and heat transfer investigations using thermoelement measurements and colored-lacquer and infrared methods. The tunnel has a three-component strain-gauge internal balance, capacitive and wire-strain-gauge pressure absorption inside a range between 10 bars and 1 mbar. The tunnel also has a fully programmable compound micrometer motion table.

Figure X.41: Schematic Diagram of the DLR Goettingen Tube Wind Tunnel (RWG)



Source: DLR

'igure X.42: DLR Koln-Porz High-
:nthalpy Wind Tunnel 1 (P1K)



Source: DLR

Data Acquisition: Test data collection and evaluation are performed on-line a Hewlett Packard data collection unit with a core memory and magnetic tape.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel was used to test infinite model and probe adjustments.

General Comments: The tunnel is not used at the present time.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 92 (EOARD Technical Report). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-5 (in German).

Date of Information: October 1989

test range between 100 bars and 100 microbars. The tunnel is capable of conducting temperature and density tests, flow visualization by electron beam stimulation, pressure tests, and heat transfer tests by thermoelement measurements and infrared thermography.

Data Acquisition: Test data collection and evaluation are performed on-line by a Hewlett Packard data collection unit equipped with a 16,000-byte core memory and magnetic tape.

Planned Improvements (Modifications/Upgrades): These include a 5-MW rectifier and contoured nozzles.

Unique Characteristics: The tunnel has a device for mixing liquid nitrogen with air, which makes the P 2 test chamber suitable for investigations in cryogenic subsonic free-jets.

Applications/Current Programs: These include testing operational systems in high-enthalpy flow.

General Comments: Technical data for cryogenic operations are as follows: test cross section, 70 mm; Mach number range, 0.4 to 0.9; static temperature, 80 to 300 degrees Kelvin; pressures, 0.2 to 0.6 bars; Reynolds Number, up to 2×10^7/m (relative to 1 m); and test time, about 2 hours (time is dependent on liquid nitrogen flux and limited by a 2 m^3 liquid nitrogen tank).

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 93 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-6 (in German).

Date of Information: October 1989

DLR Koln-Porz High-Enthalpy Wind Tunnel 2 (P2K)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: ONERA, France

Point of Contact: K. Kindler, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2484

Test Section Size: About 250 mm diameter (cross section)

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 3 to 20 (conical)
Reynolds Number: 0.003 to 0.35 x 10^6/m
Total Pressure: 0.1 mbar to 10 bars
Dynamic Pressure: Not available
Total Temperature: 1,000 to 6,000 degrees Kelvin
Run Time: Continuous
Comments: See General Comments

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: $791,557 (1989)
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 2
Scientists: 3
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 6

Description: The DLR Koln-Porz High-Enthalpy Wind Tunnel 2 is a continuous-flow hypersonic wind tunnel. The tunnel is equipped with an open-jet test chamber 2.6 m in diameter and a vacuum pump set. The gas is heated by a 20-kW to 1-MW electric arc heater. Specific thermal power in the flow can be set at up to 2 MW/m^2. Test gases include nitrogen, argon, helium, and dry air. The setting and adjustment of the desired flow condition occurs by exchange of nozzle configurations and the variation of the mass flux and the energy feed-in. The conical nozzles have half-angles between 8 and 20 degrees, the nozzle throat diameter is between 2 and 29 mm, and the exit diameter is between 100 and 600 mm. The test chamber is an open cylinder perpendicular with its axis to the direction of the flow. On request, the tunnel can be utilized for pressure, temperature, force, and heat transfer testing.

Testing Capabilities: The tunnel has a probe adjustment device along three coordinates; a model displacement device; a mirror and lens system, which allows each point of the flow field to be examined with optical probes; a monochromator; and an adjustable diffusor. The tunnel also has probes for total enthalpy and flow density; an electron beam probe; a three-component strain-gauge balance; and a wire-strain-gauge, pressure absorption, and ionization vacuum meter with a total covered

DLR Koln-Porz High-Enthalpy Wind Tunnel 3 (P3K)

Country: West Germany

Location: Deutsche Forshungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: K. Kindler, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2484

Test Section Size: 250 mm diameter (cross section)

Operational Status: Standby

Utilization Rate: Not in operation

Performance
Mach Number: 3 to 15 (conical)
Reynolds Number: 1 x 10^5/m to 1 x 10^7/m
Total Pressure: 30 bars (maximum)
Dynamic Pressure: Not available
Total Temperature: 2,000 to 6,000 degrees Kelvin
Run Time: Continuous
Comments: Test gas used is air. Open jet test section is 4 m^3.

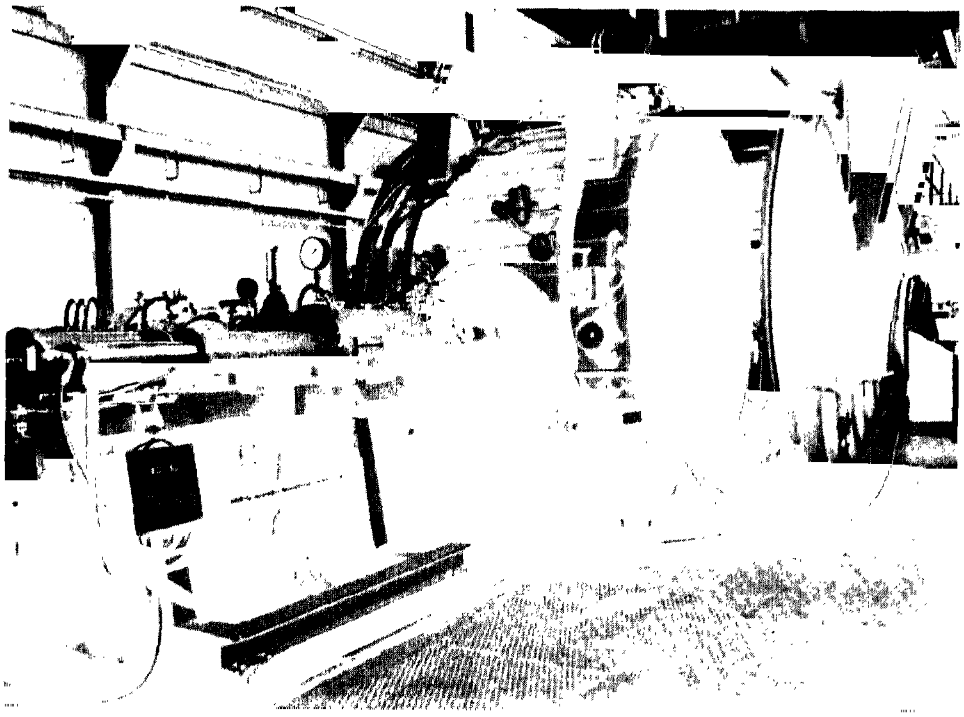
Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: $791,557 (1989)
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 2
Scientists: 3
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 6

Description: The DLR Koln-Porz High-Enthalpy Wind Tunnel 3 is a hypersonic wind tunnel. It operates continuously with a vacuum pump set. The gas is heated by a 20-kW to 1-MW electric arc heater. Test gases include nitrogen, argon, helium, and dry air. Specific thermopower in the flow can be set up to 4.5 MW/m^2. Setting and adjustment of the desired flow condition occurs by exchange of throat and nozzle configurations and variation of the mass flux and the energy feed-in. For this purpose, different nozzle configurations with conical extensions are available. Throat diameters measure between 5 and 100 mm, and conical nozzle configurations have exhaust diameters of between 30 and 600 mm. The test chamber diameter is about 250 mm. The test chamber is a cube (1.5 m) with four entries. Due to the high specific thermopower available, the tunnel is especially suited for investigations of heat transfer and protection systems.

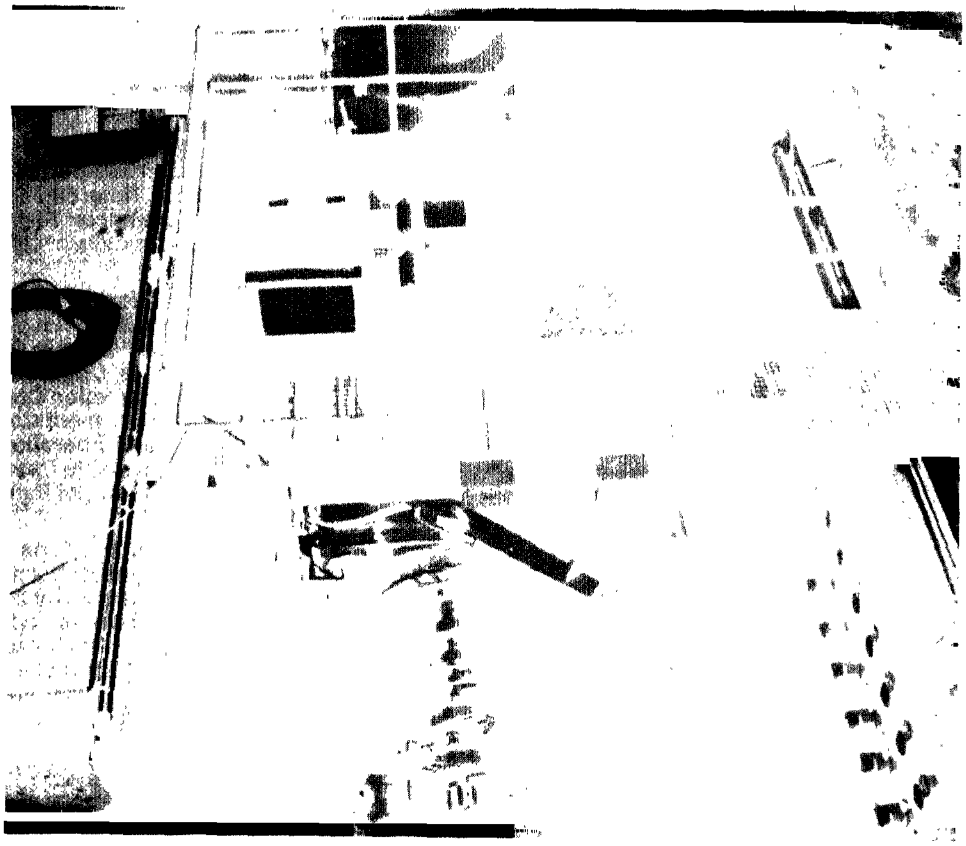
Testing Capabilities: The tunnel has probes for measuring total enthalpy and flow density, a laser light scanning probe, ablation scales, and an ionization vacuum meter with a total test range of 100 bars to 10 microbars. The tunnel is capable of conducting flow visualization tests and studies of nonequalibrium thermodynamics.

Figure X.43: DLR Koln-Porz High-Enthalpy Wind Tunnel 2 (P2K)



Source: DLR

Figure X.44: DLR Koln-Porz High-Enthalpy Wind Tunnel 3 (P3K)



Source: DLR

Data Acquisition: Test data collection and evaluation are performed on-line by a Hewlett Packard data collection unit equipped with a 16,000-byte core memory and magnetic tape.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These included material testing.

General Comments: The tunnel is currently in a standby status.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 93 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-7 (in German).

Date of Information: October 1989

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel was used to conduct aerodynamic and thermodynamic tests on flying and reentry vehicles. Typical model measurements were 30 cm (length of fuselage), 20 cm (wingspan), and 10 cm (fuselage diameter).

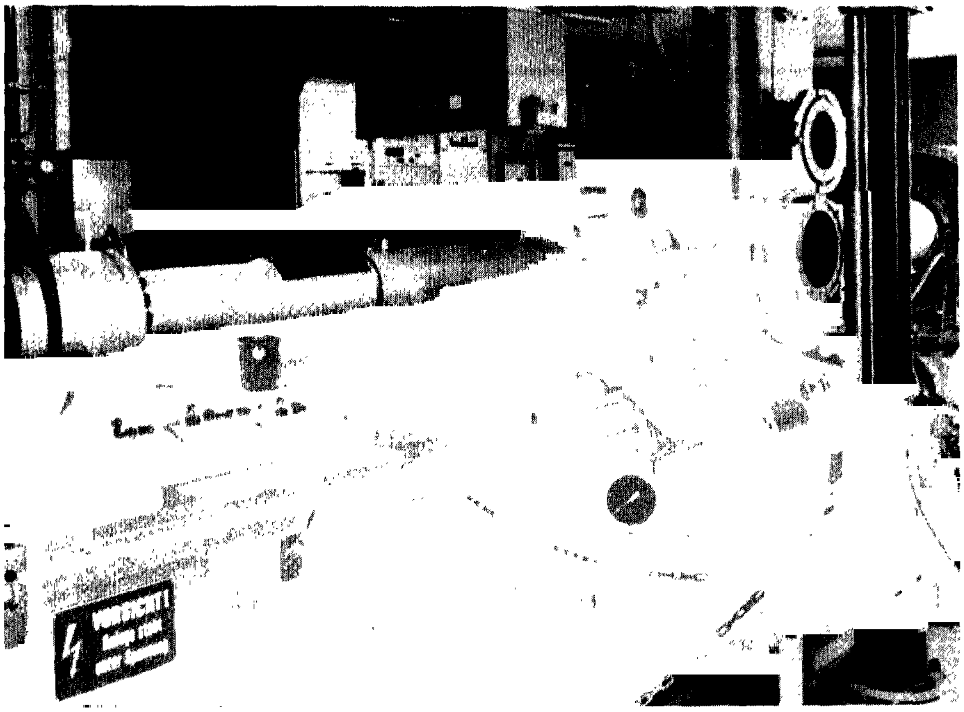
General Comments: The tunnel is out of operation and will not be reactivated.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-1 (in German).

Date of Information: October 1989

Figure X.45: DLR Koln-Porz Hypersonic Wind Tunnel 1 (H1K)



Source: DLR

DLR Koln-Porz Hypersonic Wind Tunnel 1 (H1K)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Helmut Esch, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2345

Test Section Size: 60 x 36 cm for Mach 4.5

Operational Status: Mothballed (see General Comments)

Utilization Rate: Not operational

Performance
- **Mach Number:** 4.5, 6, 8.7, and 11.2
- **Reynolds Number:** 3.6×10^5/m to 3×10^7/m
- **Total Pressure:** Not available
- **Dynamic Pressure:** 0.5 to 60 bars
- **Total Temperature:** 300 to 1,100 degrees Kelvin
- **Run Time:** 60 s
- **Comments:** Test frequency was 20 min (including evacuation of the vacuum sphere).

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** Not available
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The DLR Koln-Porz Hypersonic Wind Tunnel 1 was a continuously operating blowdown wind tunnel. It has been mothballed and will not be reactivated. It also operated intermittently at higher Mach numbers. Six nozzles were available ranging from Mach 5.7 to 14.5. Static temperature was infinitely variable through an electric air heater of 400 kW. The tunnel had a free-jet test chamber provided with a model swing-in device equipped with angle of attack adjustment and a three-coordinate probe adjustment. All mechanisms could be controlled by a computer. The tunnel was primarily used for basic research, especially for measuring pressure and temperature fields.

Testing Capabilities: The tunnel had three- and six-component internal balances, a high-speed camera, pressure measuring devices from 0.1 mbar to 60 bars, a test position switch, and a baratron. The tunnel was capable of conducting flow visualization using schlieren pictures, heat transfer measurements by color, and the phase reversion method with an infrared camera.

Data Acquisition: Not available

Unique Characteristics: None

Applications/Current Programs: The tunnel has been used to conduct flow tests on basic models of reentry vehicles. Typical model measurements are 40 cm (length of fuselage), 15 cm (wingspan), and 5 cm (fuselage diameter). At the present time, the tunnel is used to conduct tests on ESA's Hermes spaceplane and MBB's Sanger II.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 262. Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.3-2 (in German).

Date of Information: October 1989

DLR Koln-Porz Hypersonic Wind Tunnel 2 (H2K)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Joachim Niezgodka, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2367

Test Section Size: 0.6 cm diameter

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 4.8, 5.3, 6, 8.7, and 11.2
Reynolds Number: 2.4 x 10^5/m to 5.5 x 10^7/m
Total Pressure: 5 to 50 bars
Dynamic Pressure: Up to 80 kN/m^2 at Mach 6
Total Temperature: 300 to 1,300 degrees Kelvin
Run Time: Typically 30 s
Comments: Test frequency is less than 20 min (including evacuation of the vacuum sphere)

Cost Information
Date Built: 1968
Date Placed in Operation: 1968 and 1984 (reactivated)
Date(s) Upgraded: Continuously since 1984
Construction Cost: $876,754 (1968)
Replacement Cost: Not available
Annual Operating Cost: $527,704 (1989)
Unit Cost to User: Not available
Source(s) of Funding: West German government

Number and Type of Staff
Engineers: 1
Scientists: 1
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 3

Description: The DLR Koln-Porz Hypersonic Wind Tunnel 2 is an intermittently operating blowdown wind tunnel. The tunnel has five nozzles available ranging from Mach 4.8 to 11.2. Static temperature can be varied continuously by an air-heating plant to a maximum of 2,500 kW. The tunnel has a free-jet test chamber and a model swing-in device with an angle of attack and angle of sideslip adjustment.

Testing Capabilities: The tunnel is mainly used for force, pressure, and temperature measurements on missiles and reentry vehicles. It is capable of conducting flow visualization tests using schlieren and oil film pictures and heat transfer tests with an infrared camera. It has a high-speed camera, pressure measuring devices from 0.1 mbar to 10 bars, a baratron, and thermoelements.

Data Acquisition: The tunnel has 40 channel A/D converter input and on-line data reduction performed by a Hewlett Packard 1000/A900 computer with suitable peripherals.

Planned Improvements (Modifications/Upgrades): None

DLR Goettingen High-Enthalpy Tunnel (HEG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: None

Point of Contact: Dr. G. Eitelberg, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2339

Test Section Size: Not available

Operational Status: Under construction

Utilization Rate: Unknown

Performance
Mach Number: 7
Reynolds Number: Not available
Total Pressure: 1,500 bars
Dynamic Pressure: 1 to 2 bars
Total Temperature: 10,000 degrees Kelvin
Run Time: 1 ms
Comments: Test gas usually will be air.

Cost Information
Date Built: Under construction
Date Placed in Operation: Not available
Date(s) Upgraded: Not applicable
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Unknown
Unit Cost to User: Unknown
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 1
Scientists: 4
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 6

Description: The DLR High-Enthalpy Tunnel consists of a compression tube, a shock tube, a nozzle, a measuring chamber, and a vacuum tank. In the compression tube, a piston separates the compressed-air supply, which is supposed to accelerate the piston from the propellant gas that is to be compressed. Helium is chosen as the propellant gas because it is a light gas and monatomic, which enables the piston to attain as high a speed of sound as possible for a given compression ratio. The compression tube is separated at the right end by a membrane from the shock tube, which contains the test gas. At the right end of the shock tube, a second thin membrane separates the test gas from the Laval nozzle and the measuring section, in which a medium vacuum is located before testing.

Testing Capabilities: The tunnel will be able to conduct tests of reentry conditions.

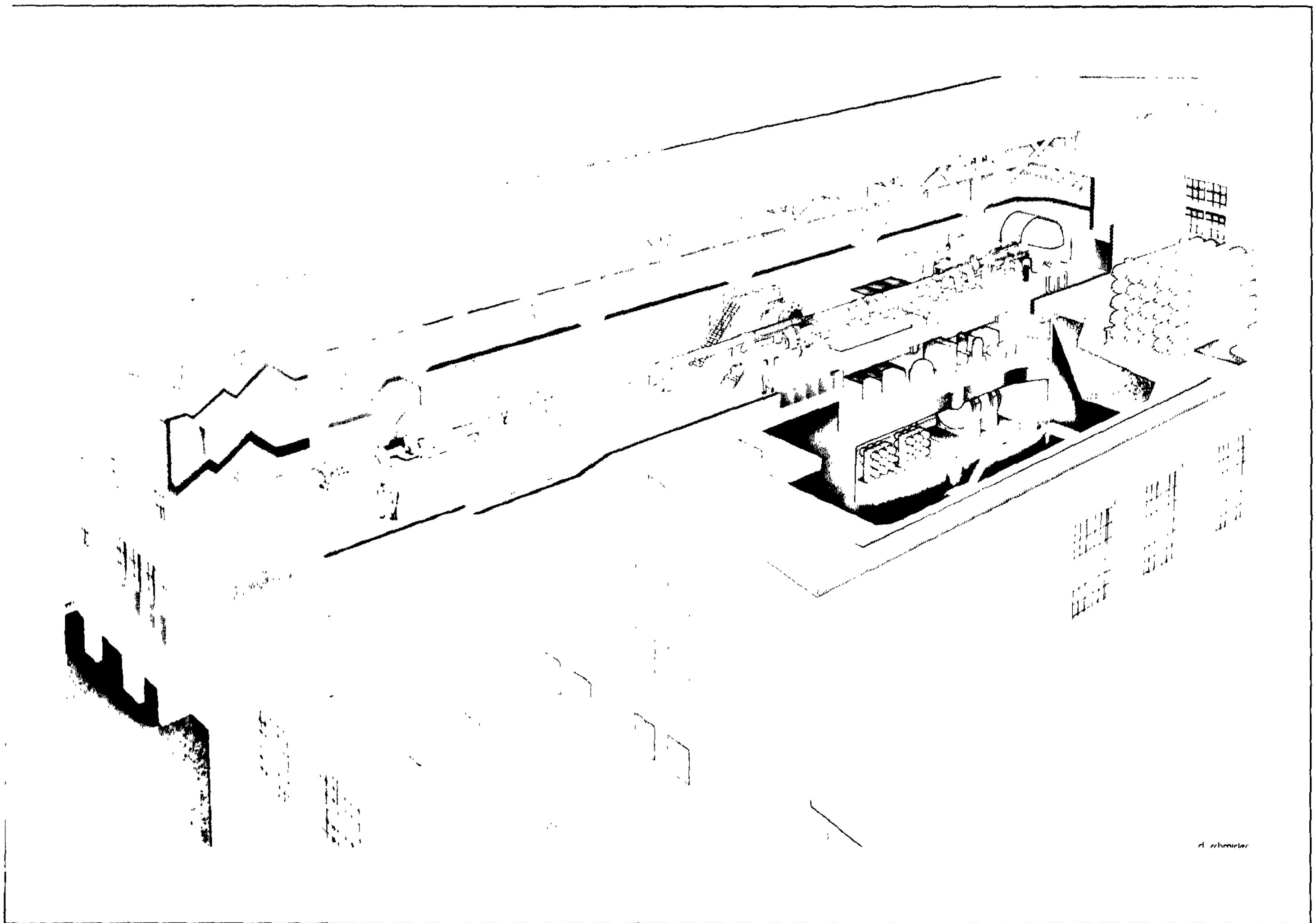
Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not applicable

Figure X.46: DLR Koln-Porz Hypersonic Wind Tunnel 2 (H2K)

Source: DLR

Figure X.47: Schematic Drawing of the DLR Goettingen High-Enthalpy Tunnel (HEG)



Source: DLR

Unique Characteristics: None

Applications/Current Programs: It will be possible to use a model held into the flow to study the flow phenomena that can be attributed to real gas effects, such as effects of dissociation.

General Comments: None

Photograph/Schematic Available: Yes

References: DLR. Description of the High-Enthalpy Tunnel (HEG). Koln, West Germany: DLR, 1989 (in German).

Date of Information: October 1989

RWTH Aachen Shock Tunnel

Country: West Germany

Location: Rheinisch-Westfalischen Technischen Hochschule Aachen, Institut fuer Luft- und Raumfahrt, Aachen, West Germany

Owner(s):
Rheinisch-Westfalischen Technischen Hochschule Aachen
Institut fuer Luft- und Raumfahrt
Stosswellenlabor
Templergraben, 55
D-5100 Aachen
West Germany

Operator(s): Rheinisch-Westfalischen Technischen Hochschule Aachen, Institut fuer Luft- und Raumfahrt

International Cooperation: ESA; and CNES and Avions Marcel Dassault-Breguet Aviation, France

Point of Contact: Professor H. Gronig, Rheinisch-Westfalischen Technischen Hochschule Aachen, Tel.: [49]-(241)-80-4606

Test Section Size: 500 x 500 mm (maximum)

Operational Status: Active

Utilization Rate: 1 or 2 tests per day (maximum)

Performance
Mach Number: 6 to 24 (conical at 10.5 degrees)
Reynolds Number: 1.2 x 10^7/m
Total Pressure: 1,500 bars (maximum)
Dynamic Pressure: 2 to 800 kN/m^2
Total Temperature: 7,000 to 8,000 degrees Kelvin (maximum)
Run Time: 10 ms (maximum)
Comments: Gases used are nitrogen and air.

Cost Information
Date Built: 1971
Date Placed in Operation: 1973
Date(s) Upgraded: 1987
Construction Cost: $1,435,956 (1971)
Replacement Cost: Not available
Annual Operating Cost: $791,556 (1989)
Unit Cost to User: Available upon request
Source(s) of Funding: ESA, CNES, BMFT, and NRW

Number and Type of Staff
Engineers: 0
Scientists: 2
Technicians: 1
Others: 3
Administrative/Management: 2
Total: 8

Description: The RWTH Aachen Shock Tunnel is a high-enthalpy shock tunnel. In the reflected mode, the shock tunnel consists of a driver section with a length of 6 m, a driven section with a length of 16 m, and a conical nozzle with exit diameters of 570, 1,000, and 2,000 mm.

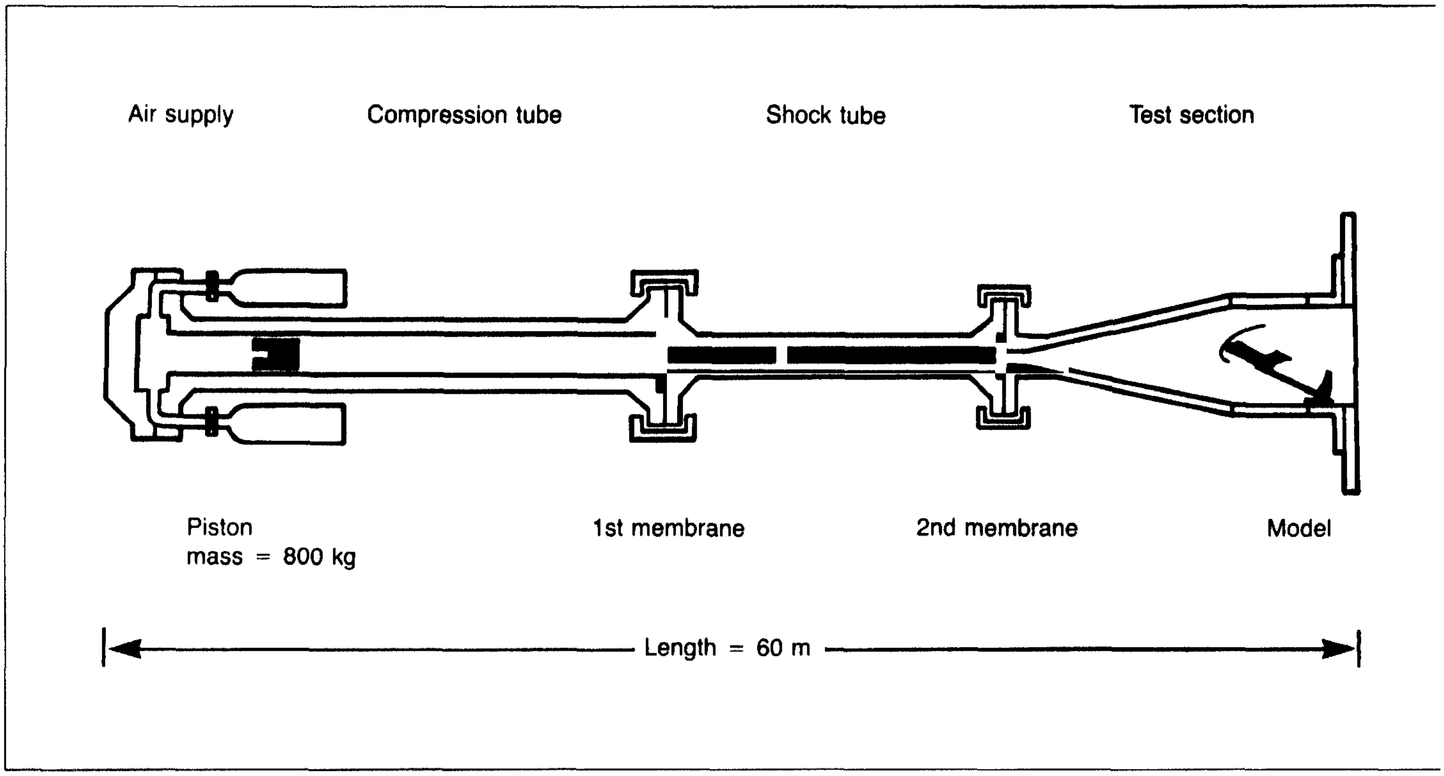
Testing Capabilities: The shock tunnel is capable of achieving driver heating up to 300 degrees Celsius. It is capable of partial Mach number and Reynolds Number simulation, duplication of flight velocity up to 4 km/s (Mach 11.75), and simulation of real gas effects. Measurement techniques include heat transfer, pressures, schlieren and shadow optics, and interferometry.

Data Acquisition: The shock tunnel has 60 channels of data.

Planned Improvements (Modifications/Upgrades): Detailed calculations and further tunnel calibration tests are underway. Force and moments balance improvements are being made as well as installation of a contoured nozzle.

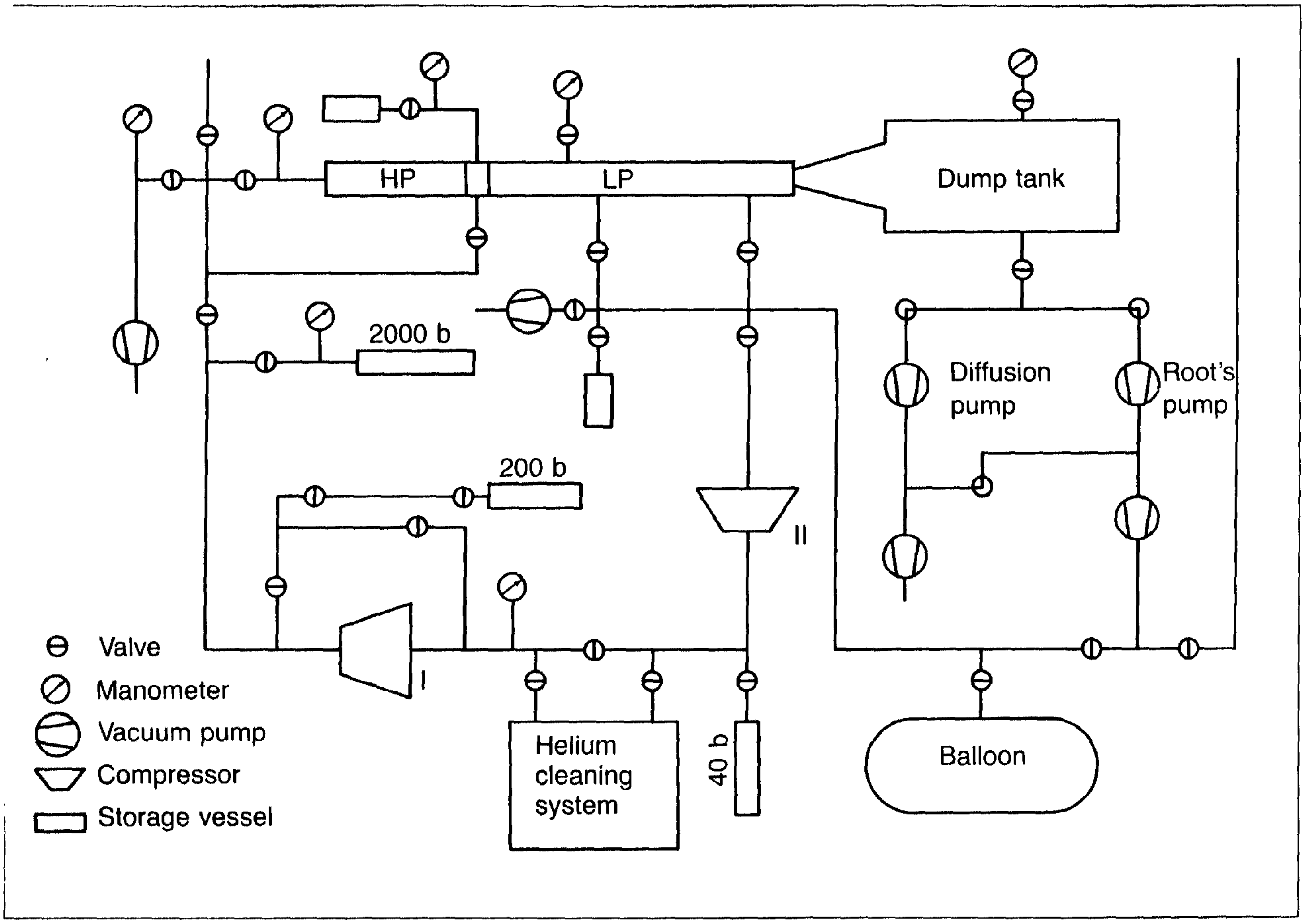
Unique Characteristics: None

Figure X.48: Schematic Diagram of the DLR Goettingen High-Enthalpy Tunnel (HEG)



Source: DLR

Figure X.50: Schematic Diagram of the RWTH Aachen Shock Tunnel



Source: U.S. Air Force EOARD

Applications/Current Programs: Current programs include research of hypersonic flow phenomena and reentry flow simulation of ESA's Hermes spaceplane.

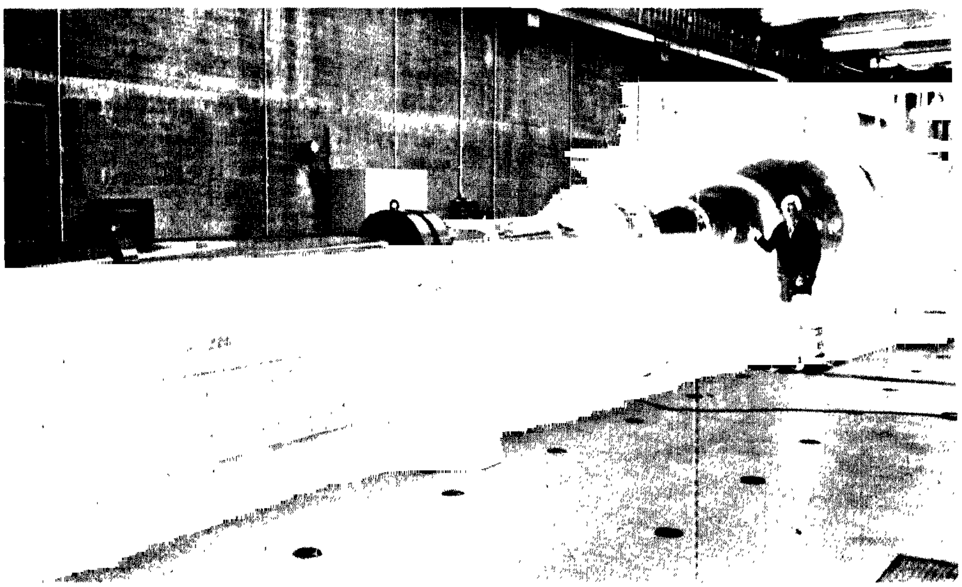
General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 102 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 41-43 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: September 1989

Figure X.49: RWTH Aachen Shock Tunnel



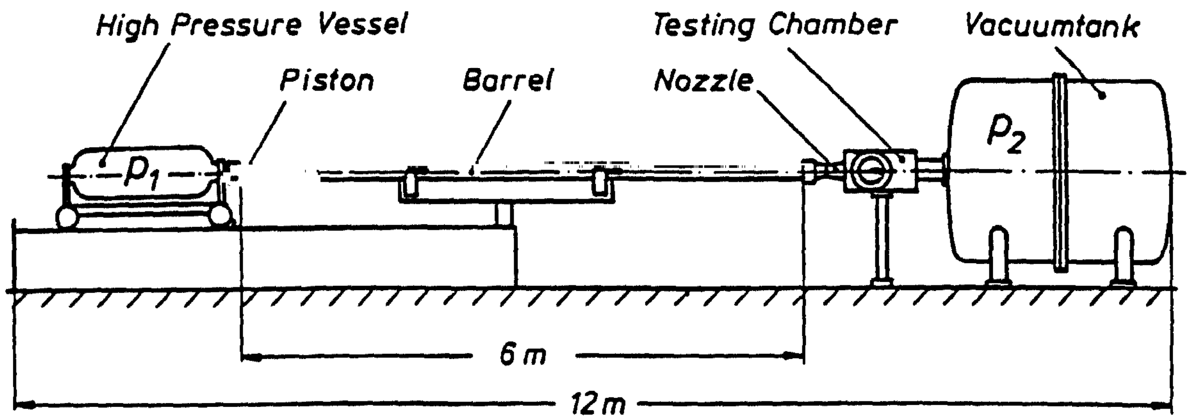
Source: RWTH Aachen

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 82 (EOARD Technical Report). Gersten, K., and G. Kausche. Die Hyperschallversuchsanlage (Gun Tunnel) der Deutsche Forschungsanstalt fuer Luft- und Raumfahrt. (The Hypersonic Experimental Installation (Gun Tunnel) of the German Research Institution for Air and Space Flight (German Aerospace Research Establishment)) Z. Flugwiss. 14, 1966, pp. 217-229. Hummel, Dietrich. "Experimental Investigations on Blunt Bodies and Corner Configurations in Hypersonic Flow." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987, pp. 6-1 to 6-16 (AGARD Conference Proceedings No. 428).

Date of Information: January 1990

Figure X.51: Schematic Diagram of the Technical University of Braunschweig Gun Tunnel



Source: Technical University of Braunschweig

Technical University of Braunschweig Gun Tunnel

Country: West Germany

Location: Technische Universitat Braunschweig, Institut fuer Stroemungsmechanik, Braunschweig, West Germany

Owner(s):
Technische Universitat Braunschweig
Institut fuer Stroemungsmechanik
Bienroder weg 3
D-3300 Braunschweig
West Germany

Operator(s): Technische Universitat Braunschweig, Institut fuer Stroemungsmechanik

International Cooperation: Not available

Point of Contact: Professor Dietrich Hummel, Technische Universitat Braunschweig, Institut fuer Stroemungsmechanik, Tel.: [49]-(531)-3-91-24-33

Test Section Size: 16 cm (nozzle exit diameter)

Operational Status: Active

Utilization Rate: 30 tests per day (see General Comments)

Performance
Mach Number: 8 to 16 (conical)
Reynolds Number: 0.8 x 10^6/ft at Mach 8
Total Pressure: 500 bars (maximum)
Dynamic Pressure: 230 kN/m^2 (maximum)
Total Temperature: 1,700 degrees Kelvin (maximum)
Run Time: 100 ms
Comments: None

Cost Information
Date Built: 1962
Date Placed in Operation: 1965
Date(s) Upgraded: 1988 to 1989
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Technical University of Braunschweig and Deutsche Forschungsgemeinschaft (DFG)

Number and Type of Staff
Engineers: 0
Scientists: 2
Technicians: 1
Others: 2 (laborers)
Administrative/Management: 0
Total: 5

Description: The Technical University of Braunschweig Gun Tunnel is a hypervelocity wind tunnel.

Testing Capabilities: The tunnel is capable of conducting six-component balance, pressure, heat transfer, and surface flow visualization tests.

Data Acquisition: The tunnel has six on-line channels of data.

Planned Improvements (Modifications/Upgrades): These include extending to 12 the number of on-line channels of data, upgrading the optical systems, and installing a new nozzle and test section.

Unique Characteristics: None

Applications/Current Programs: Current programs include basic research, tests on lifting bodies, and corner flow investigations.

General Comments: The tunnel is used continuously throughout the year.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: When it was built, the facility was the only altitude test bed for aero-engines in West Germany.

Applications/Current Programs: These include tests of single spool jet engines (steady, transient, and ignition tests of the Orpheus 803 engine and ignition tests of the J79 engine), by-pass jet engines (RB-199 engine and windmilling tests of the RB-153 engine), turboshaft engines (DB 720, APU T 112, and APU T 312 engines), aero-engines (Porsche PFM 3200 engine), pulse engines, and engine components (compressors and turbines). Compressor tests have been conducted on the HP compressor RB-199, IP compressor RB-199, transonic compressor (single-stage), transonic compressor (six-stage), and ATAR compressor. Turbine tests have been conducted on the JT10 D LP compressor, PW 2037 LP compressor, and V 2500 LP compressor.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 91. Institute for Aeronautical Propulsion, University of Stuttgart. "Altitude Test Bed for Aero-engines." In: Description of Test Plant. Stuttgart, West Germany: University of Stuttgart, 1987 (ILA-87 A 02).

Date of Information: October 1989

University of Stuttgart Altitude Engine Test Facility

Country: West Germany

Location: Universitat Stuttgart, Institut fuer Luftfahrtantriebe, Stuttgart, West Germany

Owner(s):
Universitat Stuttgart
Institut fuer Luftfahrtantriebe
Pfaffenwaldring 6
D-7000 Stuttgart 80
West Germany

Operator(s): Universitat Stuttgart, Institut fuer Luftfahrtantriebe

International Cooperation: Not available

Point of Contact: Professor Wolfgang Braig, Universitat Stuttgart, Institut fuer Luftfahrtantriebe, Tel.: [49]-(711)-685-3597

Test Cell Size: 10 ft diameter x 33 ft long

Operational Status: Active

Utilization Rate: Not available

Performance
Mass Flow: 140 kg/s
Altitude Range: 65,600 ft or 20 km
Temperature Range: −100 to 430 degrees Kelvin (maximum)
Pressure Range: 2.4 bars
Speed Range: Mach 2.2
Comments: Test time at maximum power is limited to approximately 6 hours by the capacity of the storage system. Approximately one day is required for regeneration.

Cost Information
Date Built: 1960 to 1964
Date Placed in Operation: Not available
Date(s) Upgraded: 1981, 1982, 1985, and 1987
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Source(s) of Funding: West German government, industries, and universities.

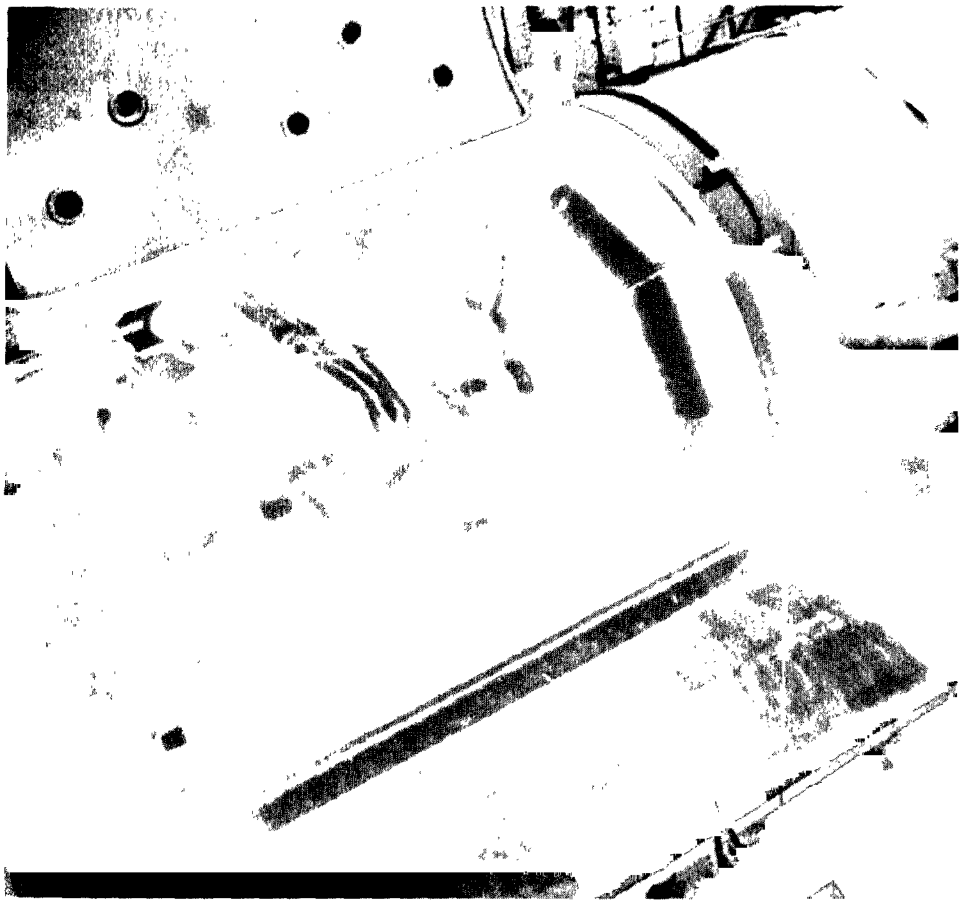
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The University of Stuttgart Altitude Engine Test Facility was designed to test engines capable of a sea level mass flow of approximately 70 kg/s and with reheat. Aero-engines and their components (particularly compressors and turbines) are run and tested under altitude conditions. Engines are normally installed in one of the two test cells with connected intake. The capacity of installed thrust stand is 22,500 lb/ft. The facility has direct-connect and free-jet testing capability. For turboshaft engines, the facility is capable of generating 6,000 hp in a full engine and flight environment.

Testing Capabilities: The facility is capable of conducting tests on engines and engine components (compressors and turbines).

Data Acquisition: For recording steady and transient measured data, several measuring systems have been developed and built. The main measuring system (ZME 5) can record up to 945 pressures, 256 temperatures, and approximately 2C digital values. The measuring system is controlled by a microprocessor, while data output and preliminary test evaluation are performed by a computer.

igure X.53: Turbo-Fan Engine in Test :ell 1 of the University of Stuttgart ıltitude Test Bed



Source: University of Stuttgart

Figure X.52: Test Cells 1 and 2 of the University of Stuttgart Altitude Test Bed

Source: University of Stuttgart

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Comments From the Director of Defense Research and Engineering, U.S. Department of Defense

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

WASHINGTON, DC 20301-3010

9 AUG 1989

(R&AT)

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and International
Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "FOREIGN AEROSPACE INVESTMENT: Technical Data and Information on Test Facilities," dated July 19, 1989, (GAO Code 392403/OSD Case 8065).

The DoD has reviewed the report, and concurs with its contents. The Department appreciates the opportunity to comment on the report in draft form.

Sincerely,

Robert C Duncan

Robert C. Duncan

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Comments From the Chief Financial Officer, U.S. Department of State

United States Department of State

Washington, D.C. 20520

AUG 21 1989

Dear Mr. Conahan:

This is in reply to your letter of July 19, 1989 to the Secretary which forwarded copies of the draft report entitled "Foreign Aerospace Investment: Technical Data and Information on Test Facilities" (Code 392403) for review and comment.

Department officials have reviewed the report and do not have any comments.

We appreciate being given the opportunity to review the draft report.

Sincerely,

Jill E. Kent
Chief Financial Officer

Mr. Frank C. Conahan,
Assistant Comptroller General,
National Security and
International Affairs Division,
U.S. General Accounting Office,
Washington, D.C.

Comments From the Acting Associate Administrator for Aeronautics and Space Technology, National Aeronautics and Space Administration

NASA

National Aeronautics and Space Administration

Washington, D.C. 20546

SEP 13 1989

Reply to Attn of: RB

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and International Affairs Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Conahan:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to comment on the General Accounting Office (GAO) draft report entitled, "Foreign Aerospace Investment: Technical Data and Information on Test Facilities" (GAO Code 392403).

NASA has reviewed the draft report, and editorial comments have been provided separately to Mr. Mark Pross.

Sincerely,

Robert Rosen
Acting Associate Administrator for
Aeronautics and Space Technology

UNITED STATES DEPARTMENT OF COMMERCE
The Under Secretary for International Trade
Washington, D.C. 20230

AUG 21 1989

Mr. Frank C. Conahan
Assistant Comptroller General
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

Thank you for the opportunity to review the General Accounting Office (GAO) draft report of July 1989 addressing foreign aerospace investment. Because of the subject matter of this report, I also asked the Office of Aerospace to review it.

The information contained in this report is valuable to the policymakers and industry analysts in aerospace trade development. Detailed information on foreign aerospace test facilities is very helpful in our efforts to assess the capabilities of our foreign competitors.

The Department of Commerce has no comments on this report. However, we would like to know when it is released to the public.

Sincerely,

J. Michael Farren

J. Michael Farren

Comments From the Assistant Secretary for Administration, U.S. Department of Commerce

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Administration
Washington, D.C. 20230

AUG 2 3 1989

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and International
Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

This is in reply to GAO's letter of July 19, 1989, requesting comments on the fact sheet report entitled, "Foreign Aerospace Investment: Technical Data and Information on Test Facilities."

We have reviewed the enclosed comments of the Under Secretary for International Trade and believe they are appropriate to the matters discussed in the report.

Sincerely,

Thomas J. Collamore
Assistant Secretary
for Administration

Enclosure

Major Contributors to This Report

National Security and International Affairs Division, Washington, D.C.

Norman J. Rabkin, Associate Director
Charles W. Thompson, Assistant Director
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Comments From the Director of Congressional Affairs, Central Intelligence Agency

Central Intelligence Agency

Washington, D.C. 20505

23 August 1989

Mr. Frank C. Conahan
Assistant Comptroller General
United States General Accounting Office
National Security and
International Affairs Division
441 G Street, N.W.
Room 4844
Washington, D.C. 20548

Dear Mr. Conahan:

The Director has asked me to respond to your letter of July 27, 1989 that forwarded a draft report entitled Foreign Aerospace Investment: Technical Data and Information on Test Facilities (GAO Code 392403).

As you are aware, GAO agreed to forward this draft report for review by the Central Intelligence Agency. The review has now been completed, and I have been advised by the appropriate components that they concur with this version of the draft report.

Enclosed please find the draft report which is being returned to your office. If possible, the components would appreciate receiving several copies of the final report.

Sincerely,

E. Norbert Garrett
Director of Congressional Affairs

Enclosure

Glossary

Aeroballistic	The flight characteristics of projectiles or high-speed vehicles in the atmosphere.
Air-Breathing	An aerodynamic vehicle engine that requires air for combustion of its fuel.
Air-Breathing Propulsion Test Cell	A ground test facility used to test an aircraft engine that requires air for combustion of its fuel.
Airflow	A flow or stream of air.
Airfoil	A specially contoured body (such as an airplane wing or propeller blade) designed to provide a desired reaction force (such as lift or thrust) when in motion relative to the surrounding air.
Altitude Wind Tunnel	A wind tunnel in which the air pressure, temperature, and humidity can be varied to simulate conditions at different altitudes.
Ambient Temperature	The temperature of the gas around a test model, which is unaffected by the model's presence.
Anechoic Chamber	A test room in which all surfaces are lined with a sound-absorbing material to reduce reflections of sound to a minimum.
Anemometer	A device which measures air speed.
Angle of Attack	The acute angle between the direction of the relative airflow and the chord (i.e., the straight line joining the leading and trailing edges of an airfoil) of the test model.

Coherent Anti-Stokes Raman Scattering	A phenomenon observed in the scattering of light as it passes through a transparent medium. The light undergoes a change in frequency and a random alteration in phase due to a change in rotational or vibrational energy of the scattering molecules.
Computational Fluid Dynamics	A tool for predicting the aerodynamics and fluid dynamics of air around flight vehicles by solving a set of mathematical equations with a computer. Also known as numerical aerodynamic simulation, computational fluid dynamics is used in aerospace vehicle research and development programs to improve the understanding of hypersonic flow physics and as an aerospace vehicle design tool.
Computer-Aided Design/ Computer-Aided Manufacturing	The generation of computer automated designs (such as pictures and specifications) for display on cathode-ray tubes and for electronic storage, and the use of computers to communicate work instructions to automatic machinery for the handling and processing needed to produce an object.
Cryogenic	Operating at extremely low temperatures.
Differential Interferometry	The design and use of an optical interferometer in which a wavelength is interfered with a shifted version of itself, resulting in fringes along which the slope or derivative of the wavefront is constant. A differential interferometer is also known as a lateral shear interferometer.
Diffuser	The expansion section of a wind tunnel that decreases the velocity of a fluid (such as air) and increases its pressure.
Doppler Effect	The change in the observed frequency of an acoustic or electromagnetic wave due to relative motion of source and observer.
Doppler Shift	The amount of the change in the observed frequency of a wave due to the Doppler effect. It is usually expressed in hertz.

Graphite Heater Blowdown Tunnel	A hypervelocity wind tunnel in which nitrogen is used to fill a heater to a pressure that is one-fourth of the desired test pressure. A graphite heater element heats the gas at a constant volume, increasing its pressure to the desired stagnation pressure. The nitrogen is confined to the heater by a double diaphragm. To begin a test, the diaphragm is ruptured by significantly increasing the pressure in the interdiaphragm volume. Controlled pressure cold gas is introduced into the bottom of the heater pushing the hot test gas up like a piston out of the heater. The hot test gas is then accelerated in a hypersonic nozzle over the model in the test section providing flows with Mach numbers up to 14 for relatively long run times of 0.25 to 2.5 s.
Gun Tunnel	A hypervelocity wind tunnel in which a shock wave generated in a shock tube ruptures a second diaphragm in the throat of a nozzle at the end of a tube. Gases emerge from the nozzle over the model in the test chamber and into a vacuum dump tank. Speeds achieved in a gun or shock tunnel typically range from Mach 6 to 25.
Gust Tunnel	A wind tunnel that is used to test the effect of gusts on a model airplane in free flight. Models are passed over a vertical jet or jets simulating gusts.
Heat Exchanger	An apparatus for cooling or heating the air in a wind tunnel.
Heat Transfer	The transfer or exchange of heat by radiation, conduction, or convection within a substance and between the substance and its surroundings.
Holographic Interferometry	The study of the formation and interpretation of the fringe pattern which appears when a wave, generated earlier and stored in a hologram, is later reconstructed and caused to interfere with a comparison wave.
Holography	An optical technique for recording, and later reconstructing, the amplitude and phase distributions of a wave disturbed by the test body. It is widely used as a method of three-dimensional optical image formation (a hologram).

Isentropic	Constant entropy or without change in entropy (a measure of the unavailability of energy).
Joule	The unit of energy in the meter-kilogram-second system of units equal to the work done by a force of magnitude of 1 N when the point at which the force is applied is displaced 1 m in the direction of the force.
Kelvin	A unit of absolute temperature equal to 1/273.16 of the absolute temperature (Kelvin scale) of the triple point of water (a particular temperature and pressure at which three different phases of one substance can coexist in equilibrium such as ice, liquid, and vapor). It equals the Celsius degree and, accordingly, absolute zero is 0 degrees, or the equivalent of −273.16 degrees Celsius.
Kilohertz	One thousand hertz (a unit of frequency equal to one cycle per second).
Kilo-Newton	One thousand newtons (the unit of force in the meter-kilogram-second system that is equal to the force that will impart an acceleration of 1 m/s^2 to the International Prototype Kilogram mass).
Kinetics	A branch of science that deals with the effects of forces on the motion of material bodies or with changes in a physical or chemical system.
Knudsen Number	A number used to describe the flow of low-density gases, equal to the ratio of the mean free path of the gas molecule divided by a characteristic length, such as boundary layer thickness or apparatus dimension.
Laser Anemometer	An anemometer in which the flow being measured passes through two perpendicular laser beams, and the resulting change in velocity of one or both beams is measured.

Pascal	A unit of pressure equal to the pressure resulting from a force of 1 N acting uniformly over an area of 1 m^2.
Piezoelectric Transducer	A piezoelectric crystal used as a transducer, either to convert mechanical or acoustical signals to electric signals or vice versa.
Piston-Driven	A type of shock tunnel in which energy is created by a piston being fired (or driven) down a cylinder, compressing the test gas ahead of it. The pressure and temperature of the test gas is increased, creating a shock.
Pitot Tube	An instrument that measures the stagnation pressure of a flowing fluid. It consists of an open-ended tube pointing into the fluid flow and is connected to a pressure-indicating device.
Plasma-Jet Tunnel	A wind tunnel that has the capability of developing the highest temperature (approximately 35,000 degrees Fahrenheit) and the longest run time (several minutes) of any hypervelocity tunnel. It is arc-heated and is capable of achieving relatively high velocities (up to 20,000 ft/s), but few plasma-jet tunnels have been built or planned for obtaining Mach numbers above 10.
Plenum Chamber	An enclosed section of a wind tunnel in which air is collected at pressure greater than that in the outside atmosphere for slow distribution downstream.
Pressure Transducer	An instrument component that detects a fluid pressure and produces an electrical, mechanical, or pneumatic signal related to the pressure.
Ramjet	An air-breathing engine that compresses or "rams" the onrushing air and slows it down to subsonic speeds, at which time it is burned with the fuel in a combustion chamber. The exhaust is expelled through the nozzle, causing the thrust. A ramjet is a propulsion system for air-breathing aerodynamic vehicles operating at supersonic speeds of about Mach 2 to 5.5.

Ramrocket	A rocket motor mounted coaxially in the open front end of a ramjet that is used to provide thrust at low speeds and to ignite the ramjet fuel.
Rankine	A scale of absolute temperature in which the temperature in degrees Rankine is equal to nine-fifths of the temperature in Kelvins and to the temperature in degrees Fahrenheit plus 459.67.
Reynolds Number	A dimensionless number used as an indication of scale of fluid flow. It is significant in the design of a model of any system in which the effect of viscosity is important in controlling the velocities or the flow pattern of a fluid. Reynolds Number is equal to the density of a fluid times its velocity times a characteristic length divided by the fluid viscosity.
Rock Wool	A fibrous glass substance, also known as mineral wool, used as insulation in cryogenic wind tunnels. Rock wool is made from molten slag, rock, glass, or a selected combination of these ingredients, and is fabricated into fine fibers by blowing or drawing.
Schlieren	An optical technique that detects density gradients occurring in a fluid flow. Schlieren is a German word that means "striations." It refers to various shadowgraphic techniques for optical investigations. Variations in density in flow through, for example, shock waves and supersonic flow are sharply visible in tonal gradations.
Scramjet	A supersonic combustion ramjet air-breathing engine in which air flows through the combustion chamber at supersonic speeds. Hydrogen is injected into the combustion chamber where it is ignited by the hot air. The exhaust is expelled through the nozzle, causing the thrust. Scramjets are being designed to operate at hypersonic speeds greater than Mach 4.
Shadowgraph	A photographic image in which disturbances that occur in fluid flow at high velocity are made visible. Light passing through a flowing fluid is refracted by density gradients in the fluid, resulting in bright and dark areas on a screen placed behind the fluid.

Shock Tube	A wind tunnel for conducting tests at hypervelocity speeds in which fluid (such as air or some other test gas) at high pressure, usually involving rapid combustion to increase energy, is released by rupturing a diaphragm and accelerated through an evacuated working section (test chamber) containing the model.
Shock Tunnel	A hypervelocity wind tunnel in which a shock wave generated in a shock tube ruptures a second diaphragm in the throat of a nozzle at the end of a tube. Gases emerge from the nozzle over the model in the test chamber and into a vacuum dump tank. Speeds achieved in a shock tunnel typically range from Mach 6 to 25.
Sonic	The speed of sound in air (761.5 mph at sea level).
Spectrometer	An optical instrument with a prism or grading which produces a spectrum of light for measurement of refraction or radiant intensities at various wavelengths.
Stagnation Point	The point on the surface of a body in a viscous fluid flow where the fluid particles have zero velocity with respect to the body. The flow in the boundary layer on each side of the stagnation point is in opposite directions.
Stagnation Pressure	The pressure at the stagnation point. In a compressible flow, it is the pressure exhibited by a moving gas or liquid brought to zero velocity by an isentropic process. It is also known as dynamic pressure, impact pressure, and total pressure.
Stator	A stationary machine part in or about which a rotor turns.
Sting	A long cantilever tube in a wind tunnel's test chamber used to support the model. It is usually attached to the rear of the model and contains connections so that information from sensors embedded in the model can be transmitted to instrumentation outside of the wind tunnel.

Strain-Gauge	A device which uses the change of electrical resistance of a wire under tension to measure mechanical deformation or pressure.
Strouhal Number	A dimensionless number used in studying the vibrations of a body past which a fluid is flowing. Strouhal number is equal to a characteristic dimension of the body times the frequency of vibrations divided by the fluid velocity relative to the body.
Subsonic	A range of speed below the speed of sound in air.
Supersonic	A range of speed between about one and five times the speed of sound in air.
Test Cell	A horizontal test stand for an air-breathing or rocket engine surrounded on three sides by a shelter providing protection from weather and limited protection from an accidental explosion.
Test Chamber	The test section of a wind tunnel.
Thermocouple	A device which converts thermal energy directly into electrical energy.
Thermography	A method of measuring surface temperature by using luminescent materials.
Thrust	The force exerted in any direction by a fluid jet.
Tomography	A diagnostic technique using X-ray photographs to show detail in a predetermined plane while blurring the images of structures in other planes.

Torr	A unit of pressure equal to 1/760 atmosphere or to approximately 133.3224 pascals.
Total Pressure	The pressure of a fluid resulting from its motion when brought to rest on a surface. It is also known as dynamic pressure, impact pressure, and stagnation pressure.
Total Temperature	The temperature of a particle of fluid at its stagnation point.
Transonic	A range of speed between about 0.8 and 1.2 times the speed of sound in air.
Trisonic	Three ranges of speed capability in a wind tunnel (such as subsonic, transonic, and supersonic).
acuum Tunnel	A wind tunnel operated at pressure that is much lower than sea level pessure.
Velocimeter	A continuous wave reflection Doppler system used to measure the radial velocity of an object.
Voltmeter	An instrument for measuring in volts the differences in potential between different points of an electrical circuit.
Wind Tunnel	A ground test facility used to test flight characteristics of an aircraft by directing a controlled stream of air around a scale model and measuring the results with attached instrumentation.

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The Office of Science and Technology Policy in the Executive Office of the President also reviewed a draft of this report and concurred with the facts as presented.

We are sending copies of this report to the Secretaries of Defense, State, Commerce, the Air Force, and the Navy; the Administrator, National Aeronautics and Space Administration; and the Directors, Defense Advanced Research Projects Agency, Strategic Defense Initiative Organization, Central Intelligence Agency, Office of Management and Budget, and Office of Science and Technology Policy in the Executive Office of the President. We are also sending copies of this report to other interested parties and will make copies available to others.

Please contact me at (202) 275-4268 if you or your staff have any questions concerning this report. Other major contributors to this report are listed in appendix XVII.

Sincerely yours,

Nancy R. Kingsbury

Nancy R. Kingsbury
Director
Air Force Issues

Contents

Appendix VI Aerospace Test Facilities in Italy

Appendix VII Aerospace Test Facilities in Japan

DC	direct current
DFG	Deutsche Forschungsgemeinschaft (German Research Association)
DFVLR	Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt (German Research and Experimental Institution for Air and Space Flight, commonly referred to as the German Aerospace Research Establishment)
DLR	Deutsche Forschungsanstalt fuer Luft-und Raumfahrt (German Aerospace Research Establishment)
DNW	Duits-Nederlandse Windtunnel/Deutsch Niederlandischer Windkanal (German-Dutch Wind Tunnel)
DOD	Department of Defense
EC	European Communities
EGG	Ebener Gitterwindkanal Goettingen (Goettingen Plane Cascades Wind Tunnel)
EMK	Eichkanal Koln-Porz (Koln-Porz Calibrating Tunnel)
EOARD	European Office of Aerospace Research and Development
ESA	European Space Agency
ESTEC	European Space Research and Technology Center
ETW	European Transonic Windtunnel
FHI	Fuji Heavy Industries
ft	foot
ft/s	foot per second
g	gram
GAO	General Accounting Office
GARTEUR	Group for Aeronautical Research and Technology in Europe
GW	Guided Weapons
H1K	Hyperschall-Windkanal 1 Koln-Porz (Koln-Porz Hypersonic Wind Tunnel 1)
H2K	Hyperschall-Windkanal 2 Koln-Porz (Koln-Porz Hypersonic Wind Tunnel 2)
HDG	Hochdruck-Windkanal Goettingen (Goettingen High-Pressure Wind Tunnel)
HEG	Hoch-Enthalpie-Kanals Goettingen (Goettingen High-Enthalpy Tunnel)
HIMES	Highly Maneuverable Experimental Space [vehicle]
HKG	Hochgeschwindigkeitskanal Goettingen (Goettingen High-Velocity Wind Tunnel)
HMK	Hyperschall-Kanal Koln-Porz (Koln-Porz Supersonic Tunnel)
HOPE	H-II Orbiting Plane
HOTOL	Horizontal Takeoff and Landing
hp	horsepower
HS	high speed

MJ	megajoule
MJ/kg	megajoule per kilogram
mm	millimeter
MPa	megapascal
mph	mile per hour
ms	millisecond
m/s	meter per second
MTU	Motoren- und Turbinen-Union
MUB	Modellunterschall-Windkanal Braunschweig (Braunschweig Model Subsonic Wind Tunnel)
MW	megawatt
N	newton
NAL	National Aerospace Laboratory
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NASP	National Aero-Space Plane
NATO	North Atlantic Treaty Organization
NIVR	Nederlands Instituut Voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Institute for Aerospace Programs)
NLR	Nationaal Lucht-en Ruimtevaartlaboratorium (National Aerospace Laboratory)
Nm^3/min	newton cubic meter per minute
NWB	Niedergeschwindigkeitswindkanal Braunschweig (Braunschweig Low-Velocity Wind Tunnel)
NWG	Niedergeschwindigkeitswindkanal Goettingen (Goettingen Low-Velocity Wind Tunnel)
OECD	Organization for Economic Cooperation and Development
ONERA	Office National d'Etudes et de Recherches Aerospatiales (National Office for Aerospace Studies and Research)
OSD	Office of the Secretary of Defense
OSTP	Office of Science and Technology Policy
P1K	Hochenthalpie-Windkanal 1 Koln-Porz (Koln-Porz High-Enthalpy Wind Tunnel 1)
P2K	Hochenthalpie-Windkanal 2 Koln-Porz (Koln-Porz High-Enthalpy Wind Tunnel 2)
P3K	Hochenthalpie-Windkanal 3 Koln-Porz (Koln-Porz High-Enthalpy Wind Tunnel 3)
Pa	pascal
PIV	particle image velocimeter
psi	pound per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge

V1G	Hypersonischer Vakuum-Windkanal Goettingen, 1 Messtreche (Goettingen Hypersonic Vacuum Tunnel, 1st Test Chamber)
V2G	Hypersonischer Vakuum-Windkanal Goettingen, 2 Messtreche (Goettingen Hypersonic Vacuum Tunnel, 2nd Test Chamber)
V3G	Hochvakuum-Windkanal Goettingen, 3 Messtreche (Goettingen High-Vacuum Tunnel, 3rd Test Chamber)
VKI	von Karman Institute
VMK	Vertikale Freistrahimesstrecke Koln-Porz (Koln-Porz Vertical Free-jet Test Chamber)
V/STOL	Vertical/Short Takeoff and Landing
VTOL	Vertical Takeoff and Landing
W	watt

Introduction

This document provides a database of key foreign aerospace test facilities from which an assessment can be made of foreign countries' capabilities in research, development, and testing of future aerospace vehicles. This document is also a catalogue of facilities that provides technical data and information on principal European, Japanese, and Australian wind tunnels[1] and air-breathing propulsion test cells,[2] including the location, owner, operator, point of contact, performance characteristics (i.e., technical parameters describing the facility's principal capabilities and operating range), cost information, and the number and type of staff required to operate the facility. This catalogue also provides narrative information describing each facility, its testing capabilities, planned improvements, unique characteristics, and current programs.

The document discusses principal aerospace test facilities in Australia, Belgium, France, Italy, Japan, The Netherlands, the United Kingdom, and West Germany. Soviet aerospace test facilities will be included in a subsequent report on aerospace investment in the Soviet Union. Aerospace test facilities in the United States are not included in the scope of our review.[3]

This is the first in a planned series of reports on aerospace investment in foreign countries. Subsequent reports will address aerospace investment in individual countries and our overall evaluation and conclusions.

Explanation of Facility Data Sheets

The technical data and information in this report were provided by the facility owners or operators. We designed the format used in this report by modifying data sheets developed by the National Aeronautics and Space Administration (NASA) and Arnold Engineering Development

[1] Wind tunnels are ground test facilities used to test flight characteristics of an aircraft by directing a controlled stream of air around a scale model and measuring the results with attached instrumentation.

[2] Air-breathing propulsion test cells are ground test facilities used to test an aircraft engine that requires air for combustion of its fuel.

[3] U.S. wind tunnels and air-breathing propulsion test cells are documented and catalogued in several publications, including the following. Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1. Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2. Crook, Robert T. Test Facility Data Base: Wind Tunnels. Arnold Air Force Base, Tullahoma, Tennessee: Arnold Engineering Development Center, 1987, vol. 1. Crook, Robert T. Test Facility Data Base: Airbreathing Propulsion Test Cells and Rocket Altitude Test Cells. Arnold Air Force Base, Tullahoma, Tennessee: Arnold Engineering Development Center, 1987, vol. 2.

programs currently being conducted. The name, organization, and telephone number of the point of contact for each facility are also included. Appendix II provides a definition and explanation of each data element used in the facility data sheets. Appendix XI contains a list of installation addresses by country for each facility's owner or operator.

Wind Tunnels and Air-Breathing Propulsion Test Cells

Ground test facilities, such as wind tunnels and air-breathing propulsion test cells, are used to conduct various tests of aircraft and aerospace vehicle models and components. Ground tests establish a database and validate computational fluid dynamic[6] (CFD) simulations.

Wind Tunnels

Wind tunnels are used to test the basic aerodynamic forces and moments acting on an aircraft in flight. These forces—lift, drag, and side force—can be tested in a wind tunnel by directing a controlled stream of air (or some other test gas such as helium or nitrogen) around a scale model held stationary in the airstream and measuring the results with instrumentation attached to the model.

Wind tunnels consist of an enclosed passage through which a test gas is driven by a fan or some other type of drive system (such as high pressure or a piston). The key component of a wind tunnel is the test section in which a scale model of an airplane—or aerospace vehicle, missile, or inlet of a supersonic combustion ramjet (scramjet),[7] for example—is supported in a carefully controlled airstream. The airstream produces a flow around the model, simulating the flow around a full-scale aircraft. The aerodynamic characteristics of the model and its flow field are directly measured by balances and test instrumentation.

Wind tunnels are used to conduct aerodynamic research, validate new aircraft designs, and refine design configurations. In addition, wind tunnels are used to measure aerodynamic forces and moments and such parameters as pressure, heat transfer, and temperature distribution.

[6]Computational fluid dynamics is a tool for predicting the aerodynamics and fluid dynamics of air around flight vehicles by solving a set of mathematical equations with a computer. CFD, also known as numerical aerodynamic simulation, is used in aerospace vehicle research and development programs to improve the understanding of hypersonic flow physics and as an aerospace vehicle design tool.

[7]A scramjet is an air-breathing engine in which air flows through the combustion chamber at supersonic speeds. Hydrogen is injected into the combustion chamber where it is ignited by the hot air. The exhaust is expelled through the nozzle, causing the thrust. Scramjets are being designed to operate at speeds of about Mach 4 to 25.

transonic, and supersonic). Typically, they have interchangeable nozzles and/or test sections for each speed regime.

Supersonic Wind Tunnels

Supersonic wind tunnels tend to have more distinct characteristics than subsonic and transonic wind tunnels such as size, speed range, temperature range, and Reynolds Number. Supersonic wind tunnels have a speed range between Mach 1.2 and 5.

Hypersonic Wind Tunnels

Most hypersonic wind tunnels are considered unique due to their size, speed range, temperature range, and Reynolds Number. Hypersonic wind tunnels have a speed capability greater than Mach 5.

Hypervelocity Wind Tunnels

Hypervelocity wind tunnels have speed and temperature capabilities greater than hypersonic tunnels and have a velocity range greater than 5,000 ft/s at Mach numbers 1 up to about 25. They operate at considerably higher supply temperatures and pressures than do hypersonic tunnels. Major types of hypervelocity wind tunnels currently operating and their speed ranges are discussed below.

- Hotshot tunnels can achieve Mach numbers of 10 to 27.
- Shock tunnels can achieve Mach numbers of 6 to 25 with velocities of 4,000 to 15,000 ft/s.
- Graphite heater blowdown tunnels can achieve Mach numbers up to 14.
- Plasma-jet tunnels have the capability of generating the highest temperature (approximately 35,000 degrees Fahrenheit) and the longest run time (several minutes) of any hypervelocity tunnel. Relatively high velocities (up to 20,000 ft/s) are achievable, but few plasma tunnels have been planned or built for obtaining Mach numbers above 10.
- Gun tunnels are capable of achieving speeds between Mach 2 and 18.
- Shock tubes can study the characteristics of shock waves at speeds of Mach 30 to 35.
- Expansion tubes can achieve speeds of about Mach 10.
- Wave superheater tunnels are capable of achieving speeds in the hypervelocity range.

Air-Breathing Propulsion Test Cells

Air-breathing propulsion test cells are used to test aircraft and aerospace vehicle engines. These facilities are divided into the following main categories: propulsion wind tunnels, altitude engine test facilities, and propulsion component facilities for engine turbines, compressors, and combustors. According to NASA, these three categories cover the full range of principal facilities required to develop and improve aircraft and aerospace vehicle engines.

engine operation at high Mach numbers or at high altitude and low Mach numbers. Not all facilities offer all of the desired conditions because some facilities were designed for specific applications or had certain limitations imposed due to cost or the technology available at the time of construction.

In free-jet engine test stands, the engine and inlet are mounted so that the air from a nozzle can strike the engine's inlet. The test stand's configuration is similar to a wind tunnel, except that the quality of airflow is not as good. Nonetheless, free-jet facilities are more economical, since the air can be directed right at the engine's inlet. Provisions for good temperature simulation are also available. Generally, a free-jet capability is available as an option or specific configuration of a direct-connect facility.

Engine/Propulsion Component Facilities

Engine/propulsion component facilities are limited to those used for testing or conducting research on engine turbines, compressors, and combustors. Component facilities are smaller, simpler, and considerably less costly than propulsion wind tunnels and engine test facilities, which require large complexes and usually large capital investments. The component facilities are most often used for conducting more basic and applied research plus experimental studies on propulsion subsystems, whereas wind tunnels and engine test facilities are principally used for testing and development of complete propulsion systems.

Quick Reference to Test Facilities

Tables I.1 and I.2 serve as a quick reference to test facility capabilities. The tables contain the most important parameters and characteristics of each facility. Appendixes III through X describe each facility in detail. Table I.1 shows the principal capabilities and operating range of wind tunnels by country and speed regime.

Installation and facility	Test section size	Mach number	Reynolds Number	Page
ONERA S3Ch Transonic	0.8 x 0.8 m	0.3 to 1.2	Not available	128
ONERA T2	0.4 x 0.4 x 1.6 m	1.1	51 x 10^6/m	131
Trisonic Wind Tunnels				
LBRA C4 Trisonic	0.4 x 0.4 m	0.15 to 4.29	12 x 10^6/m at Mach 4.29	134
ONERA R4.3 Cascade	210 to 370 x 120 mm (transonic), and 600 x 120 mm (supersonic)	0.3 to 1 and 1.45	Not available	136
ONERA S2MA	1.75 x 1.77 m (transonic) and 1.75 x 1.93 m (supersonic)	0.1 to 1.3 (transonic) and 1.5 to 3.1 (supersonic)	5.5 to 29.4 x 10^6/m	139
ONERA S3MA	0.78 x 0.56 m (transonic) and 0.8 x 0.76 m (supersonic)	0.1 to 1.1 (subsonic/ transonic); 2, 3.4, 4.5, and 5.5 (supersonic fixed); and 1.7 to 3.8 (supersonic variable)	64 x 10^6/m	147
St. Cyr Sigma 4	0.85 x 0.85 m	0.3 to 2.8	Not available	154
Supersonic Wind Tunnels				
Aerospatiale-Aquitaine Arc Heater J.P. 200	5 to 32 cm^2 (throat area)	Less than 2.4	Not available	156
CEAT S.150 Supersonic Blowdown	15 x 15 cm (nozzle exit diameter)	2, 3.5, and 4.3	20 x 10^6/m	158
ONERA S5Ch Transonic and Supersonic	0.3 x 0.3 m	0.8 to 1.15 (transonic), 1.2, and 1.45 to 3.15 (supersonic)	Not available	160
Hypersonic Wind Tunnels				
CEAT H.210 Blowdown	21 cm (nozzle exit diameter)	7 and 8	1.3 to 9.2 x 10^6/m at Mach 7 and 1.5 to 4.2 x 10^6/m at Mach 8	162
CNRS SR.3	15 to 30 cm (nozzle exit diameter) to Mach 7 and 36 cm (nozzle exit diameter) between Mach 15 and 30	2 to 30	2 x 10^3/m to 2 x 10^6/m	164
IMF Blowdown	15 cm (nozzle exit diameter)	2.3, 4, 5, 6, and 7	2 x 10^6/m at Mach 7 and 16 x 10^6/m at Mach 5	168
ONERA R2Ch Blowdown	0.19 m (nozzle exit diameter) at Mach 3 and 4 and 0.33 m at Mach 5, 6, and 7	3, 4, 5, 6, and 7	3 x 10^6/m at Mach 3 and 3.5 x 10^6/m at Mach 7	170
ONERA R3Ch Blowdown	0.35 m (nozzle exit diameter) at Mach 10	10 (contoured)	0.6 to 3.5 x 10^6/m	173
ONERA S4MA	0.68 m diameter (Mach 6 nozzle) and 1 m diameter (Mach 10 to 12 nozzle)	6 and 10 to 12	3 to 27 x 10^6/m	178
Hypervelocity Wind Tunnels				
ISL Hypersonic	20 x 20 cm (nozzle exit diameter)	4 to 11 (conical)	Not available	184
LRBA C_2 Reflected	1.2 m diameter	8 to 16 (conical) and 16 (contoured)	0.26 to 2.9 x 10^6/m	186
ONERA ARC 2 Hotshot	70 cm (nozzle exit diameter)	15 to 20	4.2 x 10^6/m at Mach 15	188

(continued)

Installation and facility	Test section size	Mach number	Reynolds Number	Page
Hypersonic Wind Tunnel				
NAL 50 cm Hypersonic	50 cm diameter (axisymmetric)	5, 7, 9, and 11	0.3 to 7.2 x 10^6/m	267
		THE NETHERLANDS		
Subsonic Wind Tunnels				
DNW Low-Speed	9.5 x 9.5 m, 6 x 8 m, and 6 x 6 m (closed and open)	0.18, 0.34, and 0.45	3.9 to 5.8 x 10^6/m	303
NLR Low-Speed	3 x 2.25 x 8.75 m	0.25	0 to 6 x 10^6/m	308
Transonic Wind Tunnel				
NLR High-Speed	1.6 x 2 x 2.7 m	1.25	10 to 15 x 10^6/m at Mach 1.25 and 31 x 10^6/m at Mach 0.7	311
Trisonic Wind Tunnels				
Delft Blowdown Tunnel B (TST 27)	27 x 28 x 40 to 90 cm	Less than 4.2 (variable)	37 to 130 x 10^6/m	315
Delft GLT 20 Boundary Layer	17 x 20 x 132 cm	0.6 to 2.4 (continuously variable)	27 x 10^6/ft at Mach 2.4	319
Supersonic Wind Tunnels				
Delft Blowdown Tunnel A (ST 15)	15 x 15 x 25 cm	Less than 3	20 x 10^6/m at Mach 3	322
NLR Continuous Supersonic	0.27 x 0.27 m	1.2 to 6 (contoured)	20 to 30 x 10^6/m	325
NLR Supersonic	1.2 x 1.2 m	1.2 to 4	75 x 10^6/m at Mach 3.9	328
		UNITED KINGDOM		
Subsonic Wind Tunnels				
ARA Bedford Two-Dimensional	8 x 18 in.	0.3 to 0.86	2 to 7 x 10^6/ft	333
BAe Brough 7 x 5 ft Low-Speed	2.1 x 1.5 m	0 to 0.25	5.4 x 10^6/m	335
BAe Filton 12 x 10 ft	10 x 12 x 25 ft	0 to 0.25	0 to 1.8 x 10^6/ft	338
BAe Hatfield 9 x 7 ft	6.7 x 8.7 x 18.5 ft	0 to 0.22	0 to 1.6 x 10^6/ft	340
BAe Hatfield 15 ft	15 x 15 x 40 ft	0 to 0.125	0 to 0.9 x 10^6/ft	343
BAe Warton 2.7 x 2.1 m Low-Speed	2.1 x 2.7 m	0.003 to 0.197	0.1 to 5 x 10^6/m	346
BAe Warton 18 ft V/STOL	5 x 5.5 m	0.035 to 0.065	0.8 to 1.5 x 10^6/m	349
BAe Weybridge 3 x 2 ft High-Speed	2 x 3 x 5 ft	0.4 to 0.92	2.6 to 4.5 x 10^6/ft	353
BAe Warton 13 x 9 ft Low-Speed	9 x 13 ft	0.18 to 0.27	0 to 2.2 x 10^6/ft	356
BAe Woodford 9 x 7 ft Low-Speed	2.74 x 2.13 x 5.5 m	0 to 0.176	0 to 4.3 x 10^6/m	359
RAE Bedford 13 x 9 ft Low-Speed	9 x 13 x 30 ft	0.01 to 0.27	0.1 to 2 x 10^6/ft	361

(continued)

Installation and facility	Test section size	Mach number	Reynolds Number	Page
RAE Farnborough Shock Tunnel—LICH Tube	0.76 m diameter x 1 m long	7 (conical)	3.7×10^7/m at Mach 7	417
RAE Farnborough Shock Tunnel—Ludwieg Tube	0.76 m diameter x 1 m long	5 (contoured)	1.7 to 4.3×10^8/m	419
RAE Farnborough Shock Tunnel—Shock Tube	0.38 x 0.38 x 0.3 m	7, 9, 10, and 13 (conical) and 9 and 13 (contoured)	1.4×10^7/m at Mach 7 and 2×10^5/m at Mach 10	421
Sheffield Shock Tunnel	8 cm diameter x less than 1 m long	6 to 15 (flight) and 1 to 5 (combustor)	About 1×10^5/ft	423
		WEST GERMANY		
Subsonic Wind Tunnels				
DLR Berlin Evacuable Free-jet Experimental Plant 1	1.2 x 2.8 m (cylindrical)	Less than 0.4	5×10^5/m	444
DLR Berlin Low-Velocity	Not available	0.14	4.5×10^6/m	447
DLR Berlin Unsteady	0.5 x 0.5 x 6 m	0.08	Not available	450
DLR Braunschweig 3.25 m x 2.8 m^2 (NWB)	3.25 m x 2.8 m^2 x 6.2 m and 9.1 m^2 (test chamber cross section)	0.22 (open) and 0.26 (closed)	5×10^6/m (open) and 6×10^6/m (closed)	452
DLR Braunschweig Jet-simulation (SSB)	440 mm diameter	0.35 to 0.8	7 to 14×10^6/m	455
DLR Braunschweig Model Subsonic (MUB)	No. 1: 1.3 m x 1.3 m^2 x 2.46 m and No. 2: 0.82 m x 0.82 m^2 x 1.64 m	0.14 to 0.38	Not available	460
DLR Goettingen 1 m (1MG)	1 x 0.7 x 1.3 m	0.002 to 0.19	1.3×10^6/m	463
DLR Goettingen 3 x 3 m Subsonic (NWG)	3 m x 3 m^2 x 6 m and 9 m^2 (test chamber cross section)	0 to 0.19	4.4×10^6/m	466
DLR Goettingen Cryogenic Tube (KRG)	0.4 x 0.35 m	0.3 to 0.9	4.5×10^8/m	469
DLR Goettingen High-Pressure (HDG)	0.6 x 0.6 x 0.575 m (open) and 0.4 x 0.6 x 1 m (closed)	0.1	2×10^8/m	470
DLR Goettingen Low-Turbulence (TUG)	0.3 m x 1.5 m^2 x 6.25 m	0.13	1×10^6/m	473
DLR Koln-Porz 2.4 x 2.4 m Cryogenic (KKK)	2.4 m x 2.4 m^2 x 5.4 m	0.01 to 0.36	36×10^6/m	475
DLR Koln-Porz European Transonic Test Rig	270 mm x 228 mm^2	0 to 0.9	Not available	480
Transonic Wind Tunnels				
DLR Braunschweig Transonic (TWB)	0.34 m x 0.6 m^2	0.4 to 0.95	2 to 7×10^7/m	482
European Transonic (ETW)	2.4 x 2 m	0.15 to 1.3	About 50×10^6/m	486
Trisonic Wind Tunnels				
DLR Goettingen 1 x 1 m Transonic (TWG)	1 x 1 m	0.5 to 2	0.3 to 1.2×10^7/m	489

(continued)

Table I.2 shows the principal capabilities and operating range of air-breathing propulsion test cells by country and category (i.e., propulsion wind tunnels; altitude engine test facilities; and engine turbine, compressor, and combustor research facilities).

Table I.2: Air-Breathing Propulsion Test Cell Facilities by Country

Propulsion Wind Tunnels

Installation and facility	Test section size	Mach number	Altitude range	Temperature range	Page
		FRANCE			
ONERA S1MA	8 m diameter x 14 m long	0.023 to approximately 1	20,000 ft	.5 and 122 degrees Fahrenheit	123
		THE NETHERLANDS			
DNW Low-Speed	9.5 x 9.5 m, 6 x 8 m, and 6 x 6 m	0.18, 0.34, and 0.45	Atmospheric	Ambient	303

Altitude Engine Test Facilities

Installation and facility	Air supply			Mach number	Altitude range	Page
	Mass flow rate	Temperature range	Pressure range			
			FRANCE			
CEPr C-1	121 lb/s	−86 to 175 degrees Fahrenheit	7 to 17 psia	0 to 1	36,000 ft	193
CEPr R-3	441 lb/s	−85 to 390 degrees Fahrenheit	30 psia	0 to 2.4	65,600 ft	195
CEPr R-4	441 lb/s	−85 to 370 degrees Fahrenheit	30 psia	0 to 2.4	65,600 ft	196
CEPr R-5	825 lb/s	1,200 degrees Fahrenheit	100 psia	0 to 4	65,600 ft	198
CEPr S-1	221 lb/s	661 degrees Fahrenheit	29 psia	2	62,000 ft	200
ONERA ATD Ramjet Cells Nos. 8 and 9	50 kg/s	1,200 degrees Kelvin	250 bars	4.5	30,000 m	201
			JAPAN			
MHI Small Turbojet Development Test Cell (1007)	12 lb/s	−30 to 180 degrees Fahrenheit	33 psia	0 to 1.2	Sea level to 20,000 ft	272
NAL Ram/Scramjet Engine Test Facility	10.41 kg/s	2,557 degrees Kelvin	10.25 MPa	6.73	Up to 35,000 m	274

(continued)

Compressor Component Research Facilities

Installation and facility	Maximum flow rate	Maximum power	Temperature range	Pressure level	Speed range	Page
			JAPAN			
IHI Large-Scale Aero-Engine Compressor Facility	310 lb/s	18,000 hp	Ambient	2 atm	13,000 rpm	283
NAL Fan/ Compressor/ Turbine Facility	Not available	Not available	Ambient	Ambient	15,500 rpm	285

Combustor Component Research Facilities

Installation and facility	Maximum flow rate	Maximum power	Temperature range	Pressure level	Speed range	Page
			JAPAN			
IHI Medium-Pressure Combustor Facility	24 lb/s	Not available	180 to 780 degrees Fahrenheit	7 atm	Not available	287
NAL High-Pressure Annular Combustor Test Facility	13.5 kg/s	Not available	660 degrees Kelvin	900 kPa	Not available	289
NAL High-Pressure Combustor Test Facility	4 kg/s	Not available	Ambient to 730 degrees Kelvin	5 MPa	Not available	291
NAL Propulsion Test Cell	Not available	Not available	Ambient	Ambient	Not available	297
NAL Ram/Scramjet Combustor Test Facility	Not available	Not available	800 to 2,500 degrees Kelvin	1.5 MPa	Not available	299

Objectives, Scope, and Methodology

The Chairman of the House Committee on Science, Space, and Technology asked us to (1) collect data and information on foreign government and industry investment in aerospace vehicle research and technological development efforts, focusing on those critical or enabling technologies that could allow foreign countries to develop and build future aerospace vehicles, and (2) identify indicators to measure foreign countries' current state of aerospace vehicle technological development and progress. The Committee requested that we provide it with technical data and information on foreign aerospace test facilities to assess foreign countries' research, development, and testing capabilities for future aerospace vehicles. The Committee is particularly interested in the potential

Our methodology involved reviewing studies and pertinent documents and interviewing appropriate officials in Washington, D.C., at the Departments of Defense, the Air Force, State, and Commerce; the Defense Advanced Research Projects Agency (DARPA); NASA; and the Office of Science and Technology Policy (OSTP) in the Executive Office of the President. We also met in Washington, D.C., with officials of Gellman Research Associates, Inc., of Jenkintown, Pennsylvania; the Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt (DFVLR);[17] and National Space Development Agency of Japan (NASDA).

We also visited the NASP Joint Program Office (JPO), the Foreign Technology Division of the Air Force Systems Command, and Air Force Wright Aeronautical Laboratories (AFWAL), Wright-Patterson Air Force Base (AFB), Dayton, Ohio; AEDC and the Foreign Technology Division of the Air Force Systems Command, Arnold AFB, Tullahoma, Tennessee; and Lovelace Scientific Resources, Inc., Albuquerque, New Mexico.

We met with Air Force, NASA, and contractor officials, engineers, and scientists to help us develop our approach and methodology, determine key enabling technologies, and identify specific data requirements needed to measure the status of a country's technological maturation and capability to develop and build a future air-breathing aerospace vehicle.

Our methodology also involved reviewing studies and pertinent documents; interviewing appropriate U.S. Embassy, international organization, and foreign government, industry, and university officials; and visiting key test facilities in France, West Germany, the United Kingdom, The Netherlands, Belgium, Italy, Japan, and Australia.

France

We conducted review work in Paris at the U.S. Embassy, U.S. Mission to the Organization for Economic Cooperation and Development (OECD), OECD Headquarters, Centre National d'Etudes Spatiales (CNES), Office National d'Etudes et de Recherches Aerospatiales (ONERA), North Atlantic Treaty Organization's (NATO) Advisory Group for Aerospace Research and Development (AGARD), ESA, Societe Europeenne de Propulsion (SEP), and Societe Nationale d'Etude et de Construction de Moteurs d'Aviation

[17] In December 1988 DFVLR changed its name to Deutsche Forschungsanstalt fuer Luft- und Raumfahrt (DLR). However, DLR is still commonly referred to in English as the German Aerospace Research Establishment. Foreign acronyms and names with their translations are included in the list of abbreviations.

We also visited the Duits-Nederlandse Windtunnel (DNW) at NLR's Noordoostpolder site near Marknesse; NLR's High-Speed Wind Tunnel, Supersonic Wind Tunnel, flight simulator, and computer center in Amsterdam; and ESA's European Space Research and Technology Center (ESTEC) in Noordwijk.

Belgium

We conducted review work in Brussels at the U.S. Embassy, U.S. Mission to the European Communities, European Communities (EC) Headquarters, and Societe Anonyme Belge de Constructions Aeronautiques (SABCA).

We also visited the VKI Longshot Free Piston Wind Tunnel ST-1 at the von Karman Institute for Fluid Dynamics in Rhode Saint Genese.

Italy

We conducted review work in Rome at the U.S. Embassy, Agenzia Spaziale Italiana (ASI), and Centro Italiano Ricerche Aerospaziali (CIRA); in Colleferro at the Societa Nazionale Industria Applicazlone-Bomprini Parodi Delfino (SNIA-BPD); and in Turin at Aeritalia-Societa Aerospaziale Italiana and Fiat Aviazione.

Japan

We conducted review work in Tokyo at the U.S. Embassy, Office of Naval Research, Air Force Office of Scientific Research, Army Research Office, Ministry of International Trade and Industry, Science and Technology Agency, Space Activities Commission of Japan, NASDA, Ishikawajima-Harima Heavy Industries (IHI), and The Japan Society for Aeronautical and Space Sciences; in Chofu at the National Aerospace Laboratory (NAL); in Sagamihara at the Institute of Space and Astronautical Science (ISAS); in Tanegashima at NASDA's Tanegashima Space Center; in Tsukuba at NASDA's Tsukuba Space Center; in Uchinoura at ISAS's Kagoshima Space Center; in Utsunomiya at Fuji Heavy Industries (FHI); in Gifu at Kawasaki Heavy Industries (KHI); and in Nagoya and Komaki at Mitsubishi Heavy Industries (MHI).

We also visited the Japanese Experimental Module mock-up and space vehicle assembly building at NASDA's Tsukuba Space Center in Tsukuba; Takesaki Range small rocket launch site, Osaki Range Control Center, Mobile Service Tower for the H-I rocket booster, Static Firing Test Facility for the LE-7 engine, Yosinobu Range for the H-II rocket launcher, and

Definition and Explanation of Data Elements

The following list of technical data and information categories provides a definition of technical parameters and an explanation of each data element used in this report. Technical terms used in the facility data sheets are defined in the glossary.

Type of facility: Wind tunnel or air-breathing propulsion test cell. Wind tunnels are further categorized by speed regimes (subsonic, transonic, trisonic, supersonic, hypersonic, and hypervelocity wind tunnels). Air-breathing propulsion test cells are grouped according to category (propulsion wind tunnels; altitude engine test facilities; and propulsion component facilities for engine turbines, compressors, and combustors).

Name: Proper or generic name of the facility, with additional qualifiers or identifiers (such as name of installation or owner), as appropriate. When the size of a wind tunnel is used in its name, the units of measurement used are those by which the facility is best known.

Country: Country where test facility is located.

Location: Name of installation, city, and country where facility is located.

Owner(s): Foreign government organization or agency, foreign industry, consortium, and/or university; street and/or postal address; city; and country.

Operator(s): Foreign government organization or agency, foreign industry, consortium, and/or university that actually runs the test facility.

International cooperation: List of countries and/or international organizations that use test facility through, for example, contracts, a data exchange agreement, memorandum of agreement, memorandum of understanding, or arrangement.

Point of contact: Name of person, organization, and telephone number ([country code]-(city code)-local number) to contact for further information.

Test section size (wind tunnels): The dimensions of the test section are given in the following order: height times width times length, or diameter and length. The units of measurement used are either feet (ft) or meters (m) except where inches (in.), centimeters (cm), or millimeters

Active status. The activity is described under Planned improvements or Applications/current programs.

Planned: A new facility is planned, and governmental approval, if required, has been sought or obtained to build the facility.

Utilization rate: How frequently and to what extent the facility is used. May be expressed in terms of number of test runs or hours per day, month, or year, etc., or shifts per day.

Performance (wind tunnels)

Mach number: Listed as maximum speed or a range of speed in Mach number and/or in feet per second (ft/s) or meters per second (m/s), as appropriate.

Reynolds Number: Indicated in millions (10^6) per foot (R_e/ft) or meter (R_e/m).

Total pressure: Indicated in atmospheres (atm) or bars.

Dynamic pressure: A range given in pounds per square foot (lb/ft^2) or kilo-newtons per square meter (kN/m^2).

Total temperature: The wind tunnel's stagnation temperature shown in degrees Fahrenheit, Kelvin, or Rankine.

Run time: Test time shown in milliseconds (ms), seconds (s), or characterized as continuous.

Comments: Supplementary information on the performance range or special conditions of the wind tunnel. Types of test gas may also be indicated.

Performance (air-breathing propulsion test cells)

Dynamic pressure: For propulsion wind tunnels, a range given in pounds per square foot (lb/ft^2) or kilo-newtons per square meter (kN/m^2).

Mass flow: For altitude engine test facilities, an indication of the amount of air flowing into an engine's inlet in a test section in pounds per second (lb/s).

Replacement cost: Best estimate of the current value of the facility or the cost to replace facility with all improvements in current dollars.

Annual operating cost: Operations and maintenance costs per year expressed in current dollars.

Unit cost to user: Typical cost, such as dollars per hour or test.

Source(s) of funding: Principal foreign government organizations or agencies, foreign industry, and/or universities that provide funding for construction, improvement, and/or operation of facility.

Number and type of staff: Number and type of personnel working at a facility, including, for example, engineers, scientists, technicians, others (such as laborers and research assistants), and administrative/management personnel.

Description: Narrative description of the facility.

Testing capabilities: Narrative description of the kinds of tests normally done or possible. Emphasis on specialized, unusual, or unique capabilities.

Data acquisition: Narrative description of data acquisition, conversion, recording, or reduction capabilities and equipment.

Planned improvements: Narrative description of major improvements in plant, facility, data acquisition, or test capabilities planned, including dates.

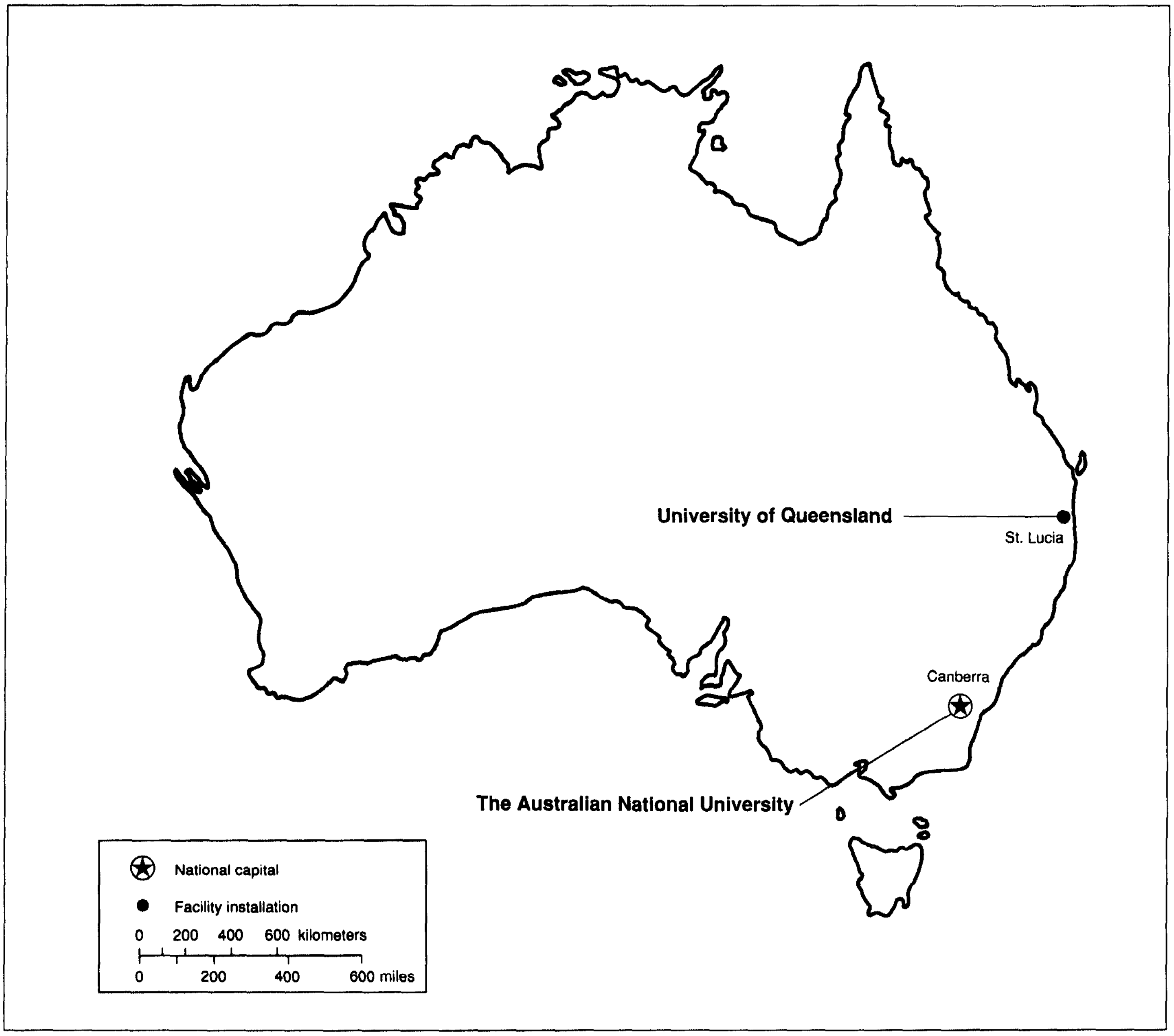
Unique characteristics: Narrative description of any unique characteristics or performance capabilities of facility in the country where located or in the world.

Applications/current programs: Narrative description of types of applications and list of activities in recent past (2 to 3 years). A description of the operational status for inactive facilities is also given.

General comments: Narrative comments regarding facility capabilities or applications not contained in any category above. Additional comments may also be provided.

Aerospace Test Facilities in Australia

Figure III.1: Map of Test Facilities in Australia



Source: GAO

Applications/Current Programs: The T-3 is being used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation, HOTOL (Horizontal Takeoff and Landing) vehicle and surface catalysts for British Aerospace, CFD code validation for MBB, and scramjet diagnostics and biconic geometry work for NASA. ANU is also planning to use the T-3 to calibrate a Re-entry Air Data System and Scramjet Air Data System for British Aerospace Australia. ANU is establishing a cooperative program on scramjet combustion efficiency with NASA's Langley Research Center in Hampton, Virginia.

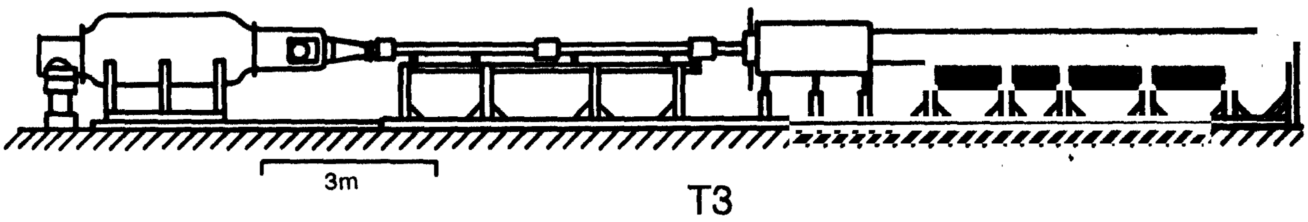
General Comments: Test gases include air, argon, nitrogen, methane, oxygen, and helium.

Photograph/Schematic Available: Yes

References: Stalker, Ray J., and R. John Sandeman. The Australian National University Free Piston Shock Tunnel T-3 Facility Handbook. Canberra: The Australian National University, 1985.

Date of Information: September 1989

Figure III.3: Schematic Diagram of The Australian National University T-3 Shock Tunnel



Source: ANU

Figure III.4: Reentry Test on a Model of HOTOL in The Australian National University T-3 Shock Tunnel

Source: BAe

University of Queensland T-4 Shock Tunnel

Country: Australia

Location: University of Queensland, St. Lucia, Queensland, Australia

Owner(s):
University of Queensland
Department of Mechanical Engineering
St. Lucia, Brisbane, Queensland 4067
Australia

Operator(s): University of Queensland

International Cooperation: ESA, France, the United Kingdom, the United States, and West Germany

Point of Contact: Professor Ray J. Stalker, University of Queensland, Tel.: [61]-(7)-377-3597

Test Section Size: 12 in. diameter

Operational Status: Active

Utilization Rate: 600 tests per year; up to 10 tests per day

Performance
- **Mach Number:** 5 to 10
- **Reynolds Number:** 2 x 10^6/ft at Mach 6
- **Total Pressure:** 1,150 atm
- **Dynamic Pressure:** Not available
- **Total Temperature:** 40 MJ/kg
- **Run Time:** About 0.5 to 0.75 ms
- **Comments:** See General Comments

Cost Information
- **Date Built:** 1983
- **Date Placed in Operation:** 1987
- **Date(s) Upgraded:** None
- **Construction Cost:** $900,000 (1983)
- **Replacement Cost:** $1,230,000 (1989)
- **Annual Operating Cost:** About $81,500 (1989)
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Australian Department of Science, Australian Research Council, University of Queensland, and NASA

Number and Type of Staff
- **Engineers:** 0
- **Scientists:** 2
- **Technicians:** 3
- **Others:** 1 experimenter and 1 operator
- **Administrative/Management:** 0
- **Total:** 2 to 7

Description: The University of Queensland T-4 Shock Tunnel is a free piston shock tunnel. The T-4 is a facility that produces a test flow at orbital velocities for short periods (milliseconds). It uses a large free piston compressor operating on a single stroke cycle, which heats the gas that drives the tunnel.

Testing Capabilities: The T-4 is capable of conducting pressure measurements, heat transfer measurements, and flow visualization.

Data Acquisition: The T-4 has 34 channels of on-line transient data that are processed on a personal computer.

Planned Improvements (Modifications/Upgrades): These include building a Mach 8 nozzle for increased flow to 15 in., developing techniques to measure forces, and installing instrumentation, including optical systems such as schlieren, mass spectrometry, and differential interferometry.

Unique Characteristics: The T-4 is capable of achieving real gas effects at orbital velocities with a hypersonic flow.

Applications/Current Programs: The T-4 is currently being used for upper surface flows and shock boundary layer interaction on ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation and scramjet combustion for NASA.

General Comments: The T-4 was built specifically to test scramjets. However, it has not yet reached its designed operating levels. Operating pressure levels have been raised so that total pressures of 1,150 atm have been achieved. This figure represents a little over one-half the nominal design value. It also represents the T-4's design value for routine operation. The test gas usually used is air and a combination of oxygen and nitrogen.

Photograph/Schematic Available: Yes

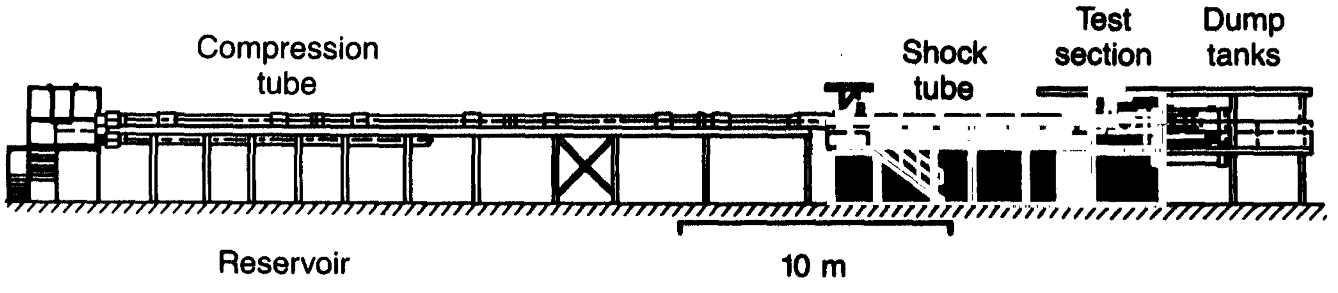
Refereces: Stalker, Ray J. "Shock Tunnels for Real Gas Hypersonics." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). University of Queensland. Free Piston Shock Tunnel T-4, Initial Operation and Calibration. St. Lucia, Queensland, Australia: University of Queensland, 1987.

Date of Information: September 1989

Figure III.5: University of Queensland T-4 Shock Tunnel

Source: GAO

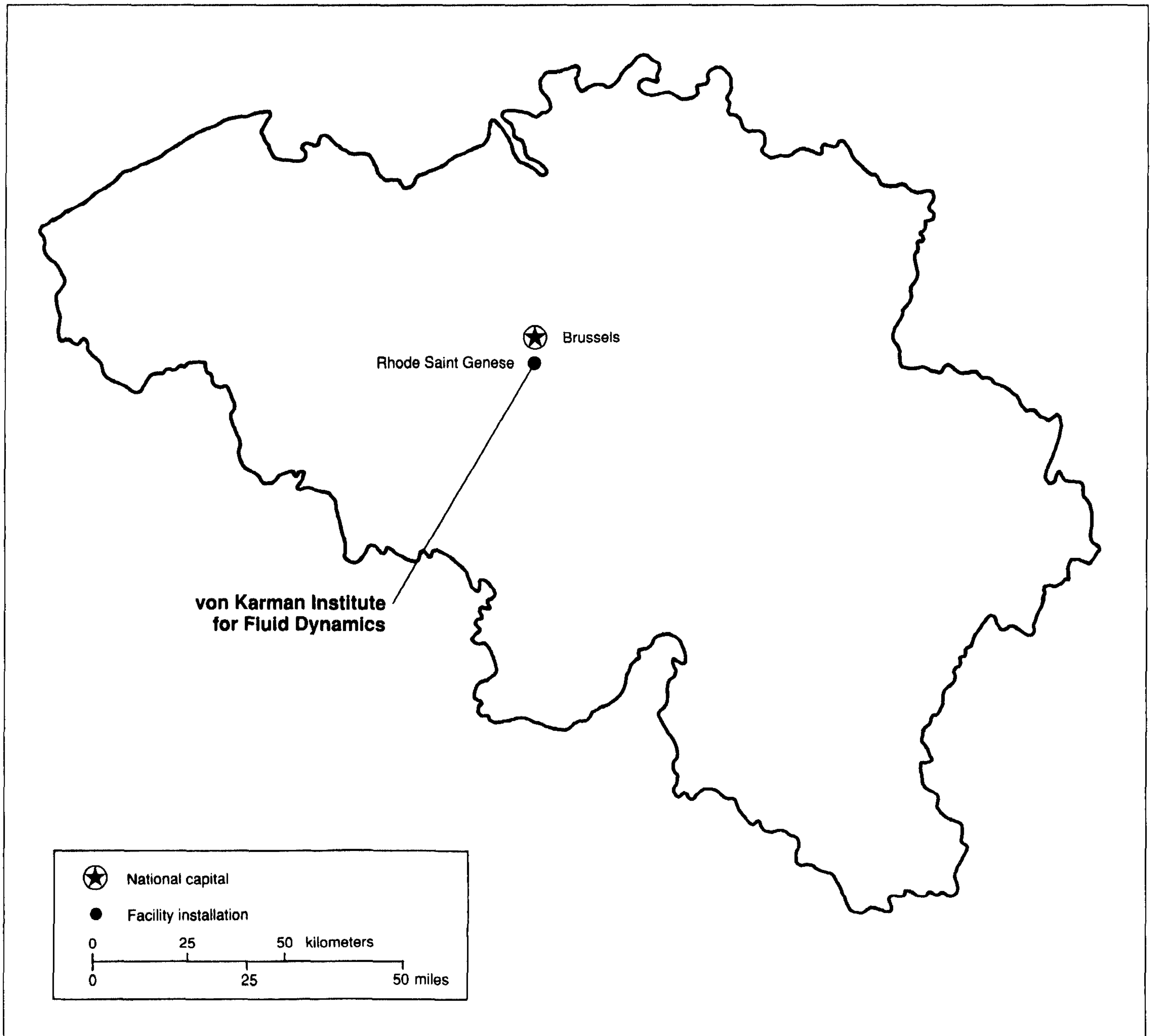
Figure III.6: Schematic Diagram of the University of Queensland T-4 Shock Tunnel



Source: University of Queensland

Aerospace Test Facilities in Belgium

Figure IV.1: Map of Test Facilities in Belgium



Source GAO

VKI Cold Wind Tunnel CWT-1

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: ESA and 16 NATO member countries (See General Comments)

Point of Contact: Professor Mario Carbonaro, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 0.1 x 0.3 x 2.2 m

Operational Status: Active

Utilization Rate: 50 days per year

Performance
Mach Number: 0.73 or 63 m/s
Reynolds Number: 4 x 10^6/m (maximum)
Total Pressure: 1 bar
Dynamic Pressure: 2 kN/m^2
Total Temperature: −70 degrees Celsius to ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1984
Date Placed in Operation: 1984
Date(s) Upgraded: 1989
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 0
Scientists: 0
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 1

Description: The VKI Cold Wind Tunnel CWT-1 is a low-speed, closed-circuit subsonic wind tunnel capable of operating at subfreezing temperatures. It incorporates a centrifugal fan, a settling chamber, a 12.4 to 1 contraction ratio, a rectangular test section with a 0.1 × 0.3 m cross section and 2.2 m length, a diffuser, and return circuit. The top and bottom walls of the test section are made of double glazing, thus providing optical access. The remainder of the facility is thermally insulated with a 5-cm rock wool layer. The fan is driven by a variable rpm 8-kW DC motor providing a maximum flow velocity of 63 m/s (Mach 0.73) that can be reached in a minimum time of 30 s after starting the tunnel. Cooling of the test air is provided by spraying liquid nitrogen into the return circuit.

Testing Capabilities: This tunnel was especially designed to study the motion of films of anti-icing fluids applied to aircraft wings during simulated takeoffs. It is also suited for optical measurements of skin friction, as well as for general flow studies at temperatures as low as −70 degrees Celsius.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: Flow acceleration in the tunnel simulates aircraft takeoff.

Applications/Current Programs: These include behavior of anti-icing fluids on aircraft wings.

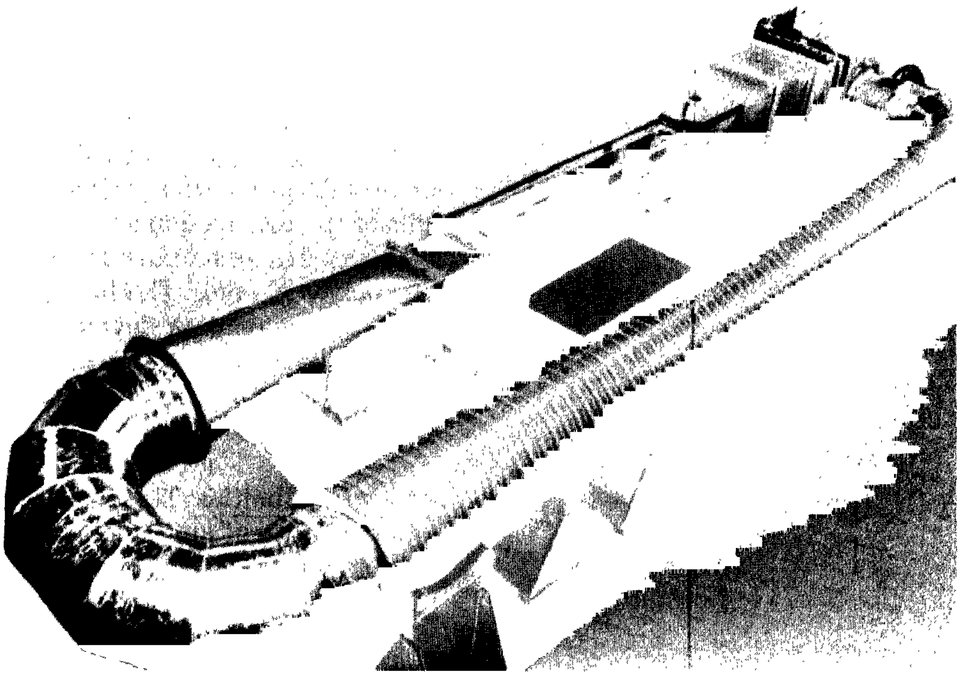
General Comments: NATO member countries consist of Belgium, Canada, Denmark, France, Greece, Iceland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Turkey, the United Kingdom, the United States, and West Germany.

Photograph/Schematic Available: Yes

References: von Karman Institute for Fluid Dynamics. Facilities and Instrumentation 1986. Rhode Saint Genese, Belgium: von Karman Institute for Fluid Dynamics, 1986, p. 6.

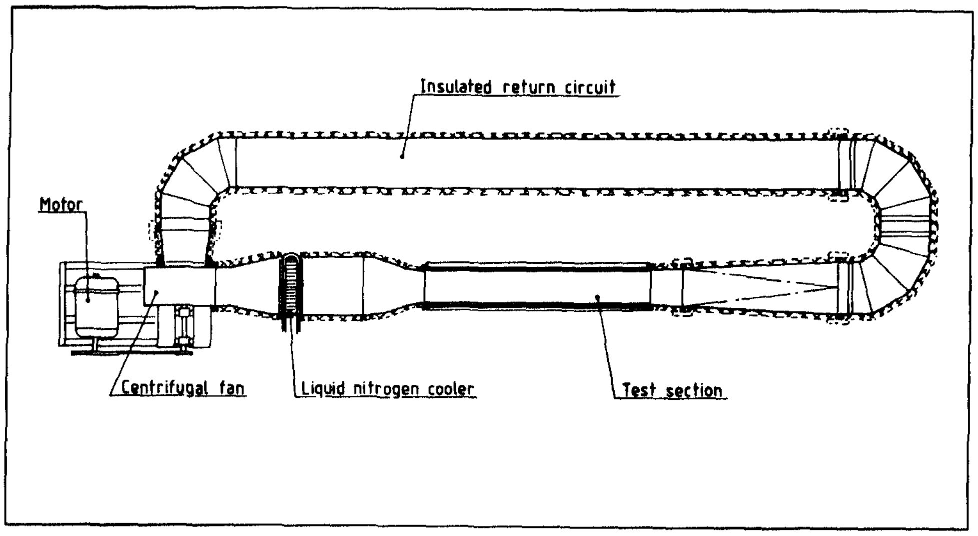
Date of Information: November 1989

Figure IV.2: von Karman Institute Cold Wind Tunnel CWT-1



Source: VKI

Figure IV.3: Schematic Diagram of the von Karman Institute Cold Wind Tunnel CWT-1



Source: VKI

VKI Low-Speed Cascade Tunnel C-1

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: ESA and 16 NATO member countries

Point of Contact: Professor John F. Wendt, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 12 x 50 cm

Operational Status: Not available

Utilization Rate: Not available

Performance
- **Mach Number:** Not available
- **Reynolds Number:** Not available
- **Total Pressure:** Not available
- **Dynamic Pressure:** Not available
- **Total Temperature:** Not available
- **Run Time:** Not available
- **Comments:** None

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** Not available
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The VKI Low-Speed Cascade Tunnel C-1 is a continuous-flow subsonic wind tunnel with a rectangular cross section of 12 x 50 cm.

Testing Capabilities: Tests are made using either compressor or turbine cascades, where each cascade may contain from 7 to 10 blades. Two-dimensional flow conditions are obtained by removal of sidewall boundary layers using a suction system independent of the main air supply. A blade mounted in the center of the cascade may be equipped with pressure taps. Flow measurements upstream and downstream of a cascade are made using two remotely-actuated probe carriages.

Data Acquisition: On-line data reduction of probe measurements is available by connection to the medium-speed 16-channel acquisition system that is connected directly to the data acquisition computer.

Planned Improvements (Modifications/Upgrades): Reynolds Number capability has been improved over the critical value for cascade testing.

Unique Characteristics: None

Applications/Current Programs: Not available

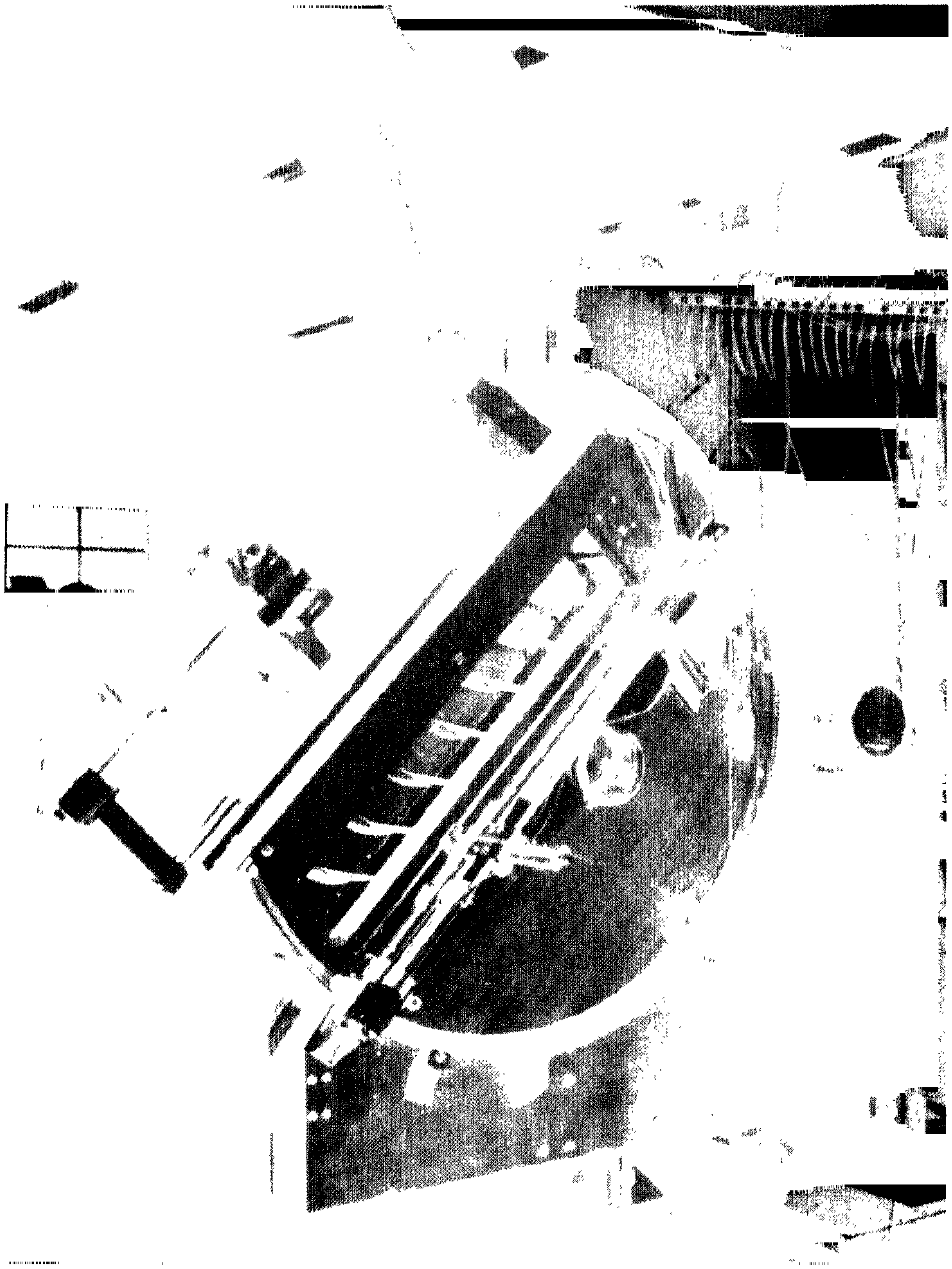
General Comments: None

Photograph/Schematic Available: Yes

References: von Karman Institute for Fluid Dynamics. Facilities and Instrumentation 1986. Rhode Saint Genese, Belgium: von Karman Institute for Fluid Dynamics, 1986, p. 3.

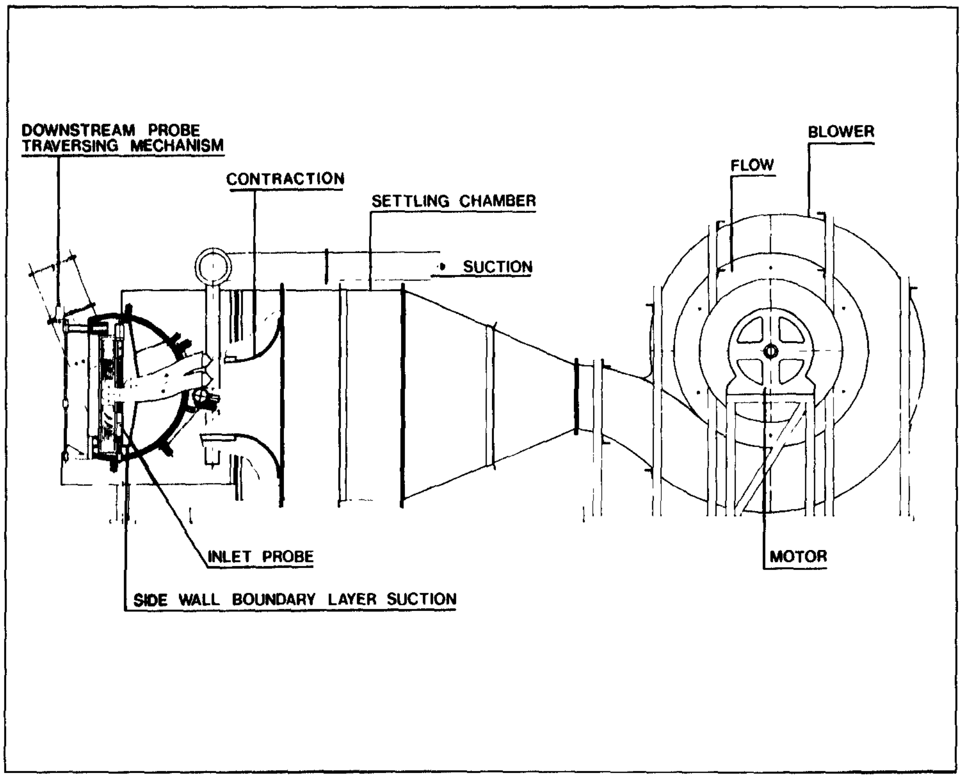
Date of Information: November 1989

Figure IV.4: von Karman Institute Low-Speed Cascade Tunnel C-1



Source: VKI

Figure IV.5: Schematic Diagram of the von Karman Institute Low-Speed Cascade Wind Tunnel C-1



Source: VKI

VKI Low-Speed Wind Tunnel L-1A

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: ESA and 16 NATO member countries

Point of Contact: Professor Mario Carbonaro, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 3 m diameter (open-jet)

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.17 or 60 m/s
Reynolds Number: 4 x 10^6/m
Total Pressure: 1 bar
Dynamic Pressure: 2 kN/m^2
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1949
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 1
Scientists: 0
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 2

Description: The VKI Low-Speed Wind Tunnel L-1A is a subsonic wind tunnel. It has a free-jet test section of 3 m diameter. The contrarotating fans are driven by a variable speed DC motor of 580 kW, allowing a continuous variation of velocity from 2 to 60 m/s (Mach 0.005 to 0.17). The contraction ratio is 4 with a typical turbulence level of 0.3 percent.

Testing Capabilities: The tunnel is provided with a full-range of test equipment, including a six-component overhead hydromechanical balance for aircraft model testing. The test section may also be equipped with a flat plate/turntable system including means for atmospheric wind simulation to be used for tests on ground structures and on environmental problems. For special applications, a number of multi-component strain-gauge balances, instrumentation for the measurement and recording of pressure and flow characteristics, and flow visualization methods are available.

Data Acquisition: The facility may be connected to the medium- and high-speed data acquisition systems of the Computer Center.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include general aeronautical testing.

General Comments: None

Photograph/Schematic Available: Yes

References: von Karman Institute for Fluid Dynamics. Facilities and Instrumentation 1986. Rhode Saint Genese, Belgium: von Karman Institute for Fluid Dynamics, 1986, p. 11.

Date of Information: November 1989

Figure IV.6: von Karman Institute Low-Speed Wind Tunnel L-1A

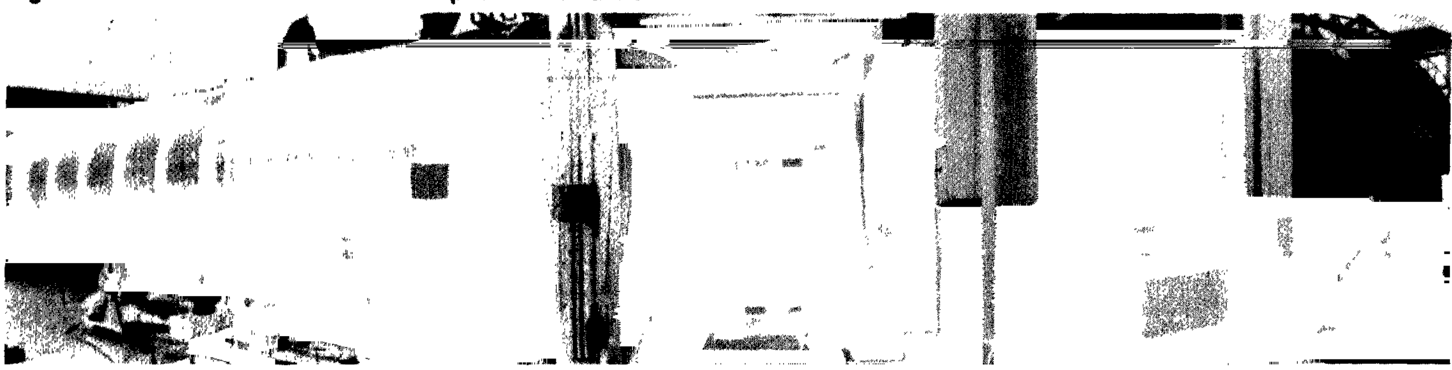
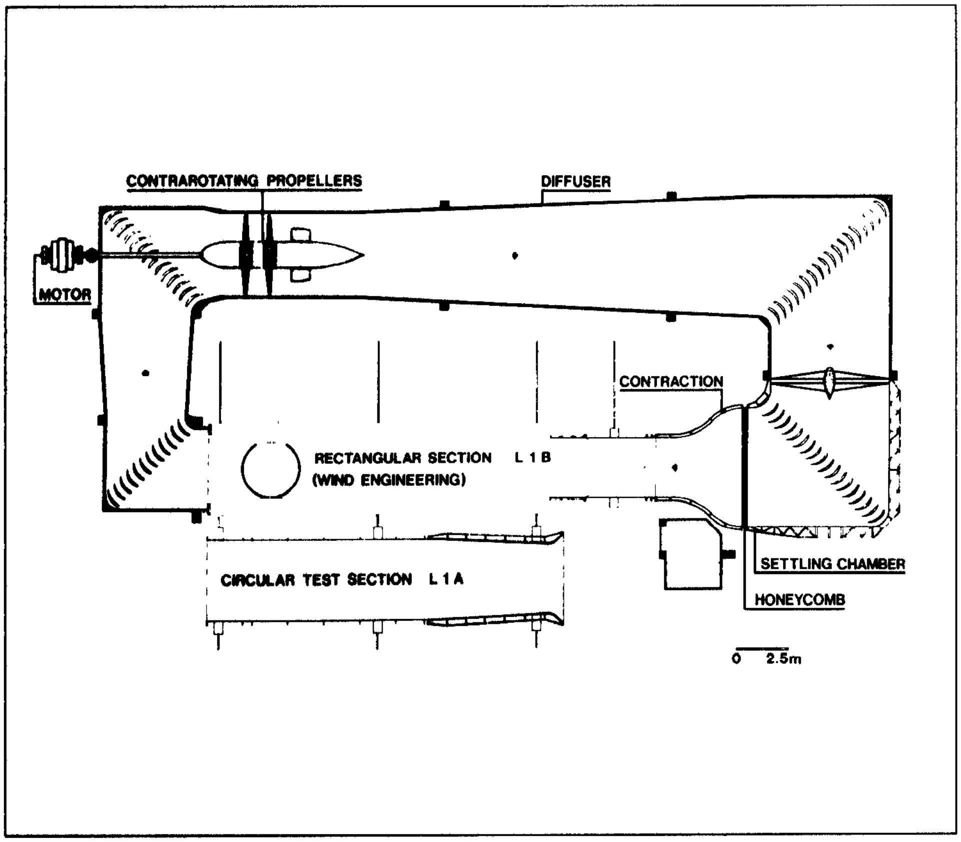


Figure IV.7: Schematic Diagram of the von Karman Institute Low-Speed Wind Tunnel L-1A



Source: VKI

VKI Compression Tube Annular Cascade Facility CT-3

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: EC, France, Italy, and West Germany

Point of Contact: Professors Claus H. Sieverding and T. Arts, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 850 mm (maximum tip), 600 mm (hub minimum), and 50 to 70 mm (typical blade height)

Operational Status: Not available

Utilization Rate: Not available

Performance
Mach Number: See General Comments
Reynolds Number: See General Comments
Total Pressure: 1 to 5 bars
Dynamic Pressure: Not available
Total Temperature: 300 to 500 degrees Kelvin
Run Time: 100 to 500 ms
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The VKI Compression Tube Annular Cascade Facility CT-3 is a transonic wind tunnel. The CT-3 is an isentropic light piston compression tube annular cascade facility that provides full similarity with modern aero-inlet guide vanes with respect to Mach number and Reynolds Number as well as free-stream/wall/coolant flow temperature ratios. The facility consists of (1) a 1.6 m diameter × 8 m long tube containing a lightweight piston with a central pressure release valve to prevent pressure loads that are too high, (2) a fast-opening shutter valve mounted on the cylinder end plate opening the flow path via a radial diffuser to a small settling chamber (900 mm tip and 500 mm hub), (3) a test section containing the inlet guide vanes with provision of film cooling of all blades as well as top and bottom endwalls, and (4) a diffuser discharging the flow into a large dump tank. A variable sonic hole device in the diffuser stabilizes the vane exit static pressure.

Testing Capabilities: Pressure, temperature, and convection heat transfer measurements are performed using fast response transducers or transient techniques. A fast moving pneumatic drive probe carriage with pressure and temperature probes allows surveying the exit flow field over an annular sector of 40 degrees.

Data Acquisition: The data are acquired by a 48-channel high-speed data acquisition system. The data are visualized and processed on a VAX 3500 computer. Tunnel operation is controlled by an IBM personal computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: Mach number and Reynolds Number are in the typical range for transonic gasturbines.

Photograph/Schematic Available: No

References: None available

Date of Information: November 1989

VKI High-Speed Cascade Tunnel C-3

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: France, Italy, the United Kingdom, the United States, and West Germany

Point of Contact: Professor Claus H. Sieverding, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 100 x 250 mm^2

Operational Status: Not available

Utilization Rate: Not available

Performance
Mach Number: 0.2 to 2
Reynolds Number: Not available
Total Pressure: 1 to 3 bars
Dynamic Pressure: Not available
Total Temperature: 290 degrees Kelvin
Run Time: Up to 20 min
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The VKI High-Speed Cascade Tunnel C-3 is a blowdown trisonic wind tunnel with discharge to atmosphere. The maximum test section dimensions are 100 × 250 mm^2. The tunnel is only used for testing turbine cascades.

Testing Capabilities: The inlet angle can be changed continuously by rotating the test section. The measuring equipment includes differential electric transducers for the pressure readings taken by probes mounted on remotely controlled carriages, multimanometers for blade surface pressure distributions and schlieren systems for flow visualization.

Data Acquisition: The low-speed on-line data acquisition system samples the probe data at a rate of 100 Hz. Data are processed on the central VAX 3300 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include transonic turbine cascade testing, shock boundary layer interaction, trailing edge flow, and wake mixing.

General Comments: None

Photograph/Schematic Available: Yes

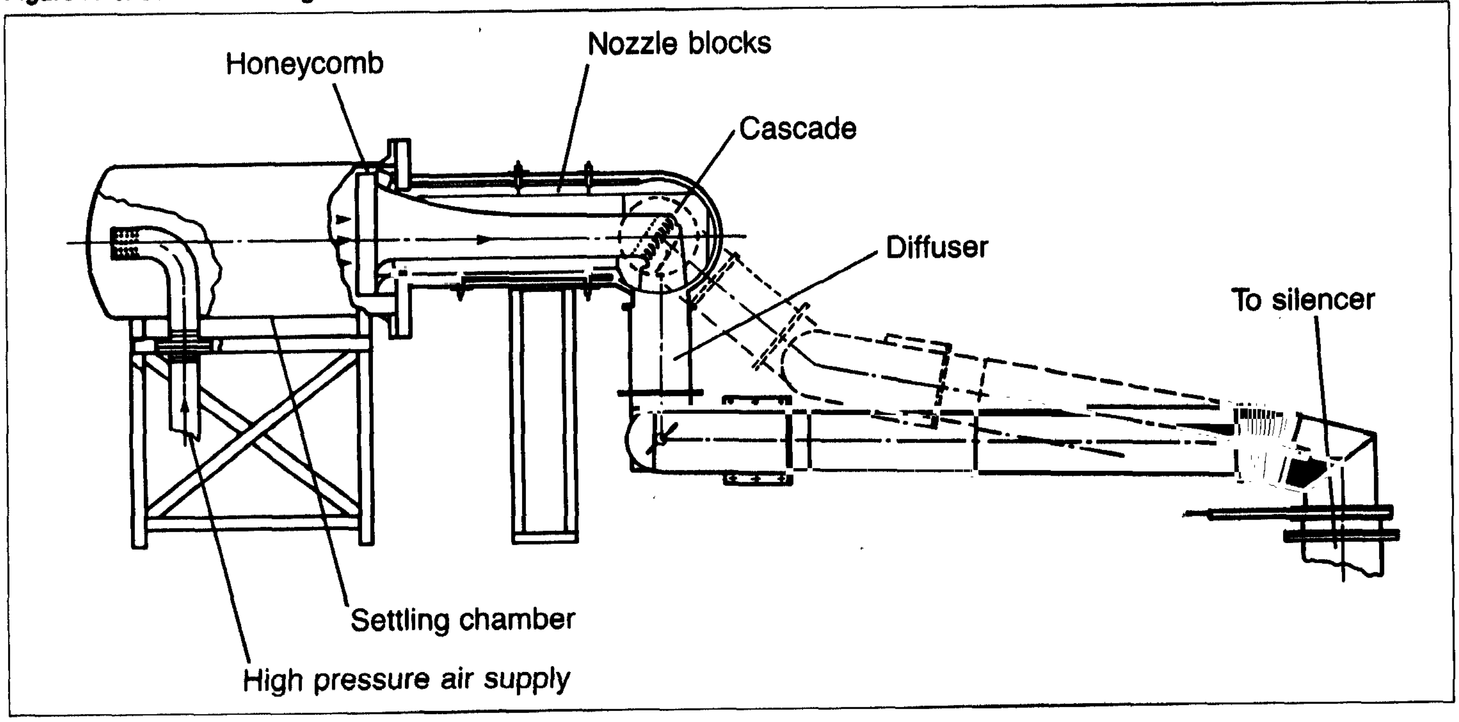
References: von Karman Institute for Fluid Dynamics. Facilities and Instrumentation 1986. Rhode Saint Genese, Belgium: von Karman Institute for Fluid Dynamics, 1986, p. 3.

Date of Information: November 1989

Figure IV.8: von Karman Institute High-Speed Cascade Tunnel C-3

Source: VKI

Figure IV.9: Schematic Diagram of the von Karman Institute High-Speed Cascade Tunnel C-3



Source: VKI

VKI Supersonic/Transonic Wind Tunnel S-1

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: ESA and 16 NATO member countries

Point of Contact: Professor John F. Wendt, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 40 x 40 cm (transonic) and 40 x 40 cm (supersonic)

Operational Status: Active

Utilization Rate: 100 days per year

Performance
Mach Number: 0.4 to 1.05 (slotted transonic), 1.43, and 2 to 2.25 (contoured supersonic)
Reynolds Number: 4 x 10^6/m at Mach 2
Total Pressure: 0.3 bars
Dynamic Pressure: 10 kN/m^2
Total Temperature: 300 degrees Kelvin
Run Time: Continuous
Comments: None

Cost Information
Date Built: About 1950
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 1
Scientists: 0
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 2

Description: The VKI Supersonic/Transonic Wind Tunnel S-1 is a continuous-flow, closed-circuit supersonic wind tunnel. The tunnel is of the Ackeret type and is driven by a 615-kW axial flow compressor. Two 40 × 40 cm test sections (one supersonic and one transonic) are available. The tunnel has Mach 2 and 2.25 contoured nozzles and a slotted transonic test section with a Mach 0.4 to 1.05 nozzle. A Mach 1.43 solid half-nozzle is also available for shock wave and boundary layer interaction studies. The test section, which is followed by a variable geometry diffuser, contains a three-degree-of-freedom traversing mechanism for model and probe support, as well as a variable incidence mechanism (less than 35 degrees). The tunnel is equipped with shadow and schlieren systems.

Testing Capabilities: Instrumentation includes scanivalves for pressure distribution measurements, multi-component strain-gauge balances, a 4-W laser Doppler velocimeter with programmable table, and data acquisition systems.

Data Acquisition: The tunnel may be connected to the von Karman Institute's data acquisition system.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include projectile stability and general aeronautical testing and research.

General Comments: None

Photograph/Schematic Available: Yes

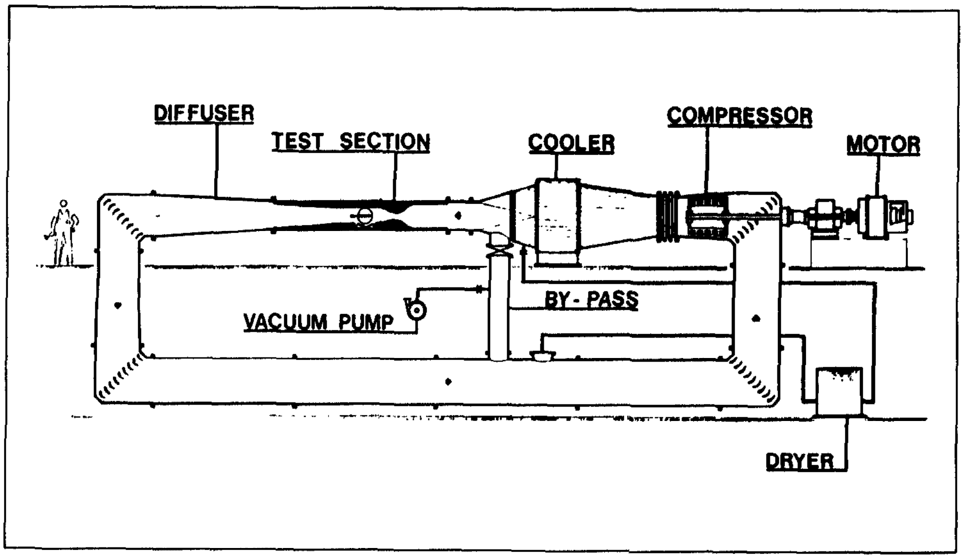
References: von Karman Institute for Fluid Dynamics. Facilities and Instrumentation 1986. Rhode Saint Genese, Belgium: von Karman Institute for Fluid Dynamics, 1986, p. 23.

Date of Information: November 1989

Figure IV.10: von Karman Institute Supersonic/Transonic Wind Tunnel S-1

Source: VKI

Figure IV.11: Schematic Diagram of the von Karman Institute Supersonic/Transonic Wind Tunnel S-1



Source: VKI

VKI Isentropic Light Piston Compression Tube CT-2

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: France, Italy, the United Kingdom, the United States, and West Germany

Point of Contact: Professor T. Arts, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 250 x 100 mm

Operational Status: Not available

Utilization Rate: Not available

Performance
Mach Number: Not available
Reynolds Number: Not available
Total Pressure: 0.5 to 7 bars
Dynamic Pressure: Not available
Total Temperature: 300 to 600 degrees Kelvin
Run Time: 100 to 800 ms
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The VKI Isentropic Light Piston Compression Tube CT-2 is a shock tunnel. It is a short-duration facility that provides full similarity with modern aero-engines with respect to Mach and Reynolds Numbers as well as free-stream, wall, and coolant temperature ratios. It consists of a 5 m long, 1 m diameter cylinder containing a lightweight piston that is isolated from the test section by a fast opening valve. As the piston moves, the gas in front of it is isentropically compressed until it reaches the desired pressure and temperature levels. The fast opening valve is then actuated, allowing the pressurized air to flow over the model, typically a cascade. Steady free-stream flow conditions are maintained for 100 to 800 ms; they can be varied between 300 and 600 degrees Kelvin and 0.5 and 7 bars. A 15-m^3 dump tank allows downstream pressure adjustments between 0.1 and 4 bars. Secondary air to be used in film cooling applications can be produced at temperatures as low as 170 degrees Kelvin. The maximum test section dimensions are 250 × 100 mm.

Testing Capabilities: The tunnel is capable of conducting pressure, temperature and convective heat transfer measurements. Additional qualitative information is obtained from oil flow or schlieren visualizations.

Data Acquisition: Measurements are performed using fast response transducers or transient techniques. They are acquired by a 48-channel high-speed computer, visualized, and processed using the VAX 11/780 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: Yes

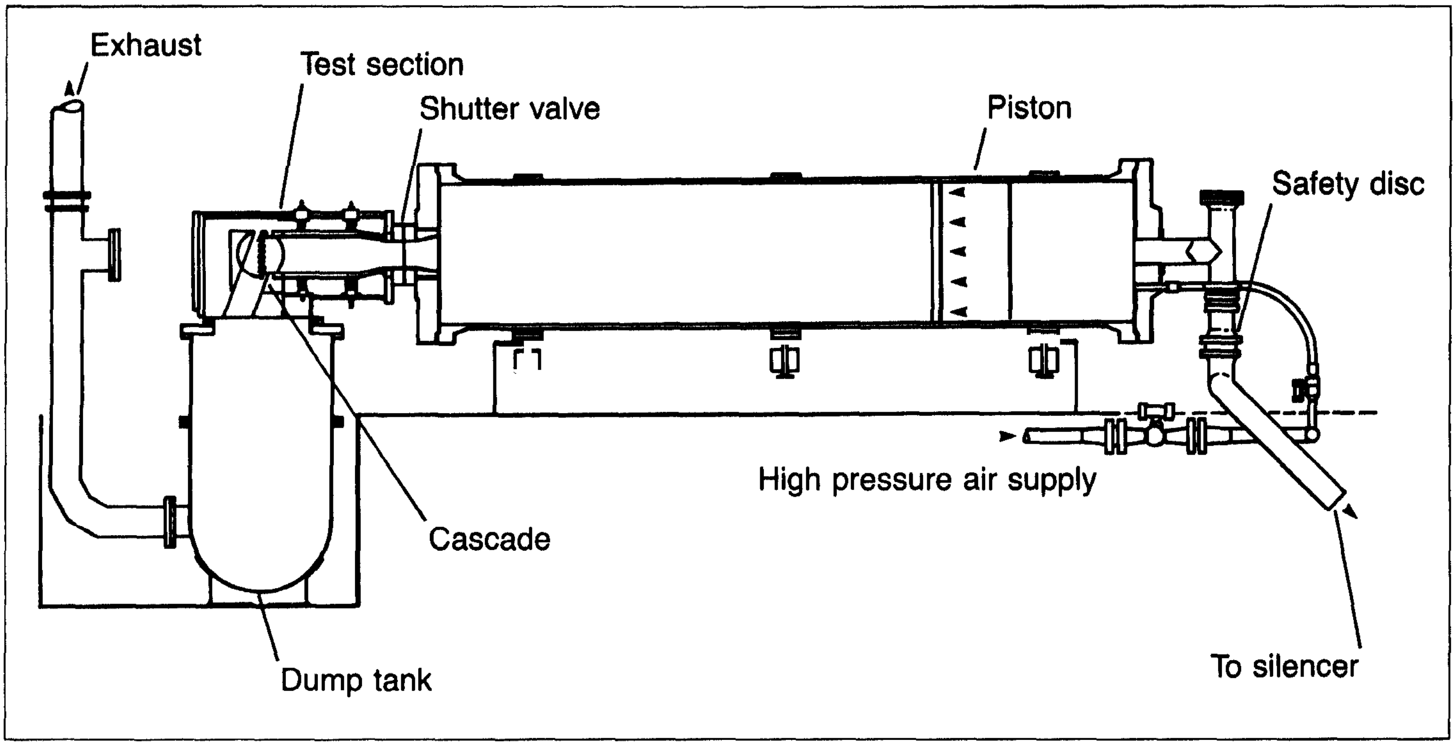
References: von Karman Institute for Fluid Dynamics. Facilities and Instrumentation 1986. Rhode Saint Genese, Belgium: von Karman Institute for Fluid Dynamics, 1986, p. 5.

Date of Information: November 1989

Figure IV.12: von Karman Institute Isentropic Light Piston Compression Tube CT-2

Source: VKI

Figure IV.13: Schematic Diagram of the von Karman Institute Isentropic Light Piston Compression Tube CT-2



Source: VKI

VKI Longshot Free Piston Tunnel ST-1

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: ESA and 16 NATO member countries

Point of Contact: Professor John F. Wendt, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Test Section Size: 16 m^3 (open-jet section)

Operational Status: Active

Utilization Rate: 1 to 2 tests per day

Performance
Mach Number: 15 (contoured) and 20 (conical)
Reynolds Number: 20 x 10^6/m (maximum)
Total Pressure: 4,000 bars (maximum)
Dynamic Pressure: 1 to 2 bars
Total Temperature: 2,400 degrees Kelvin (maximum)
Run Time: 5 to 10 ms
Comments: Gas used is nitrogen. Nozzle exit diameters are 43 cm (Mach 15 contoured nozzle) and 60 cm (Mach 20 conical nozzle).

Cost Information
Date Built: Early 1960s
Date Placed in Operation: 1967
Date(s) Upgraded: 1987 to 1988
Construction Cost: $400,000 (early 1960s)
Replacement Cost: $4 million (1989)
Annual Operating Cost: $400,000 (1989)
Unit Cost to User: $3,000 per test (1989)
Source(s) of Funding: See General Comments

Number and Type of Staff
Engineers: 1 (full-time)
Scientists: 2 (part-time)
Technicians: 4 (2 full-time)
Others: 2 (doctoral degree students)
Administrative/Management: 0
Total: 3 full-time plus 6 part-time

Description: The VKI Longshot Free Piston Tunnel ST-1, also known as the VKI Longshot Hypersonic Wind Tunnel, is a piston-driven intermittent facility. Compressed nitrogen is trapped at peak reservoir conditions by a series of check valves.

Testing Capabilities: Measurements are made of heat transfer, pressures, forces, and moments. Reynolds Numbers (based on a typical model length of 30 cm) range from 2 to 6 x 10^6/m at Mach 15.

Data Acquisition: The tunnel has 64 transient recorders, operating at 50 KHz each, that are controlled by a personal computer. Data reduction is performed on a VAX computer.

Planned Improvements (Modifications/Upgrades): A precision model incidence mechanism will be ready by March 1990.

Unique Characteristics: The VKI Longshot Hypersonic Wind Tunnel has the highest unit Reynolds Number of any facility in the world in the Mach 15 to 20 range.

Applications/Current Programs: The VKI Longshot is being used to test hypersonic heat transfer and aerodynamic characteristics of reentry vehicles. Since 1986 it has been used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation.

General Comments: The VKI Longshot has been operational since 1967 and has had the same team of technical personnel since 1975. It was reactivated in 1982. Sources of funding include ESA, the Belgian Science Policy Office, CNES, and Avions Marcel Dassault-Breguet Aviation.

Photograph/Schematic Available: Yes

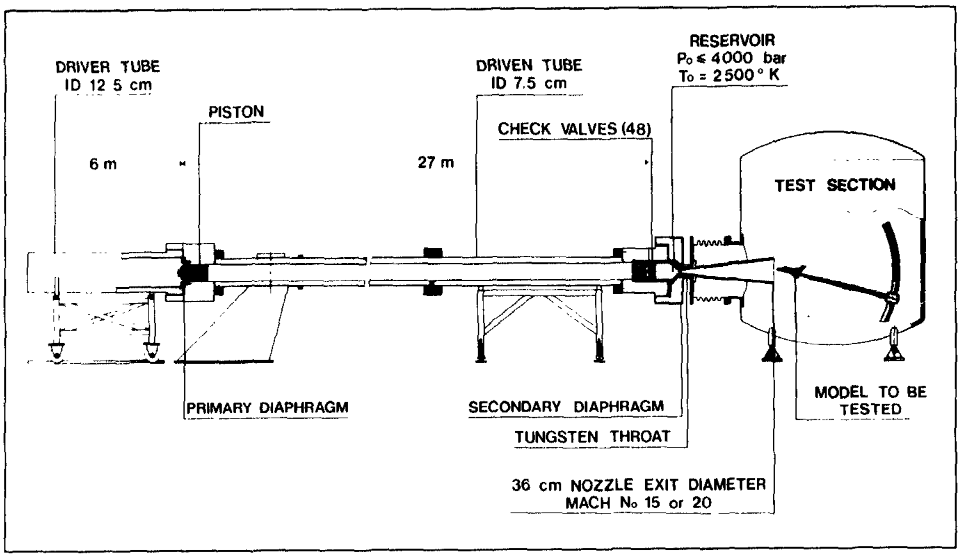
References: Hoyt, Capt. Anthony R. European Hypersonic Technology London: European Office of Aerospace Research and Development, 1986, p. 105 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 26-28 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). Simconides, G., and John F. Wendt. Modernization of the VKI Longshot Hypersonic Tunnel. Rhode Saint Genese, Belgium: von Karman Institute, 1988 (von Karman Institute preprint).

Date of Information: November 1989

Figure IV.14: von Karman Institute Longshot Free Piston Tunnel ST-1

Source: VKI

Figure IV.15: Schematic Diagram of the von Karman Institute Longshot Free Piston Tunnel ST-1



Source: U.S. Air Force EOARD

VKI High-Speed Compressor Facility R-4

Country: Belgium

Location: von Karman Institute for Fluid Dynamics, Rhode Saint Genese, Belgium

Owner(s):
von Karman Institute for Fluid Dynamics
Chaussee de Waterloo, 72
B-1640 Rhode Saint Genese
Belgium

Operator(s): von Karman Institute for Fluid Dynamics

International Cooperation: ESA and 16 NATO member countries

Point of Contact: Professor John F. Wendt, von Karman Institute for Fluid Dynamics, Tel.: [32]-(2)-358-1901

Component Size: Not available

Operational Status: Not available

Utilization Rate: Not available

Performance
Maximum Flow Rate: Not available
Pressure Level: 0.1 to 2.5 atm
Inlet Temperature Range: Ambient
Speed Range: 25,000 rpm
Power Level: Not available
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The VKI High-Speed Compressor Facility R-4 is a compressor component research facility. The R-4 is a closed-loop system, which allows testing of axial or radial compressors using air or other gases. For axial compressors, rotor diameters must not exceed 0.4 m and hub-tip ratio may be as low as 0.35. Freon 12 or air can be used for rotor, single-stage, and multistage testing. The facility is driven with a 500-kW electric motor with continuously variable speed. Maximum shaft speed is either 25,000 or 69,000 rpm.

Testing Capabilities: The facility is instrumented with pressure transducers, scanivalves, a torquemeter, a flow measurement device, and a gas analyzer.

Data Acquisition: Measurements are recorded on a data logger through an eight-channel automatic scanning system that is microprocessor-controlled. A second unit keeps track of three directional probes for the automatic detection and recording of the aerodynamic and thermodynamic quantities at preselected radial stations. The high-frequency signals from velocity and pressure sensors are directly sent to a data acquisition computer for further processing.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

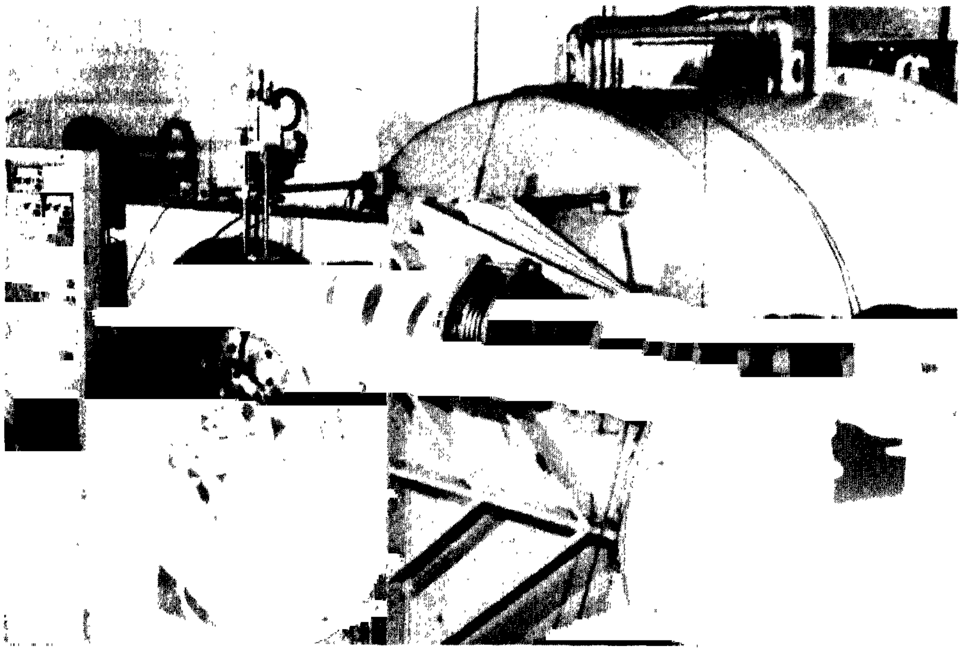
General Comments: None

Photograph/Schematic Available: Yes

References: von Karman Institute for Fluid Dynamics. Facilities and Instrumentation 1986. Rhode Saint Genese, Belgium: von Karman Institute for Fluid Dynamics, 1986, p. 21.

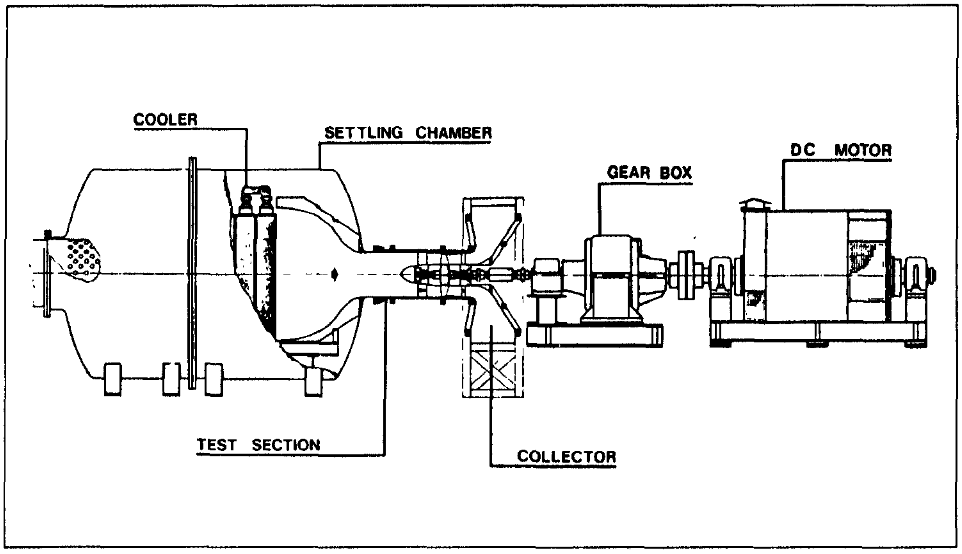
Date of Information: November 1989

Figure IV.16: von Karman Institute High-Speed Compressor Facility R-4



Source: VKI

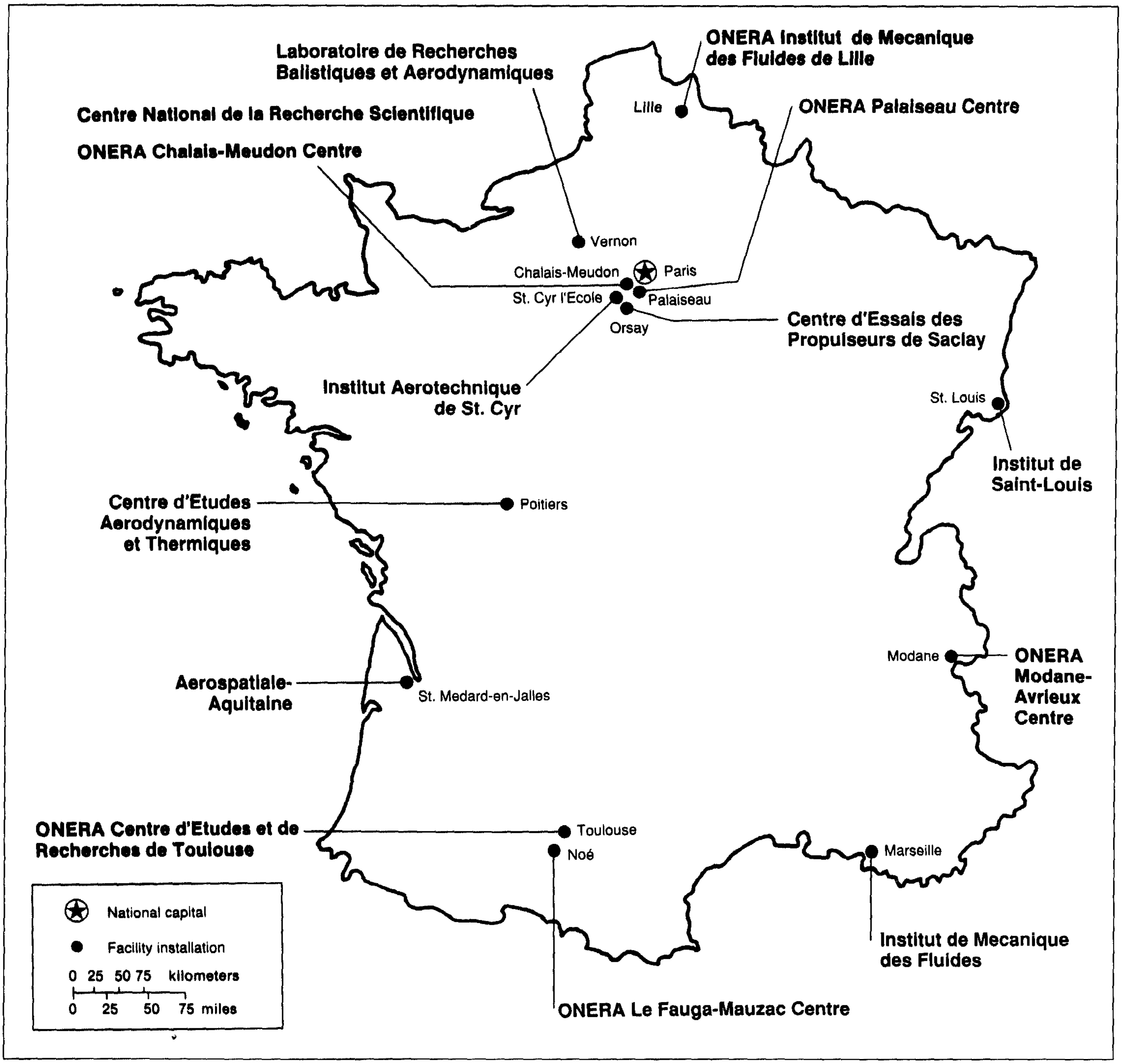
Figure IV.17: Schematic Diagram of the von Karman Institute High-Speed Compressor Facility R-4



Source: VKI

Aerospace Test Facilities in France

Figure V.1: Map of Test Facilities in France



Source: GAO

CEPRA 19 Anechoic Wind Tunnel

Country: France

Location: Centre d'Essais des Propulseurs de Saclay, Orsay, France

Owner(s):
Centre d'Essais des Propulseurs de Saclay and Office National d'Etudes et de Recherches Aerospatiales
F-91406 Orsay Cedex
France

Operator(s): Centre d'Essais des Propulseurs de Saclay and Office National d'Etudes et de Recherches Aerospatiales

International Cooperation: Not available

Point of Contact: M. Fayot, Centre d'Essais des Propulseurs de Saclay, Tel.: [33]-(6)-941-81-50

Test Section Size: 2 or 3 m diameter and 11 m long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: Greater than 0.29 at 2 m diameter and greater than 0.18 at 3 m diameter
Reynolds Number: Up to 66 x 10^6/m at 2 m diameter and up to 2.2 x 10^6/m at 3 m diameter
Total Pressure: Atmospheric
Dynamic Pressure: Not available
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1979
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: CEPr and ONERA

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 5

Description: The CEPRA 19 Anechoic Wind Tunnel is a subsonic wind tunnel with a continuous-flow, open-circuit, and open-jet test circuit inside a large anechoic chamber. The tunnel was built jointly by CEPr and ONERA. The free test section occupies the central part of a vast anechoic chamber where the flow can reach 100 m/s (Mach 0.29).

Testing Capabilities: The CEPRA 19 Anechoic is used to study the acoustic effects of an airflow on various active models (nozzles or rotors) or passive models (airfoils). It is specially dedicated to acoustic testing driven by a centrifugal exhauster on an electric motor.

Data Acquisition: The tunnel has a data acquisition system for noise analysis on and around the models.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The CEPRA 19 Anechoic is being used to conduct tests of noise around submarine models, helicopter rotors, engine exhaust (high bypass ratio and afterburning engines), and full-scale small jet engines.

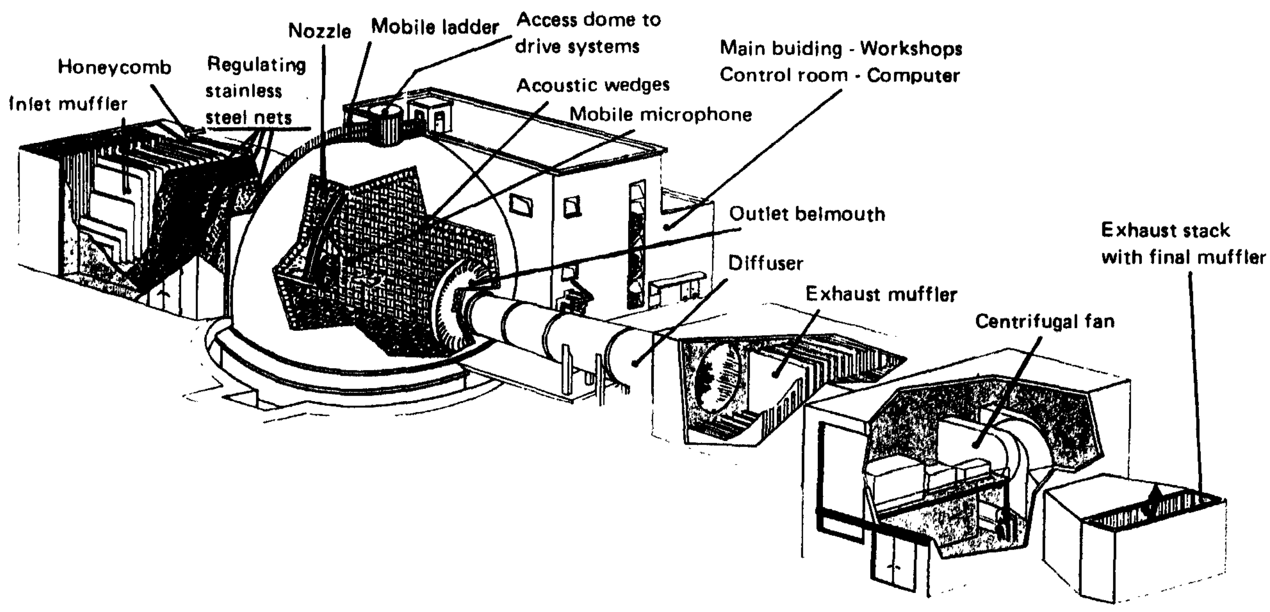
General Comments: Tests are conducted by a joint CEPr/ONERA team.

Photograph/Schematic Available: Yes

References: ONERA. Activities 1986: Physics. Chatillon, France: ONERA, 1987, p. 36. Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 116. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, p. 121.

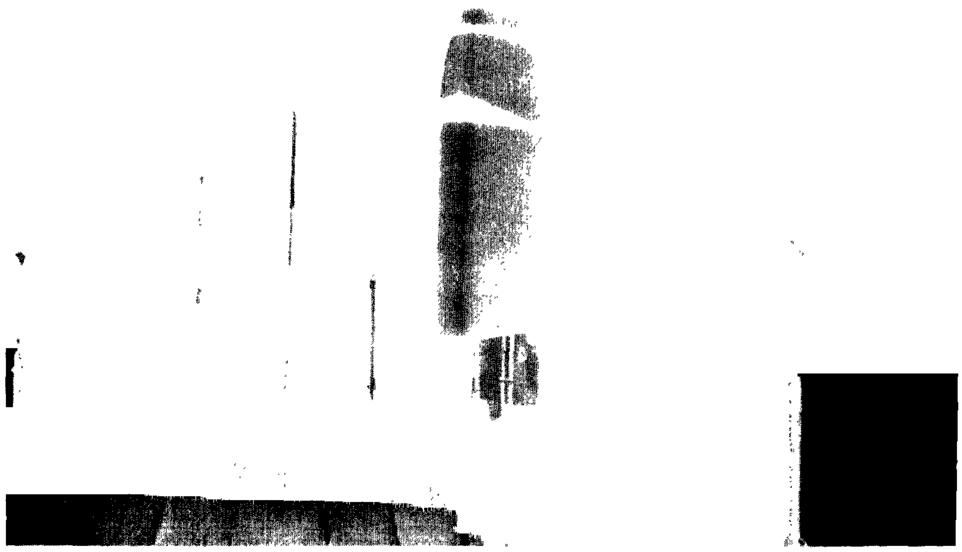
Date of Information: October 1989

Figure V.2: Schematic Drawing of the CEPRA 19 Anechoic Wind Tunnel



Source: ONERA

Figure V.3: Aerospatiale Rotor Test Bench and Microphones Installed Inside Test Chamber of the CEPRA 19 Anechoic Wind Tunnel



Source: ONERA

ONERA F1 Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre, Noe, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator: Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre

International Cooperation: Not available

Point of Contact: Jean-Marie Carrara, Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre, Tel.: [33]-(61)-56-63-01

Test Section Size: 3.5 x 4.5 x 10 m

Operational Status: Active

Utilization Rate: Single shift

Performance
Mach Number: 0.37 or 125 m/s
Reynolds Number: 10 x 10^6/ft
Total Pressure: 4 bars
Dynamic Pressure: 14,000 Pa
Total Temperature: 263 to 313 degrees Kelvin
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1974
Date Placed in Operation: 1977
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $58.7 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ONERA F1 Wind Tunnel is a continuous-operation subsonic wind tunnel. It is driven by a variable-pitch constant-speed fan powered by an electric motor with a maximum output of 9.5 MW. The airflow is water-cooled. The test section is installed inside a cart that moves on rails in front of the cells where the tests are prepared. The side walls and ceiling of the test section remain fixed to the cart. The floor, which supports the test devices, is a removable pallet assembly. After testing, the pallet is rolled out of the cart and placed in one cell to pick up another test pallet. The pallet then returns to its place in the airflow. The tunnel has four fully equipped pallets.

Testing Capabilities: Pallet no. 1 is equipped with a computer-controlled stingholder sector that varies the model's angle of incidence and roll variation. Pallets nos. 2, 3, and 4 are equipped with a (1) turret that can support either a six-component balance for wall half-models, complete models on a three-mast support, or an incidence table for testing complete models mounted on a single mast, (2) "2 k pi" device for testing models at very high angles of attack and slideslip, (3) civilian aircraft intake device, and (4) two-dimensional airfoil test set-up. A computer-controlled probing device explores the wake and flow around the airfoil.

The F1 can be connected to the 11-bar and 120-bar compressed air systems used for engine simulations. Special test devices used in the F1 include a four-degree-of-freedom flow survey device (with or without a vertical translational mast), a six-degree-of-freedom device, and an air-intake survey. Special acquisition techniques commonly used include hot-wire and film transducers and pressure scanners (scanivalve and PSI). Several visualization techniques are also used including acenaphthene and infrared thermography for transition and surface visualizations by oil and colored pigments, and tufts in black light. A laser tomography setup is installed on the fixed section ceiling and is used for incense visualizations.

Data Acquisition: Each pallet has its own 64-channel measurement system connected to the wind tunnel's DEC 6320 computer (through a Hewlett Packard 1000 acquisition computer).

Planned Improvements (Modifications/Upgrades): A two-dimensional laser Doppler anemometer meter will be installed on one of the lateral walls of the F1.

Unique Characteristics: None

Applications/Current Programs: Current programs include Airbus, ATR 42, and Rafale development and performance control on complete or half-scaled models for low-speed configurations. The F1 is also used for research programs, aeroelastic testing, and intake testing.

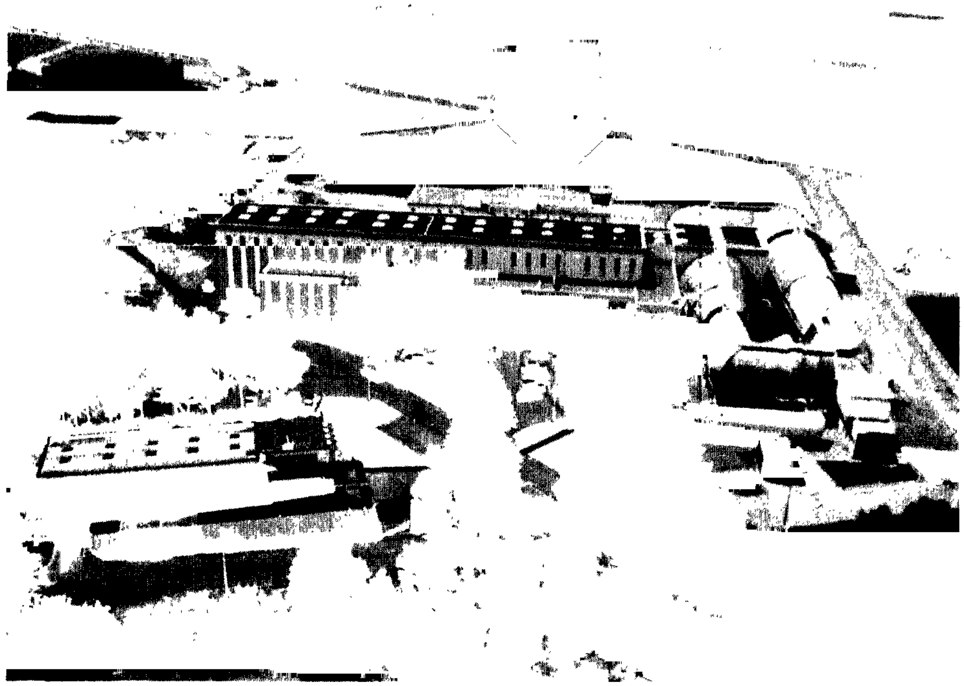
General Comments: None

Photograph/Schematic Available: Yes

References: ONERA. Activities 1986: Large Testing Facilities. Chatillon, France: ONERA, 1987, pp. 28-32. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 78-84. Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 106.

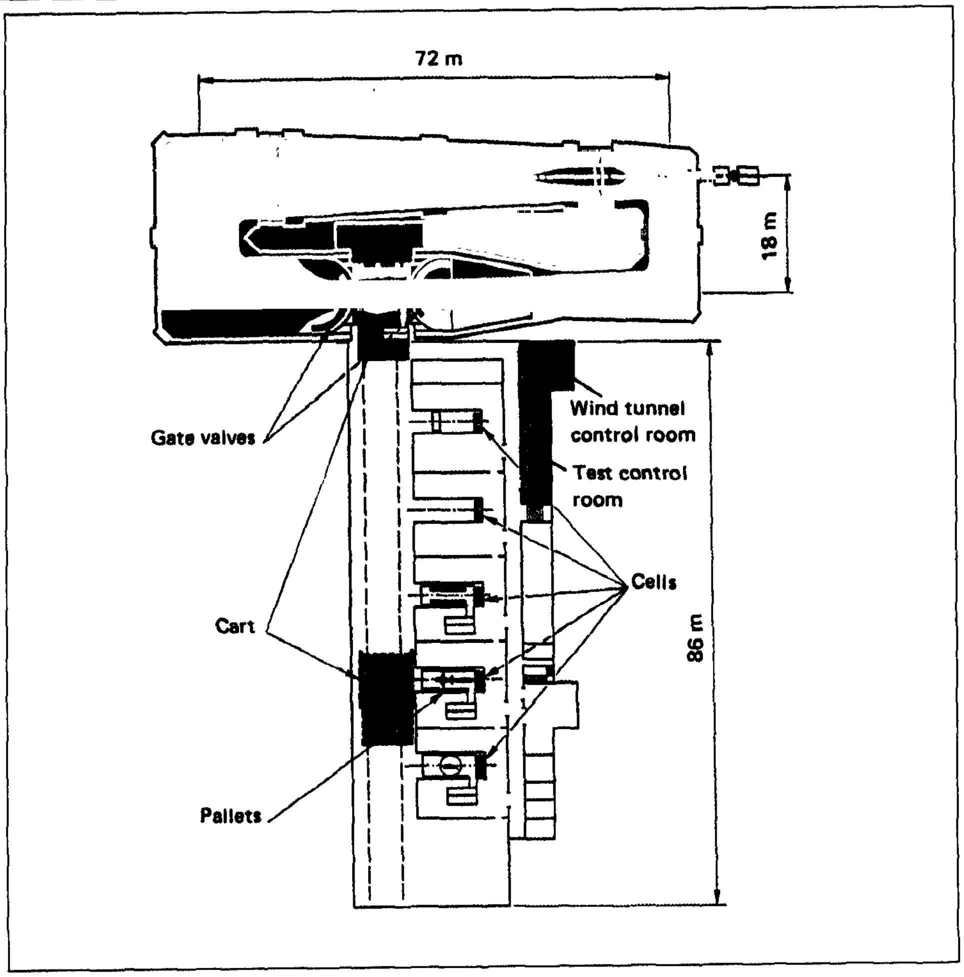
Date of Information: September 1989

Figure V.4: ONERA F1 Wind Tunnel



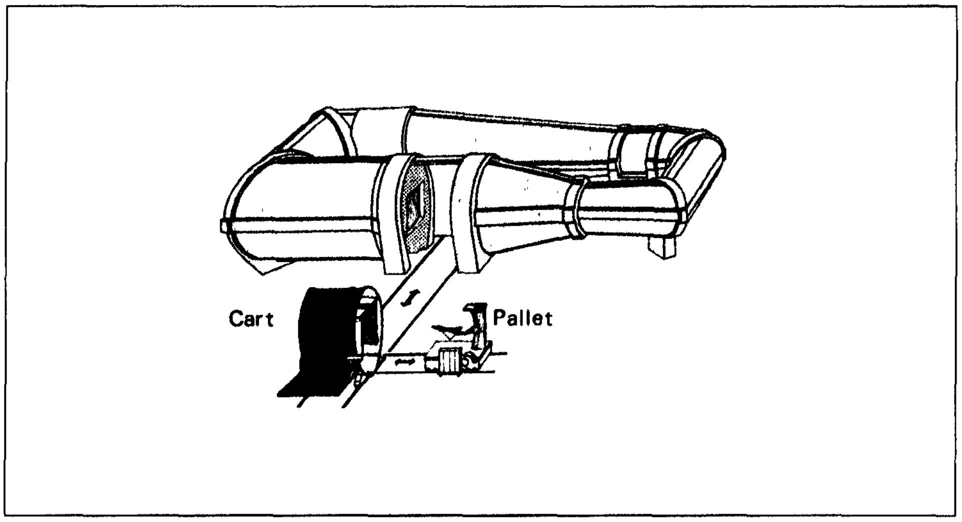
Source: ONERA

Figure V.5: Schematic Diagram of the ONERA F1 Wind Tunnel



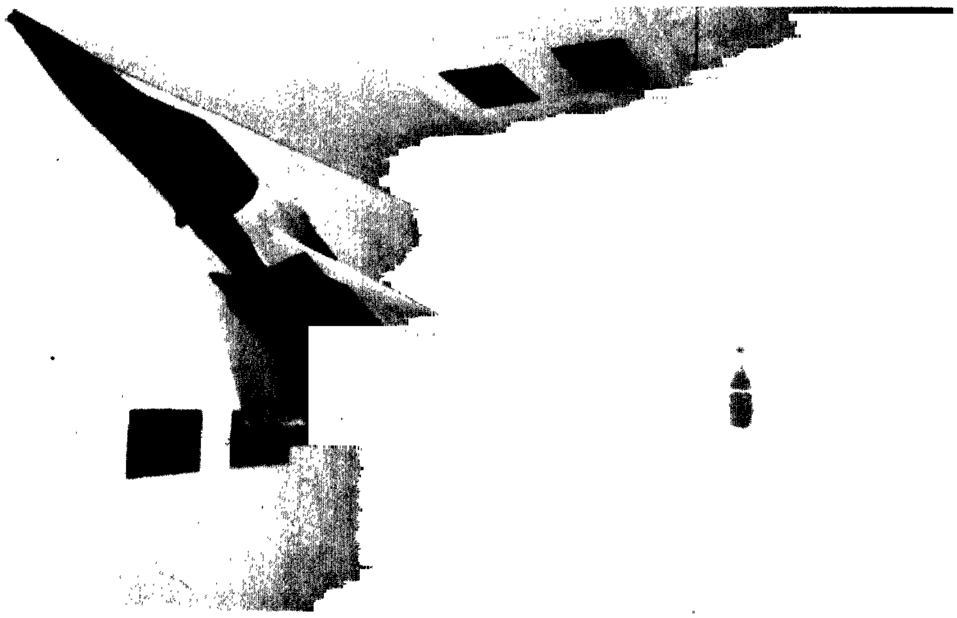
Source: NASA

Figure V.6: Movement of Test Cart and Pallets in the ONERA F1 Wind Tunnel



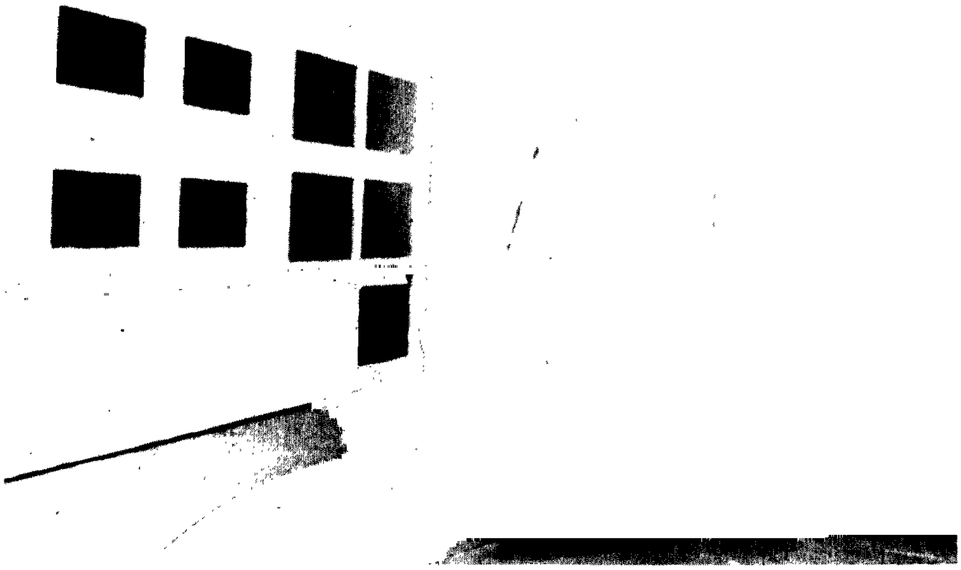
Source: ONERA

Figure V.7: Mirage 2000 on Stingholder in Pallet No. 1 of the ONERA F1 Wind Tunnel



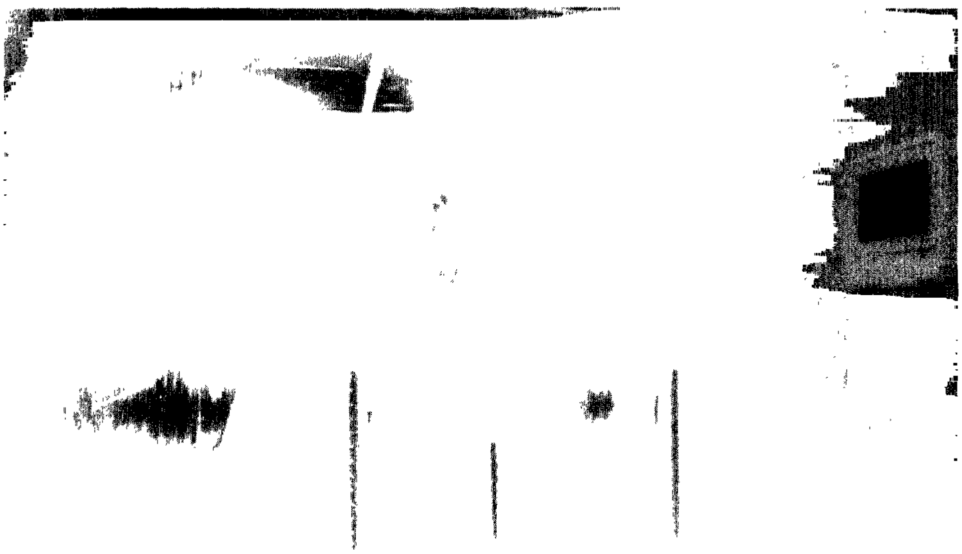
Source: ONERA

Figure V.8: Probing of Wake Behind the Wing of an Airbus A310 Half-Model in Pallet No. 1 of the ONERA F1 Wind Tunnel



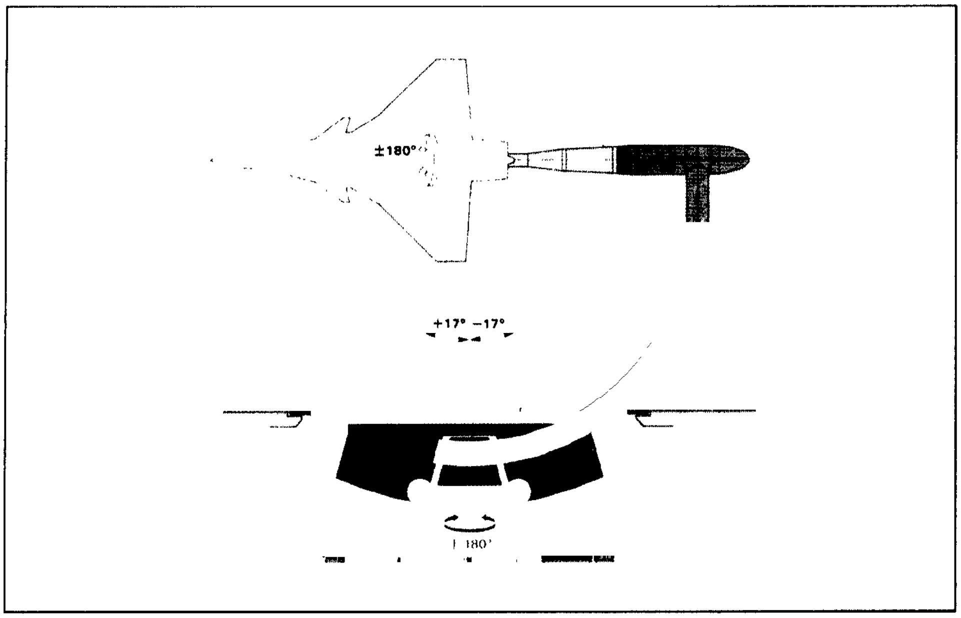
Source: ONERA

Figure V.9: Test on Full Airbus Model on Three-Mast Setup in Pallet No. 1 of the ONERA F1 Wind Tunnel



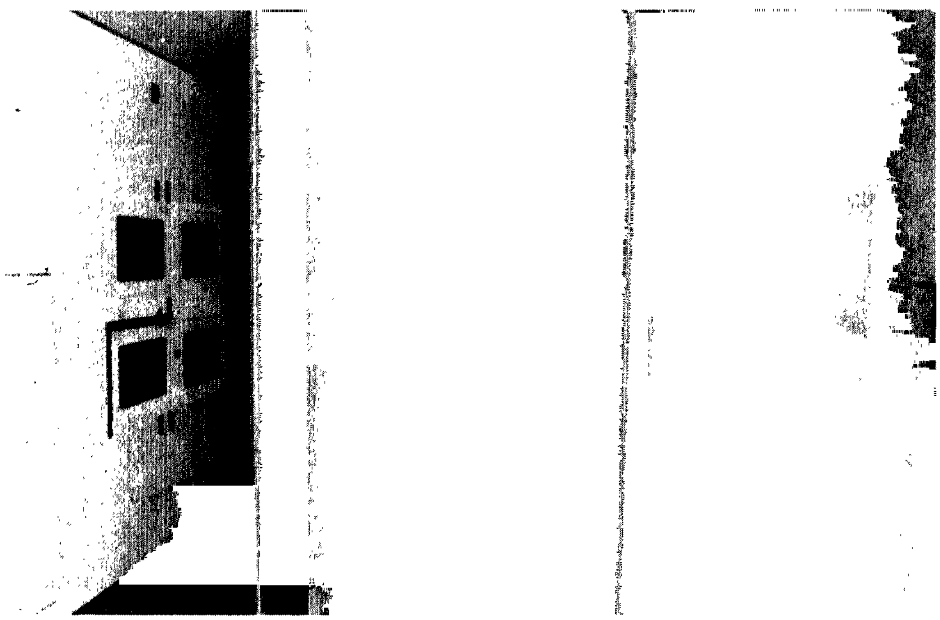
Source: ONERA

Figure V.10: Schematic Diagram of "2 k pi" Test Device in the ONERA F1 Wind Tunnel



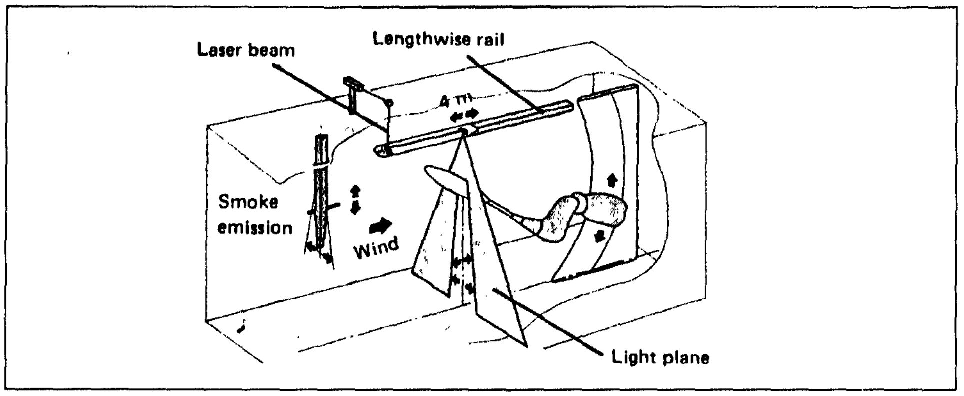
Source: ONERA

Figure V.11: Two-Dimensional Flow Airfoil Test Setup in the ONERA F1 Wind Tunnel



Source: ONERA

Figure V.12: Laser Tomography Device in the ONERA F1 Wind Tunnel



Source: ONERA

ONERA F2 Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre, Noe, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator: Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre

International Cooperation: Not available

Point of Contact: Jean-Marie Carrara, Office National d'Etudes et de Recherches Aerospatiales, Le Fauga-Mauzac Centre, Tel.: [33]-(61)-56-63-01

Test Section Size: 1.8 x 1.4 x 5 m

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.3 or 105 m/s
Reynolds Number: 6 x 10^6/m
Total Pressure: Atmospheric
Dynamic Pressure: 5.8 kN/m^2
Total Temperature: 313 degrees Kelvin
Run Time: Not available
Comments: None

Cost Information
Date Built: 1983
Date Placed in Operation: 1983
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 1
Scientists: 0
Technicians: 3
Others: 0
Administrative/Management: 0
Total: 4

Description: The ONERA F2 Wind Tunnel is a continuous-operation subsonic wind tunnel with a fixed-blade, variable-speed fan driven by a 680-kW DC motor. The airflow is water-cooled. The stagnation pressure is close to atmospheric (the airflow is open to the atmosphere at the end of the test section), and the wind velocity can be varied continuously from 0 to 105 m/s (Mach 0 to 0.3). The lateral walls of the test section are made of a set of removable opaque or transparent panels, which allows easy installations and extensive observation areas.

Testing Capabilities: The F2 is equipped with a permanent laser flow diagnostics system (LDA and tomography) on a moving support. Three velocity components can be measured simultaneously. It also has a sting support and half-model devices.

Data Acquisition: 32 channels are available. Data processing is performed by a Hewlett Packard 1000 computer system.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The F2 is used for research testing by ONERA's Aerodynamics Department and the Centre d'Etudes et de Recherches de Toulouse (CERT).

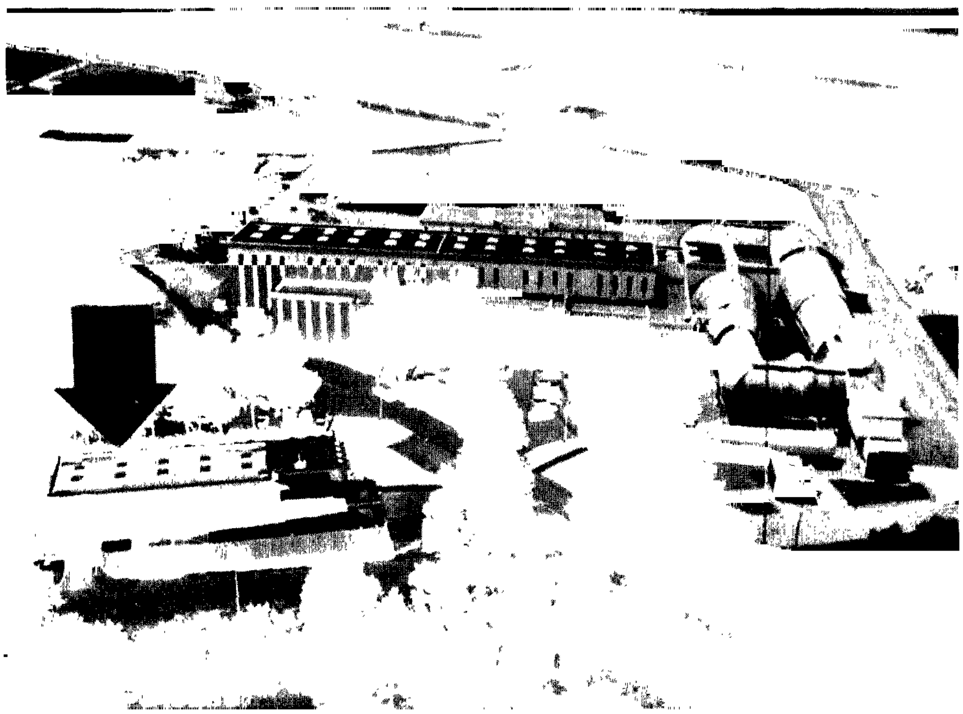
General Comments: None

Photograph/Schematic Available: Yes

References: ONERA. Activities 1986: Large Testing Facilities. Chatillon, France: ONERA, 1987, pp. 32-33. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, p. 84. Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 124.

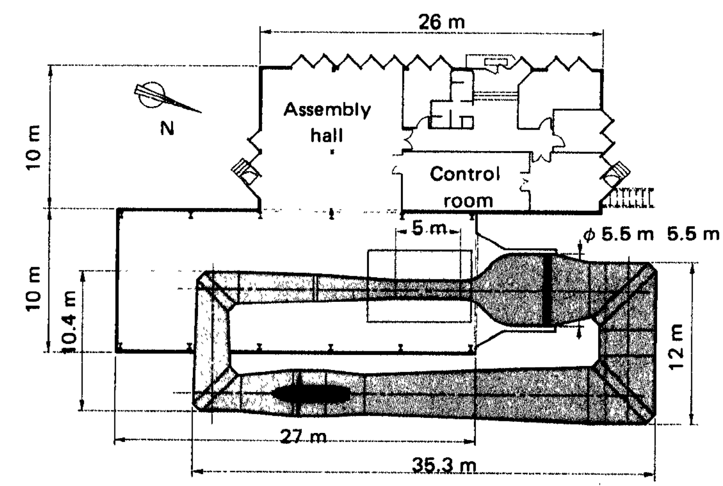
Date of Information: September 1989

Figure V.13: ONERA F2 Wind Tunnel



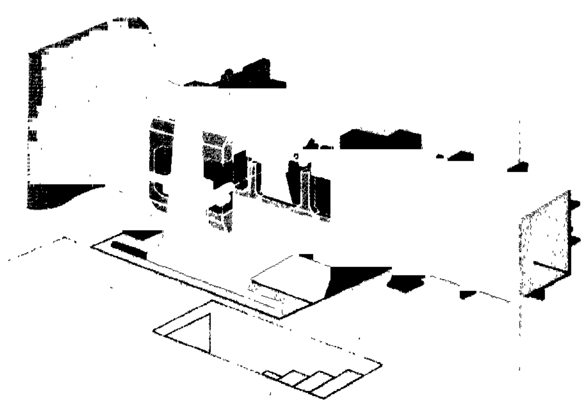
Source: ONERA

Figure V.14: Schematic Diagram of the ONERA F2 Wind Tunnel



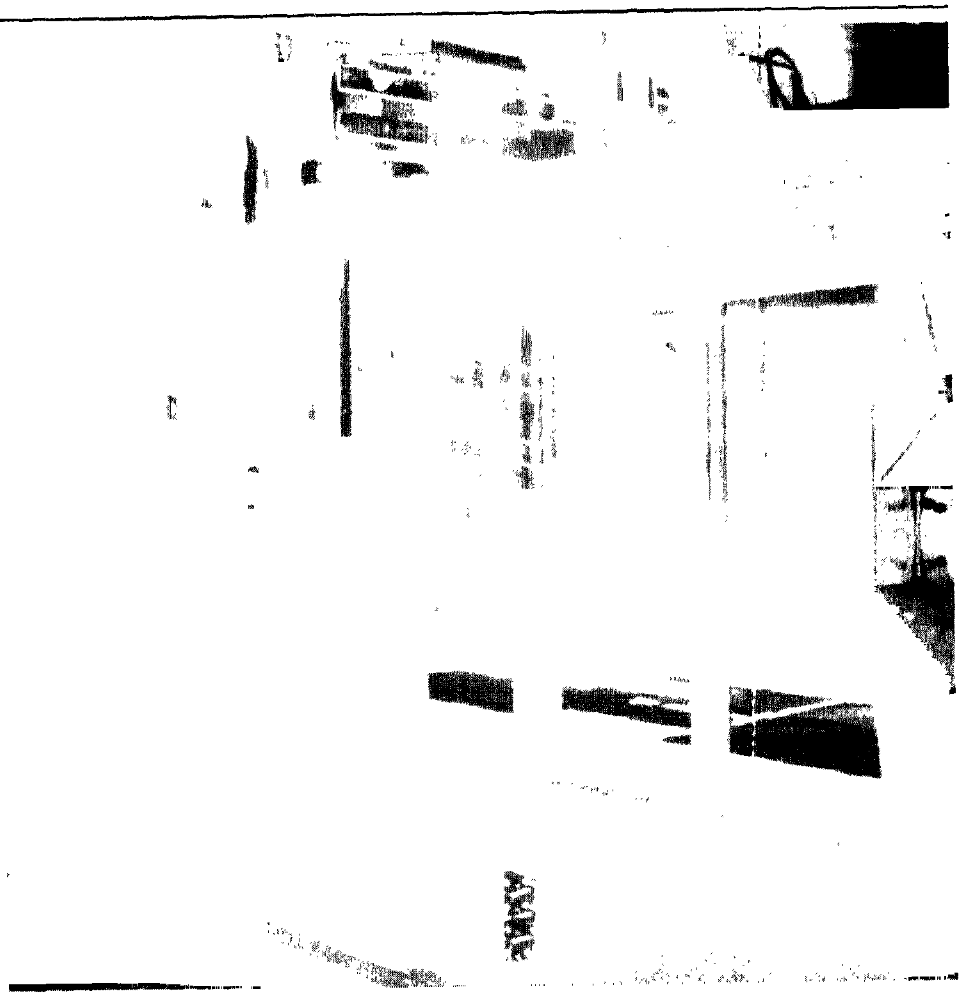
Source: ONERA

Figure V.15: Schematic Drawing of the Laser Velocimetry Setup Around the Test Section of the ONERA F2 Wind Tunnel



Source: ONERA

Figure V.16: Laser Doppler Anemometer Stand Around the Test Section of the ONERA F2 Wind Tunnel



Source: ONERA

ONERA IMFL SV4 Spin Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Institut de Mecanique des Fluides de Lille, Lille, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Institut de Mecanique des Fluides de Lille

International Cooperation: Not Available

Point of Contact: Marc Pianko, Office National d'Etudes et de Recherches Aerospatiales, Institut Mecanique des Fluides de Lille, Tel.: [33]-(20)-53-61-32

Test Section Size: 4 m diameter x 36 m high

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.12 or 40 m/s
Reynolds Number: Up to 2.7×10^6/m
Total Pressure: 1 bar
Dynamic Pressure: Up to 1 kN/m^2
Total Temperature: Atmospheric
Run Time: Not available
Comments: None

Cost Information
Date Built: 1966
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ONERA IMFL SV4 Spin Wind Tunnel is a continuous-flow, annular-return circuit subsonic wind tunnel. It has an open-jet test section. This vertical wind tunnel is primarily used for the investigation of aircraft behavior at high angles of attack. Appropriate models are used for various configurations, including free spin, instrumented spin, and rotary balance. The open-section vertical tunnel is 4 m in diameter and 36 m high. The height of the free section is 3.5 m, and a total height of 6 m may be used for observation. The 13-blade fan is driven by a 460-kW DC motor. The maximum wind velocity is 40 m/s (Mach 0.12) which can be controlled continuously and set to any velocity up to that point within about 4 s. The velocity gradient is slightly negative with the height of the test section, and can be adjusted by special flaps. The section is surrounded with a removable protective net for free spin testing.

Testing Capabilities: The SV4 is used to investigate spin characteristics of airplanes by testing free spinning of dynamically scaled models (Foude criteria). The test section can be equipped with a new rotary balance rig for studying the dynamic derivatives on the same models, including the steady characteristics up to very large angles of attack and sideslip combinations.

Data Acquisition: The tunnel is capable of recording onboard instrumentation (accelerometers) and control surfaces positions.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: SV4 tests are used to define spin and recovery procedures for test pilots and to study possible geometric modifications for series-built aircraft, either to correct for phenomena that are judged critical or to devise emergency systems for full-scale tests. In addition to free-spin tests, the SV4 is used to study the stability of various bodies in an airflow. These bodies include meteorological rockets, parachutes, and the ESA Hermes spaceplane ejection cabin.

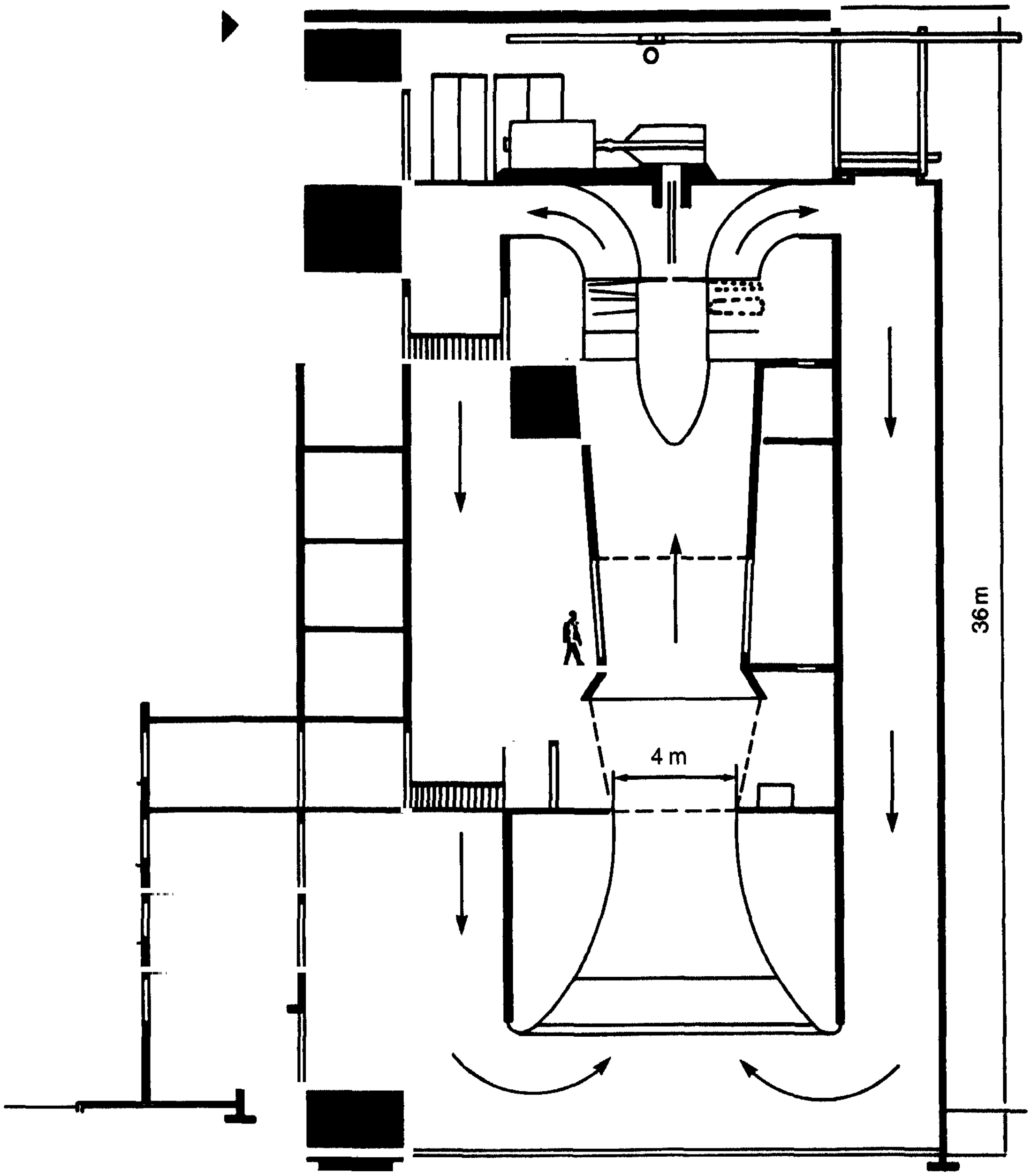
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 113. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 147-148.

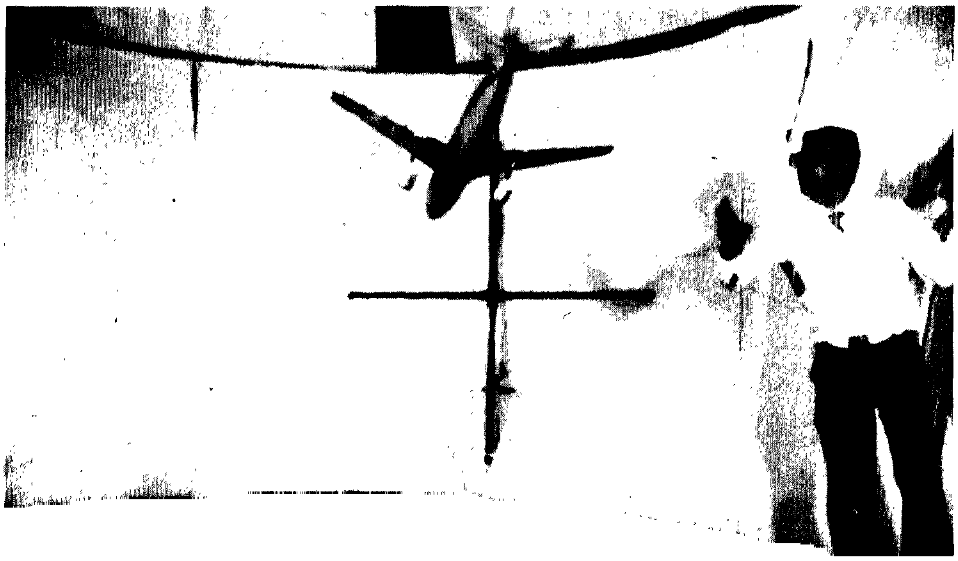
Date of Information: January 1989

Figure V.17: Schematic Diagram of the ONERA IMFL SV4 Spin Wind Tunnel



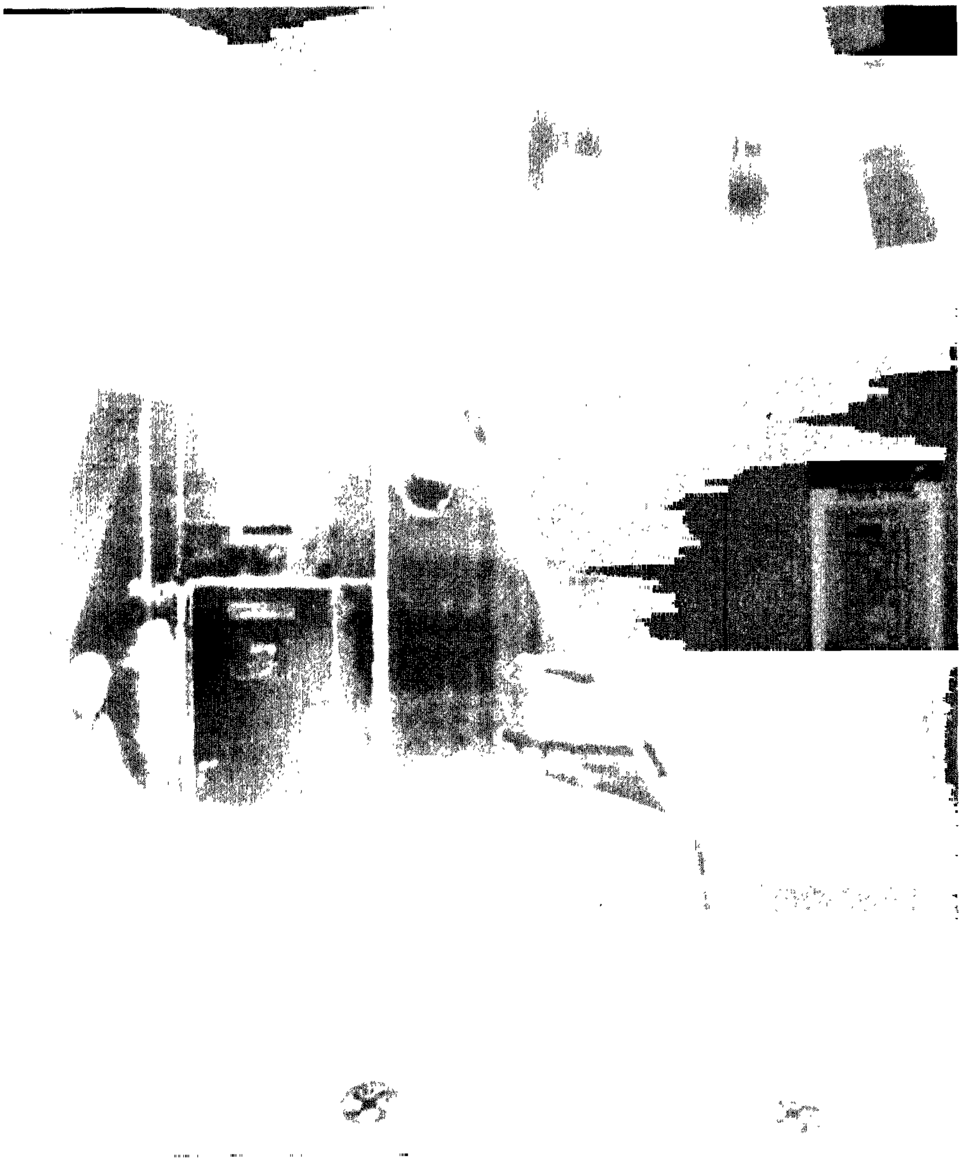
Source: ONERA

Figure V.18: Free Spin Test in the ONERA IMFL SV4 Spin Wind Tunnel



Source: ONERA

Figure V.19: Rotary Balance Test in the ONERA SV4 Spin Wind Tunnel



Source: ONERA

ONERA S2Ch Subsonic Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Chalais-Meudon, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre

International Cooperation: Not available

Point of Contact: M.C. Capelier, Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Tel.: [33]-(1)-46-57-11-60

Test Section Size: 3 m diameter x 5 m long

Operational Status: Not available

Utilization Rate: Not available

Performance
- **Mach Number:** 0.29 or 100 m/s
- **Reynolds Number:** Not available
- **Total Pressure:** Not available
- **Dynamic Pressure:** Not available
- **Total Temperature:** Not available
- **Run Time:** Not available
- **Comments:** None

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** 1964
- **Date(s) Upgraded:** 1978, 1985, and 1987
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The ONERA S2Ch Subsonic Wind Tunnel from the "Service Technique Aeronautique" of Issy-les-Mouineaux was put into operation in Chalais-Meudon in 1964. The S2Ch is a continuous-flow, Eiffel-type subsonic wind tunnel. The guided test section is 3 m in diameter and 5 m long. The maximum speed is normally 100 m/s (Mach 0.29).

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: Initially, the tunnel was used by divisions of Sud-Aviation company involved in designing the Concorde for testing the static and dynamic stability of the model, studying air intakes at low speed, and simulating takeoff conditions. Beginning in 1968, tests were conducted mainly on an Airbus A300 model. The S2Ch is used regularly by Avions Marcel Dassault-Breguet Aviation in its aerodynamic studies of the trajectories of stores released from a fuselage or wing. In addition, the S2Ch is increasingly being used for fundamental research, since its dimensions are well suited for research needs. Its dimensions are intermediate in size and fall between those of the ONERA F2 and ONERA F1 tunnels. In 1978, a bench was installed for studying helicopter rotors and analyzing the aerodynamic behavior of the blade tips in unsteady flow, particularly in a critical regime. Tests are carried out either on models provided by Aerospatiale or on a specific rotor model designed for general research. Since 1985, the test section walls can be soundproofed to study the acoustical signatures of various blade tips. A cyclic pitch system was installed in 1987 to simulate better actual operating conditions of a rotor. Also, the inclination of the rotor head can now be adjusted during the test to study rotor characteristics in forward flight.

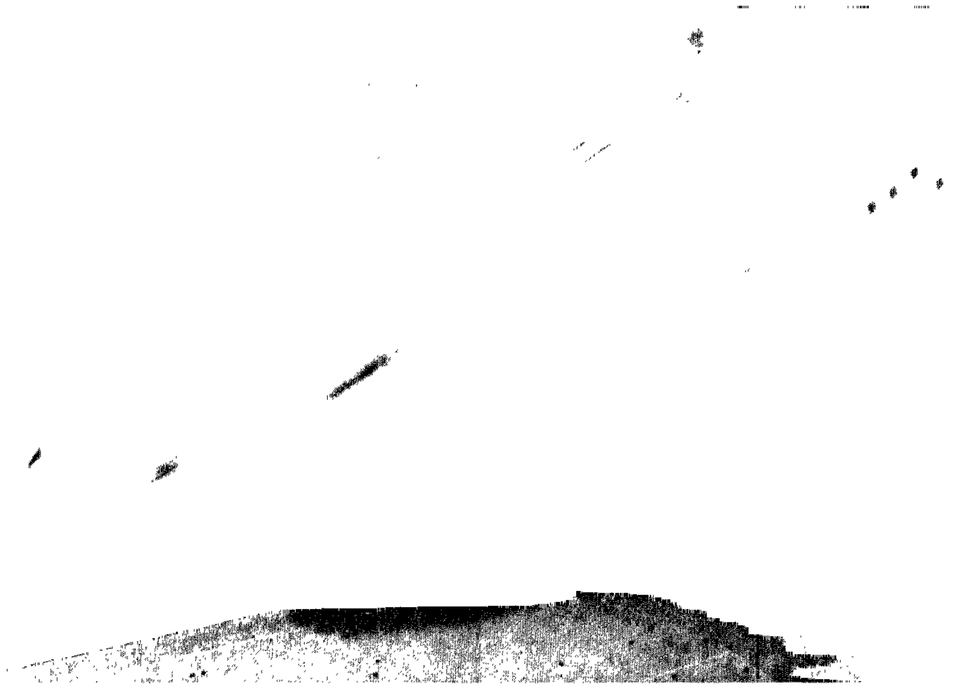
General Comments: None

Photograph/Schematic Available: Yes

References: ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 8-9.

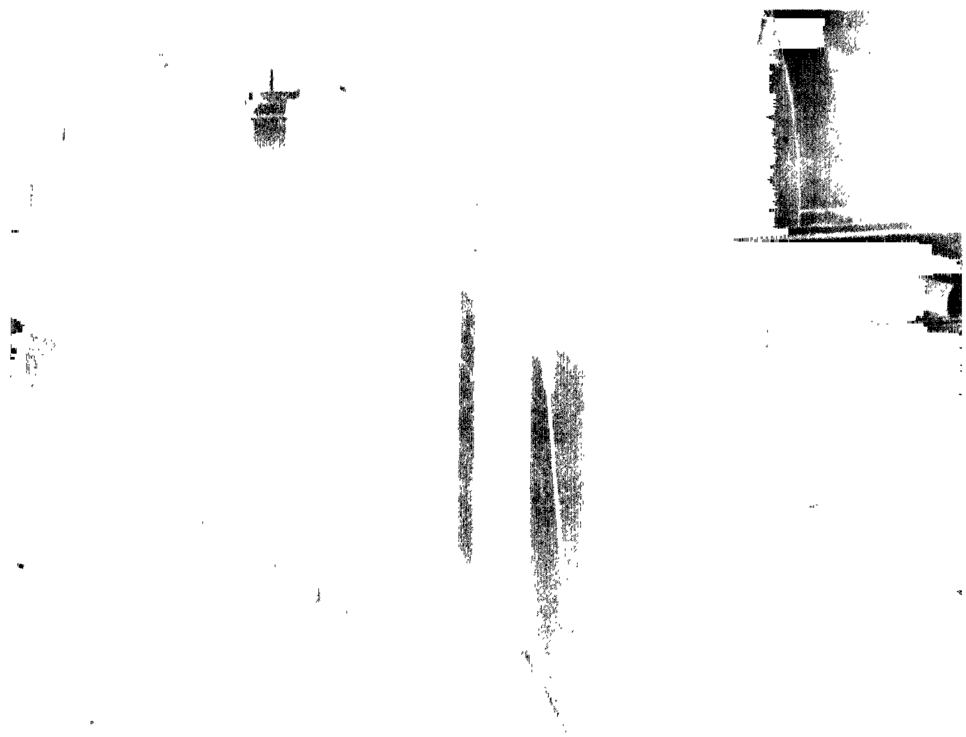
Date of Information: January 1989

Figure V.20: Oblate Ellipsoid With Laser Doppler Anemometer in Test Section of the ONERA S2Ch Subsonic Wind Tunnel



Source: ONERA

Figure V.21: Three-Dimensional Laser Doppler Anemometry Setup in the ONERA S2Ch Subsonic Wind Tunnel



Source: ONERA

ONERA IMFL Transonic Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Institut de Mecanique des Fluides de Lille, Lille, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Institut de Mecanique des Fluides de Lille

International Cooperation: Not available

Point of Contact: Office National d'Etudes et de Recherches Aerospatiales, Institut de Mecanique des Fluides de Lille, Tel.: [33]-(20)-53-61-32

Test Section Size: No. 1: 200 x 42 x 350 mm; and No. 2: 42 x 240 mm

Operational Status: Not available

Utilization Rate: Not available

Performance
- **Mach Number:** 0.3 to 1.1
- **Reynolds Number:** 140,000 per cm (14 x 10^2/m) at Mach 0.8
- **Total Pressure:** Atmospheric
- **Dynamic Pressure:** Not available
- **Total Temperature:** 30 to 50 degrees Celsius
- **Run Time:** Not available
- **Comments:** None

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** 1948
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The ONERA IMFL Transonic Wind Tunnel is a two-dimensional wind tunnel used essentially for research testing of a fundamental or applied character. The tunnel has a return circuit and operates in a continuous mode. The guided test section has longitudinal slots in the upper and lower walls providing a permeability of seven percent. The divergence of these walls can be varied. The guided test section can be replaced with a 42 × 240 mm test section. The aspiration device has two electric blowers (50 and 75 kW). The tunnel is also equipped with a 55-kW regeneration system.

Testing Capabilities: The aerodynamic fields around the airfoils are studied, including explorations of boundary layers and wakes. Surface flow patterns can also be visualized, and high-speed schlieren or shadow visualizations of the flow can be made. The models are also equipped with unsteady pressure transducers.

Data Acquisition: Most of the calculations involved in analyzing the test data are done on the IMFL computation systems, in particular on the Perkin Elmer 8/32 and 3230 computers.

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: These include fundamental and applied research.

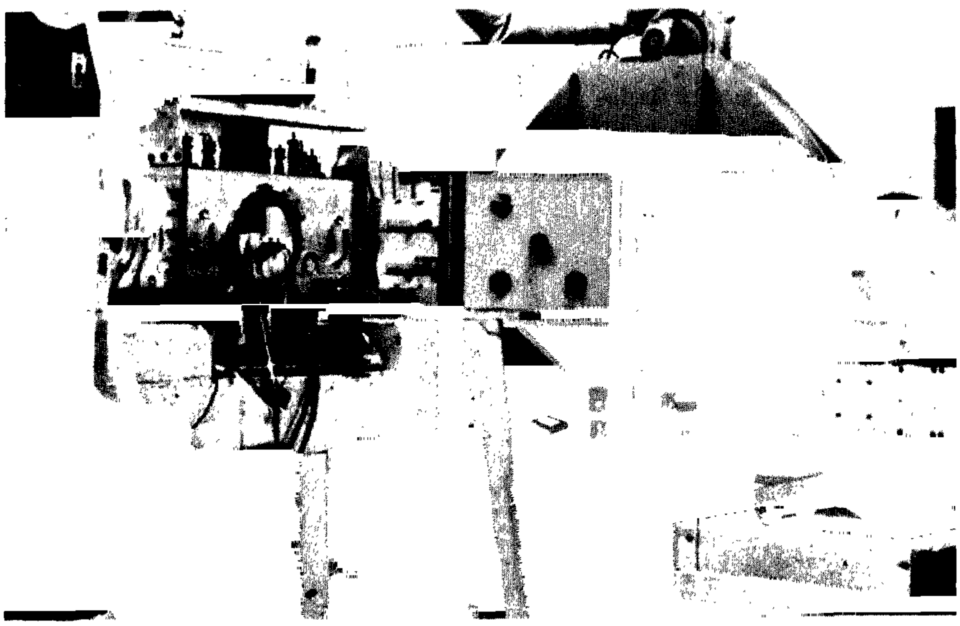
General Comments: Not available

Photograph/Schematic Available: Yes

References: ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 155-156.

Date of Information: January 1989

Figure V.22: ONERA IMFL Transonic Wind Tunnel



Source: ONERA

ONERA S1MA Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Modane, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre

International Cooperation: Not available

Point of Contact: Jean Laverre, Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Tel.: [33]-(79)-20-20-00

Test Section Size: 8 m diameter x 14 m long

Operational Status: Active

Utilization Rate: 1,800 hours per year (of which about 500 hours are actual test run time)

Performance
Mach Number: 0.023 to approximately 1
Reynolds Number: 13.5 x 10^6/m
Total Pressure: 0.91 bars
Dynamic Pressure: 0 to 33 kN/m^2
Total Temperature: 263 to 333 degrees Kelvin
Run Time: Not available
Comments: The lowest speed possible is 2.5 m/s.

Cost Information
Date Built: 1948
Date Placed in Operation: 1952
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $150.9 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 15 to 16

Description: The ONERA S1MA Wind Tunnel is a continuous flow transonic wind tunnel and is equipped with three interchangeable test carts. The maximum power is 88 MW. It is driven by two counter-rotating fans 15 m in diameter, powered by water turbines, and cooled by air exchange with the atmosphere. The velocity can be varied from 2.5 m/s to approximately Mach 1. The stagnation pressure is atmospheric pressure, or 0.91 bars (the tunnel is at an altitude of 1,100 m). The stagnation temperature can be controlled by exchanging air with the atmosphere, and can be raised up to 50 degrees Celsius. This avoids problems of water condensation from the atmospheric air.

Testing Capabilities: Test section no. 1 is used for sting setups (aircraft and missile angles of incidence) and wall testing. Test section no. 2 is used for low-velocity tests. A special device is used for tests with ground effect with the boundary layer blowing. Test section no. 3 is used for engine tests, helicopter or tilt rotor tests, propeller tests, and store separation tests from airplanes filmed by high-speed cameras.

Data Acquisition: The measurement system with its basic 80 channels can be expanded if necessary. The data are processed in real time on a DEC 6320 computer, which is reserved for wind tunnel-related uses.

Planned Improvements (Modifications/Upgrades): A new helicopter rotor is in operation with an electric motor drive offering up to 500 kW of power. Also, a more powerful test stand of more than 2,000 kW is being designed for propellers—single or counter-rotating, isolated or ducted—and for jet engines with a very high bypass ratio. Acoustic wall treatment for tests up to speeds of Mach 0.85 is currently being studied.

Unique Characteristics: Special devices are provided for various tests such as air intake tests; canopy releases; parachute openings; and bad weather, rain, and icing tests.

Applications/Current Programs: Current programs include the Mirage 2000; Alphajet; Rafale; Airbus A320, A330, and A340; J-15 turbo engine; and HT3 propeller; store separation tests; icing tests on helicopter rotors; air intake tests; and missile tests.

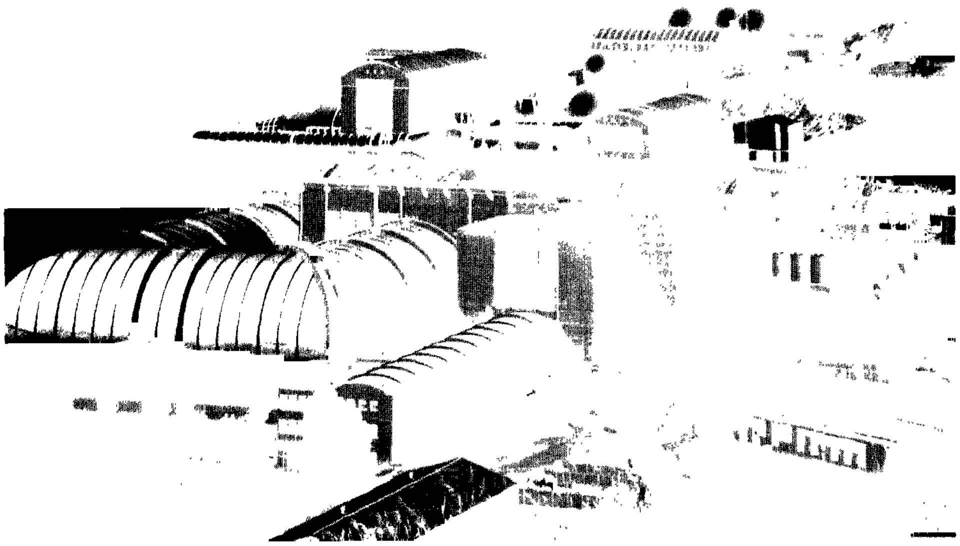
General Comments: The S1MA has one of the largest sonic test sections in the world (8 m diameter).

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 146. ONERA. Activities 1986: Large Testing Facilities. Chatillon, France: ONERA, 1987, pp. 19-21. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 58-64.

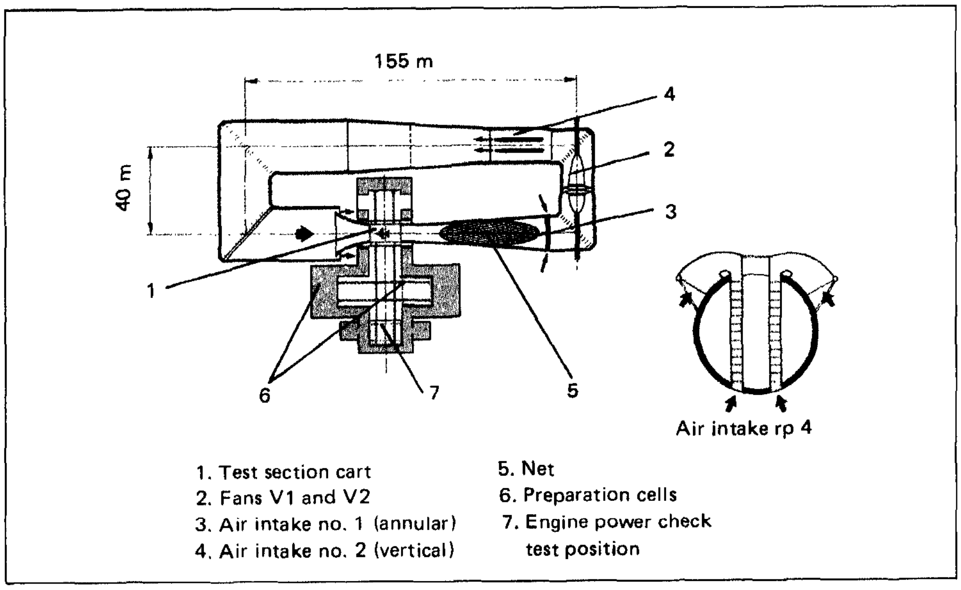
Date of Information: September 1989

Figure V.23: ONERA S1MA Wind Tunnel



Source: ONERA

Figure V.24: Schematic Diagram of the ONERA S1MA Wind Tunnel



Source: ONERA

Figure V.25: Mirage 2000 Model on Tripod Support in Test Section of the ONERA S1MA Wind Tunnel

Source: ONERA

ONERA S3Ch Transonic Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Chalais-Meudon, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre

International Cooperation: Not available

Point of Contact: M.C. Capelier, Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Tel.: [33]-(1)-46-57-11-60

Test Section Size: 0.8 x 0.8 m

Operational Status: Not available

Utilization Rate: Not available

Performance
- **Mach Number:** 0.3 to 1.2
- **Reynolds Number:** Not available
- **Total Pressure:** Not available
- **Dynamic Pressure:** Not available
- **Total Temperature:** Not available
- **Run Time:** Not available
- **Comments:** None

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** 1949
- **Date(s) Upgraded:** 1983 and 1986 to 1987
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The ONERA S3Ch Transonic Wind Tunnel is an unpressurized closed-circuit transonic wind tunnel. It was originally constructed to serve as a 1 to 8 scale model of the ONERA S1MA Transonic Wind Tunnel at ONERA's Modane-Avrieux Centre. The tunnel operates continuously with partial renewal of the air.

Testing Capabilities: The transonic test section has permeable walls. The tunnel has a gust generator with oscillating blown flaps for unsteady flow measurements. The performance of the S3Ch is such that it is used periodically in perfecting specific test systems for later use in the industrial-size wind tunnels of the ONERA's Large Testing Facilities Department.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): A renovation was undertaken in 1983 with the installation of a cooler. The tunnel was shut down from mid-1986 to mid-1987 for additional improvements involving the collector, test section, diffuser, and fan drive to upgrade its performance to a maximum Mach number of 1.2 and to make the test section readily accessible. This modernization is to be continued with the

Figure V.27: ONERA S3Ch Transonic Wind Tunnel

Source: ONERA

Figure V.28: Setup on Balance-Sting in Test Section of the ONERA S3Ch Transonic Wind Tunnel

Source: ONERA

Unique Characteristics: None

Applications/Current Programs: The T2 is being used to conduct basic two-dimensional tests on calibration models (CAST 7 and 10) including Reynolds Number effects through stagnation pressure and temperature variations.

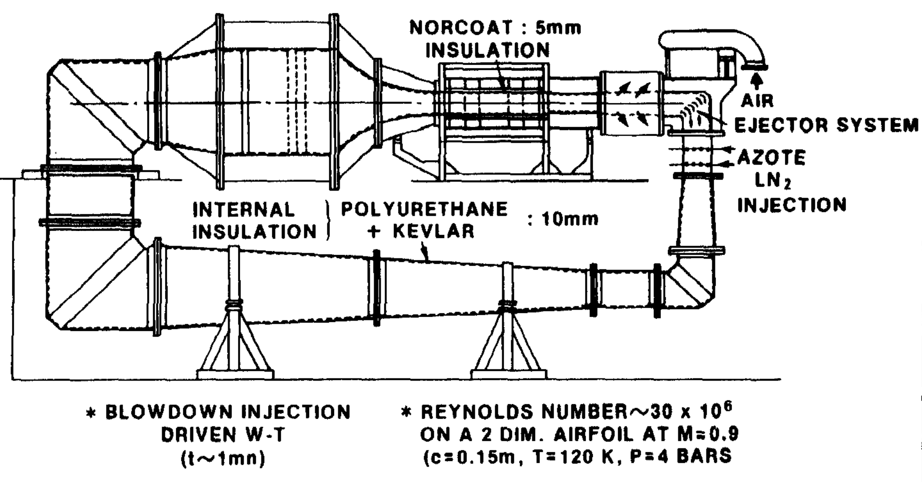
General Comments: Initially designed as a pilot facility for studying new test techniques, the T2 has become a full-blown measuring instrument and is now a valuable facility for detailed analysis of transonic flows.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 142. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 174-175.

Date of Information: September 1989

Figure V.29: Schematic Diagram of the ONERA T2 Wind Tunnel



Source: NASA

LRBA C4 Trisonic Wind Tunnel

Country: France

Location: Laboratoire de Recherches Balistiques et Aerodynamiques, Vernon, France

Owner(s):
Laboratoire de Recherches Balistiques et Aerodynamiques
Boite Postale 914
F-27207 Vernon Cedex
France

Operator(s): Laboratoire de Recherches Balistiques et Aerodynamiques

International Cooperation: None

Point of Contact: M. Desgardin, Laboratoire de Recherches Balistiques et Aerodynamiques, Tel.: [33]-(32)-21-43-24

Test Section Size: 0.4 x 0.4 m

Operational Status: Active

Utilization Rate: 10 tests per day

Performance
Mach Number: 0.15 to 4.29 in 15 steps (contoured)
Reynolds Number: 12 x 10^6/m at Mach 4.29
Total Pressure: 1.1 to 8 bars
Dynamic Pressure: Not available
Total Temperature: 300 degrees Kelvin
Run Time: Continuous
Comments: Nozzle exit diameter is 0.4 x 0.4 m.

Cost Information
Date Built: 1948
Date Placed in Operation: 1951
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $4,000 per hour (1989)
Source(s) of Funding: French Ministry of Defense

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 5 plus 2 engineers for results analysis

Description: The LRBA C4 Supersonic Wind Tunnel is a trisonic wind tunnel with a closed, continuous-flow, and pressurized circuit. The C4 is driven by two compressors powered by 13.5-MW electric motors. The tunnel is capable of conducting subsonic, transonic, and supersonic tests.

Testing Capabilities: The C4 is capable of conducting force balance, schlieren visualization, and pressure scanning tests. The tunnel is equipped with one subsonic nozzle (Mach 0.15 to 0.7), three subsonic-transonic nozzles (Mach 0.4 to 0.975, 1.2, and 1.29), 11 dedicated subsonic nozzles, and two adjustable nozzles (Mach 1.85 to 2.2 and 2.86 to 3.22) for force and pressure measurements.

Data Acquisition: The C4 has 18 analog channels of data and two scannings of 48 channels each.

Planned Improvements (Modifications/Upgrades): These include four pneumatic scanners (2 × 15 psi, 1 × 30 psi, and 1 × 45 psi) of 32 channels each, laser velocimetry, and hot gas continuous injection (3 kg/s at 900 degrees Kelvin). Each of these improvements are planned for 1990.

ONERA R4.3 Cascade Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Modane, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre

International Cooperation: Not available

Point of Contact: Jean Laverre, Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Tel.: [33]-(79)-20-20-00

Test Section Size: 210 to 370 x 120 mm (transonic) and 600 x 120 mm (supersonic)

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.3 to 1.0 and 1.45
Reynolds Number: Not available
Total Pressure: Not available
Dynamic Pressure: 2.5 bars (maximum)
Total Temperature: Not available
Run Time: More than 10 min
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: 1977
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ONERA R4.3 Cascade Wind Tunnel is a long blowdown (more than 10 min) trisonic wind tunnel. It has two test sections, each 120 mm wide. The R4.3 has one transonic test section, the height of which can be varied from 210 to 370 mm, depending on the inclination of the cascade, and one supersonic test section (600 mm high) with a Mach 1.45 nozzle.

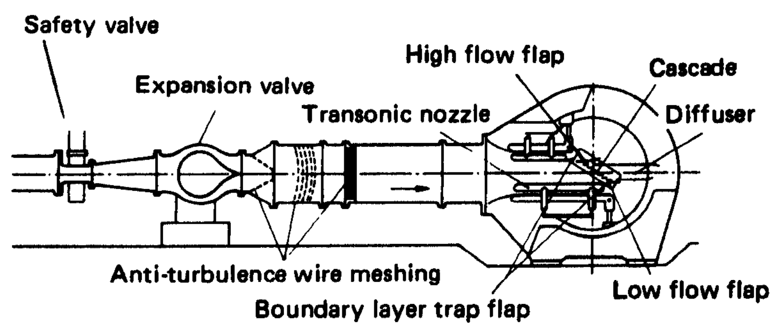
Testing Capabilities: The R4.3 is equipped with a device for placing the cascade at a given angle, a device for applying a controllable suction to the boundary layers, an automatic wake measurement rake, many motorized flow-control elements (such as a diffuser and flap), and a shadowgraph.

Data Acquisition: The tunnel has 32 basic channels of data that can be expanded, if needed. Measurement data are processed by a VAX 750 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Figure V.32: Schematic Diagram of the ONERA R4.3 Cascade Wind Tunnel



Source: ONERA

degrees-of-freedom for studying the trajectories of stores released from aircraft and external flow survey, and an instrument for measuring the coefficients of dynamic stability by forced oscillations. The test devices, stingholder sector, and wall mount are all connectable to the 9-bar and 64-bar compressed air systems to simulate jets or to drive the turbine power simulators as well as to the 150-bar system (15 kg/s maximum). The S2MA is equipped with a shadowgraph device. Many visualization techniques are used, such as acenaphthene or infrared thermography for transition, and surface visualizations by oil or colored fluids.

Data Acquisition: The measurement system includes 80 basic channels that can be expanded if needed. Measurement data are processed in real time by a DEC 6320 computer reserved for the wind tunnel. Pressure scanner systems (scanivalves and PSI) are commonly used.

Planned Improvements (Modifications/Upgrades): Improvements in automatization were planned for 1989.

Unique Characteristics: None

Applications/Current Programs: Current programs include the Mirage 2000, Mirage IV, Mirage F-1, Airbus, Rafale, Jaguar, Ariane 5, and the air intakes of missiles (such as the Armat, AQM37, AS30L, AM39, and ASMP Super Etendard).

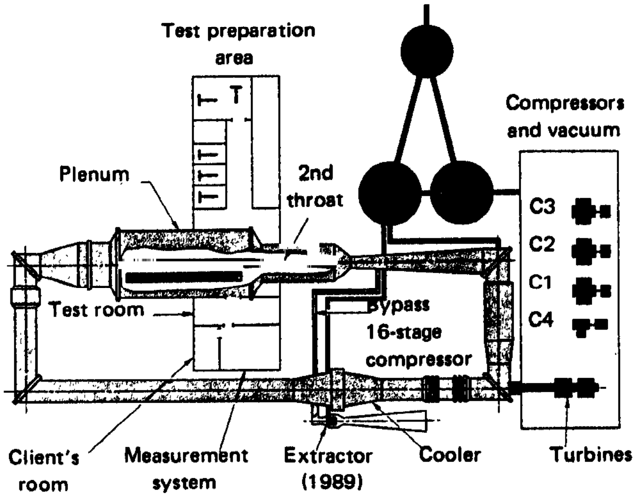
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 166. ONERA. Activities 1986: Large Testing Facilities. Chatillon, France: ONERA, 1987, pp. 21-23. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 58-59 and 65-67.

Date of Information: September 1989

Figure V.34: Schematic Diagram of the ONERA S2MA Wind Tunnel

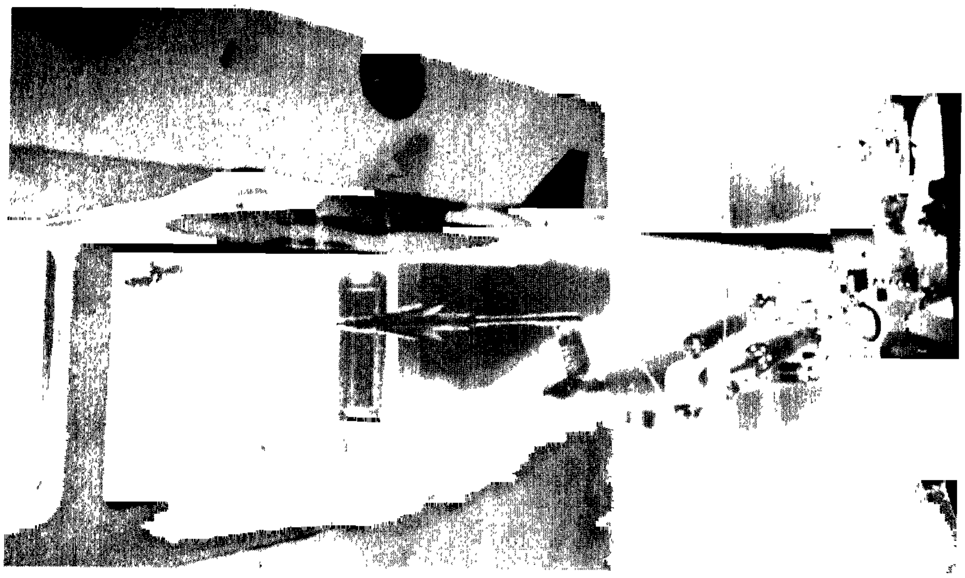


Source: ONERA

Figure V.36: Half-Model of Airbus With Engine Simulator Mounted on Wall Turret and Balance in Transonic Test Section of the ONERA S2MA Wind Tunnel

Source: ONERA

Figure V.38: Stores Trajectory Under Jaguar Model With Six-Degree-of-Freedom Device In Transonic Test Section of the ONERA S2MA Wind Tunnel



Source: ONERA

variety of stings can be mounted on the stingholder including a motorized variable-elbow device for tests at very high angles of incidence of up to 90 degrees. The tunnel is also equipped with a setup for wall-mounted models with a motorized turret, wall balance and compressed air passage, and boundary plate. It has a rain erosion test device (up to Mach 0.83), and a compressed air supply for simulating jets (using the 9-, 64-, and 150-bar compressed air systems). An optical test bench installed on both sides of the test section is used for shadowgraph and schlieren visualizations. The visualizations are recorded in the form of high-speed video, photographs, or film. ONERA's two-dimensional laser Doppler anemometer stand can be used with the S3MA. Many visualization techniques are used, such as acenaphthene transition, surface oil, and colored pigments.

Data Acquisition: The basic measurement system has 50 channels. The measurement data is processed in real time on a DEC 6320 computer.

Planned Improvements (Modifications/Upgrades): These include improved regulation of (1) Mach number, (2) pressure stagnation, (3) heater, and (4) the number of tests per day.

Unique Characteristics: None

Applications/Current Programs: Current programs include Ariane 5, missiles, two-dimensional testing, and tests of rain erosion on radomes.

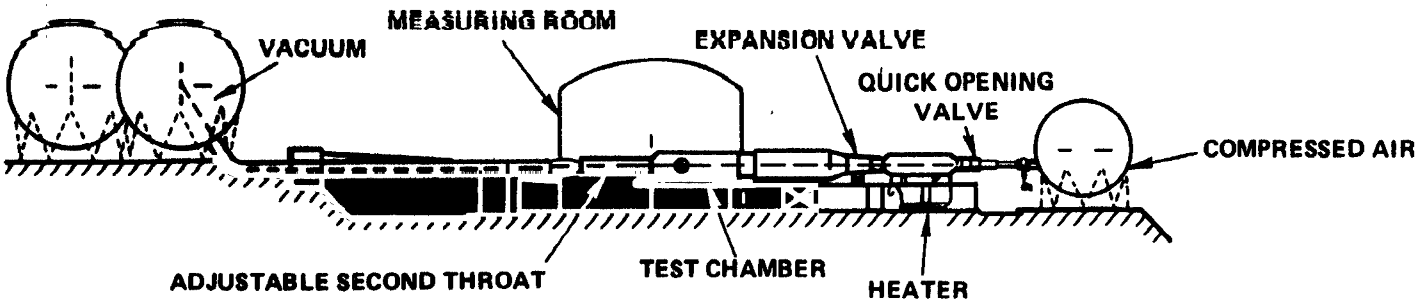
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 216. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 99 (EOARD Technical Report). ONERA. Activities 1986: Large Testing Facilities. Chatillon, France: ONERA, 1987, pp. 23-24. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 58-59 and 68-70.

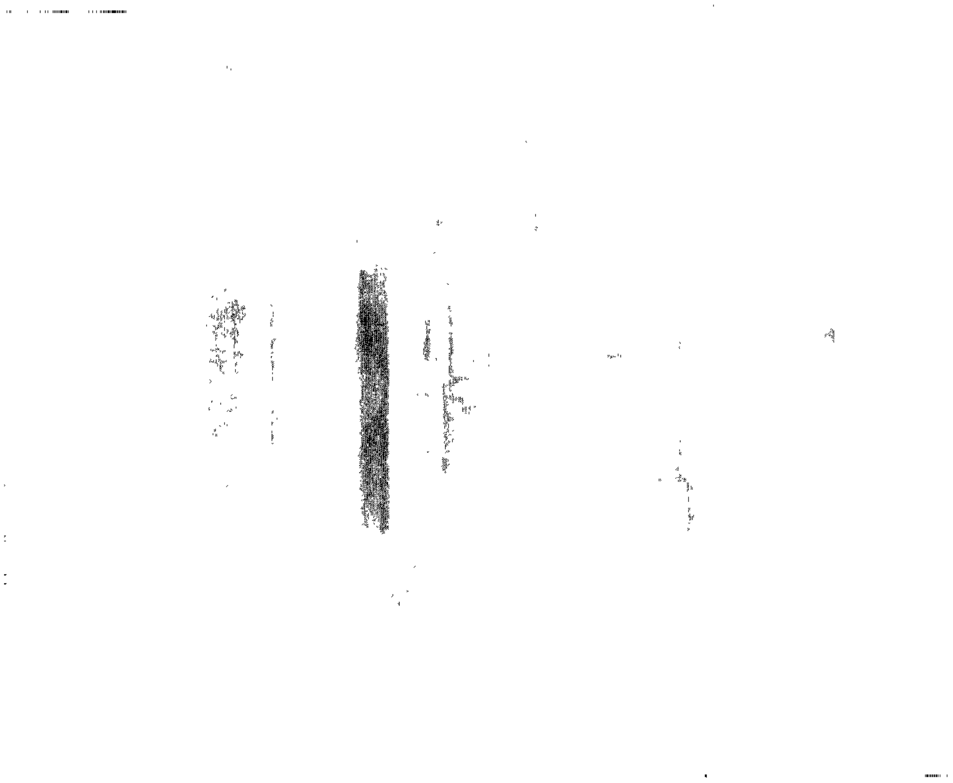
Date of Information: September 1989

Figure V.40: Schematic Drawing of the ONERA S3MA Wind Tunnel



Source: NASA

Figure V.43: Two-Dimensional Test Section of the ONERA S3MA Wind Tunnel



Source: ONERA

Figure V.44: Ariane Launch Vehicle on Stingholder Sector in Test Section of the ONERA S3MA Wind Tunnel

Source: ONERA

Institut Aerotechnique de St. Cyr Sigma 4 Wind Tunnel

Country: France

Location: Institut Aerotechnique de St. Cyr, St. Cyr l'Ecole, France

Owner(s):
Institut Aerotechnique de St. Cyr
15, Rue Marat
78210 St. Cyr l'Ecole Cedex
France

Operator(s): Institut Aerotechnique de St. Cyr

International Cooperation: Not available

Point of Contact: Mr. Menard, Institut Aerotechnique de St. Cyr, Tel.: [33]-(3)-045-00-09

Test Section Size: 0.85 x 0.85 m

Operational Status: Active

Utilization Rate: 1 shift; 2,000 hours per year

Performance
Mach Number: 0.3 to 2.8
Reynolds Number: Not available
Total Pressure: 70 bars
Dynamic Pressure: Not available
Total Temperature: Ambient to 520 degrees Kelvin
Run Time: About 60 s
Comments: None

Cost Information
Date Built: 1960
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The Institut Aerotechnique de St. Cyr Sigma 4 Wind Tunnel is an induction-driven, open-circuit blowdown trisonic wind tunnel. It uses a water steam generator.

Testing Capabilities: The Sigma 4 has a transonic perforated test section. Variable supersonic Mach numbers are possible through sliding half-bodies on lateral walls in the convergent section.

Data Acquisition: Data are processed on the Solar 16-40 local computer.

Planned Improvements (Modifications/Upgrades): These include a new dryer.

Unique Characteristics: None

Applications/Current Programs: The tunnel is currently testing aircraft and missile models for preliminary design studies by French manufacturers. The Sigma 4 is also being used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation.

General Comments: None

Aerospatiale-Aquitaine Arc Heater J.P. 200 Wind Tunnel

Country: France

Location: Aerospatiale-Aquitaine, Saint Medard-en-Jalles, France

Owner(s):
Aerospatiale-Aquitaine
Establishment d'Aquitaine
F-33165 Saint Medard-en-Jalles Cedex
France

Operator(s): Aerospatiale-Aquitaine

International Cooperation: Not available

Point of Contact: A. Allard, Establishment d'Aquitaine, Tel.: [33]-(56)-058405

Test Section Size: 5 to 32 cm^2 (throat area)

Operational Status: Active

Utilization Rate: 1 test per day

Performance
Mach Number: Less than 2.4
Reynolds Number: Not available
Total Pressure: 4 to 80 bars
Dynamic Pressure: Not available
Total Temperature: 5,000 degrees Kelvin
Run Time: 60 s at 24 MW; continuous below 2.5 MW
Comments: Nozzle exit diameter is 5 to 32 cm^2 in the throat area.

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 10

Description: The Aerospatiale-Aquitaine Arc Heater J.P. 200 Wind Tunnel is a supersonic wind tunnel.

Testing Capabilities: The Arc Heater J.P. 200 is capable of conducting force balance, pressure, temperature distribution, visualization, and ablation rate tests.

Data Acquisition: The tunnel has 100 off-line channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

CEAT S.150 Supersonic Blowdown Wind Tunnel

Country: France

Location: Centre d'Etudes Aerodynamiques et Thermiques, Poitiers, France

Owner(s):
Centre d'Etudes Aerodynamiques et Thermiques
43, Route de l'Aerodrome
F-86000 Poitiers Cedex
France

Operator(s): Centre d'Etudes Aerodynamiques et Thermiques

International Cooperation: Not available

Point of Contact: Professor T. Alziary de Roquefort, Centre d'Etudes Aerodynamiques et Thermiques, Tel.: [33]-(49)-58-37-50

Test Section Size: 15 x 15 cm (nozzle exit diameter)

Operational Status: Active at Mach 2

Utilization Rate: 10 tests per day

Performance
Mach Number: 2, 3.5, and 4.3
Reynolds Number: 20 x 10^6/m
Total Pressure: 10 to 30 bars
Dynamic Pressure: Not available
Total Temperature: Ambient
Run Time: Less than 1 min
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 1

Description: The CEAT S.150 Supersonic Blowdown Wind Tunnel is a supersonic wind tunnel.

Testing Capabilities: The S.150 is capable of conducting pressure distribution, hot-wire, and visualization tests.

Data Acquisition: Data are acquired on-line.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

S5Ch Transonic and Supersonic Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Chalais-Meudon, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre

International Cooperation: Not Available

Point of Contact: Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Tel.: [33]-(1)-46-57-11-60

Test Section Size: 0.3 x 0.3 m

Operational Status: Not available

Utilization Rate: Not available

Performance
Mach Number: 0.8 to 1.15 (transonic) and 1.2 and 1.45 to 3.15 (supersonic)
Reynolds Number: Not available
Total Pressure: Not available
Dynamic Pressure: Not available
Total Temperature: Not available
Run Time: Not available
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: 1953
Date(s) Upgraded: 1970s
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ONERA S5Ch Transonic and Supersonic Wind Tunnel is a continuous-flow, closed-circuit wind tunnel. With several variable Mach nozzles, the tunnel can now cover the transonic and supersonic domains.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: The tunnel was initially used for studying the aerodynamic characteristics of aircraft in transonic flow. The precise Mach number adjustment was used for air intake tests, particularly in studies of the recompression ramp fairings and inner diverter of two-dimensional air intake. The S5Ch was used for afterbody tests of the Concorde, which required the use of particularly high-performance thrust measurement balances to optimize the external forms and the geometry of the dual-flow exhaust nozzles. Beginning in the 1970s, with

CEAT H.210 Blowdown Wind Tunnel

Country: France

Location: Centre d'Etudes Aerodynamiques et Thermiques, Poitiers, France

Owner(s):
Centre d'Etudes Aerodynamiques et Thermiques
43, Route de l'Aerodrome
F-86000 Poitiers Cedex
France

Operator(s): Centre d'Etudes Aerodynamiques et Thermiques

International Cooperation: Not available

Point of Contact: Professor T. Alziary de Roquefort, Centre d'Etudes Aerodynamiques et Thermiques, Tel.: [33]-(49)-58-37-50

Test Section Size: 21 cm (nozzle exit diameter)

Operational Status: Active

Utilization Rate: 6 tests per day

Performance
Mach Number: 7 and 8
Reynolds Number: 1.3 to 9.2 x 10^6/m at Mach 7 and 1.5 to 4.2 x 10^6/m at Mach 8
Total Pressure: 22 to 100 bars
Dynamic Pressure: Not available
Total Temperature: 600 to 800 degrees Kelvin
Run Time: Approximately 2 to 3 min
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

Description: The CEAT H.210 Blowdown Wind Tunnel is a hypersonic wind tunnel.

Testing Capabilities: The H.210 is capable of conducting force balance, heat transfer, pressure distribution, and schlieren visualization tests.

Data Acquisition: The tunnel has 20 on-line channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The H.210 is being used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation.

General Comments: None

Photograph/Schematic Available: No

CNRS SR.3 Wind Tunnel

Country: France

Location: Laboratoire d'Aerothermique du Centre National de la Recherche Scientifique, Meudon, France

Owner(s):
Laboratoire d'Aerothermique du Centre National de la Recherche Scientifique
4 ter Route des Gardes
F-92190 Meudon Cedex
France

Operator(s): Laboratoire d'Aerothermique du Centre National de la Recherche Scientifique

International Cooperation: ESA/ESTEC (The Netherlands) and Hughes Aircraft (the United States)

Point of Contact: Dr. Jean Allegre, Laboratoire d'Aerothermique du Centre National de la Recherche Scientifique, Tel.: [33]-(1)-45-34-75-50

Test Section Size: 15 to 30 cm (nozzle exit diameter) to Mach 7 and 36 cm (nozzle exit diameter) between Mach 15 and 30

Operational Status: Active (in regular use)

Utilization Rate: Not available

Performance
Mach Number: 2 to 30
Reynolds Number: 2×10^3/m to 2×10^6/m
Total Pressure: Up to 120 bars
Dynamic Pressure: Not available
Total Temperature: Up to 1,500 degrees Kelvin
Run Time: Continuous
Comments: Test gas is air and nitrogen.

Cost Information
Date Built: 1963
Date Placed in Operation: 1965
Date(s) Upgraded: 1986
Construction Cost: Not available
Replacement Cost: $7 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: The CNRS SR.3 was built with financial support from CNES. Sources of funding also include contracts with aerospace agencies and industry.

Number and Type of Staff
Engineers: 3
Scientists: 2
Technicians: 2
Others: 0
Administrative/Management: 0
Total: 7

Description: The CNRS SR.3 Wind Tunnel is a continuous low-density wind tunnel with an open-jet test section. An 80-kW graphite heater is used to heat the nitrogen test gas to 1,500 degrees Kelvin at a pressure of up to 120 bars. The SR.3 can cover an extensive range of conditions from continuum to near free molecular flow at speeds of Mach 2 to 30.

Testing Capabilities: The SR.3 is capable of conducting force balance and heat transfer tests using thermocouples and an infrared system. It has pressure transducers and an electron gun for local density measurement and visualization.

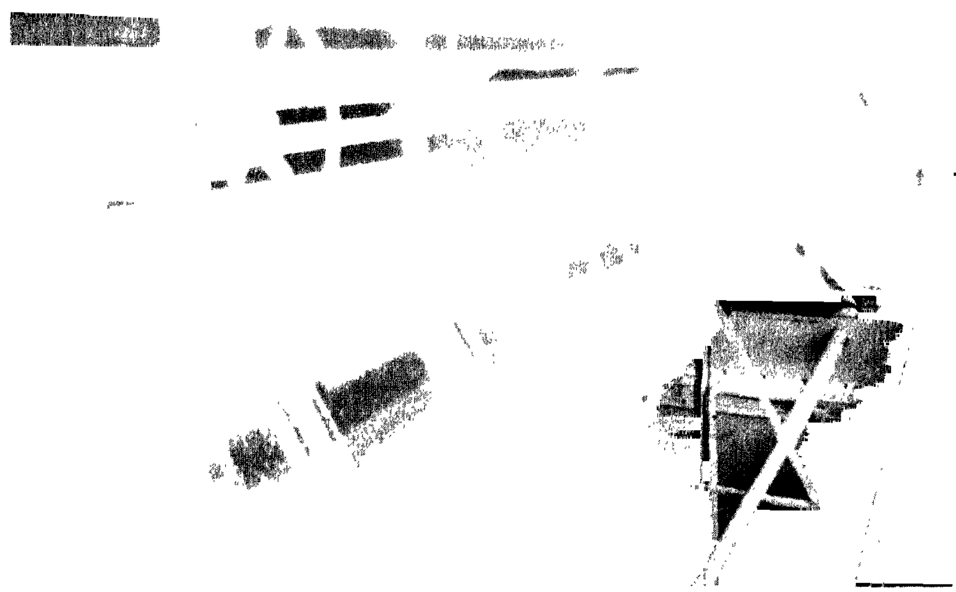
Data Acquisition: The SR.3 has 6 to 20 channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Even though flows from continuum to transitional regimes may be produced, high altitude aerodynamics (such

Figure V.47: CNRS SR.3 Wind Tunnel



Source: CNRS

IMF Blowdown Tunnel SH

Country: France

Location: Institut de Mecanique des Fluides, Marseille, France

Owner(s):
Institut de Mecanique des Fluides
1, Rue Honnorat
F-13003 Marseille Cedex
France

Operator(s): Institut de Mecanique des Fluides

International Cooperation: Not available

Point of Contact: J. Marcillat, Institut de Mecanique des Fluides, Tel.: [33]-(91)-081690

Test Section Size: 15 cm (nozzle exit diameter)

Operational Status: Mothballed

Utilization Rate: 10 to 20 tests per day (when tunnel was operational)

Performance
Mach Number: 2.3, 4, 5, 6, and 7
Reynolds Number: 2 x 10^6/m at Mach 7 and 16 x 10^6/m at Mach 5
Total Pressure: 10 to 30 bars
Dynamic Pressure: Not available
Total Temperature: 300 to 600 degrees Kelvin
Run Time: 10 s
Comments: Nozzle exit diameter is 15 cm.

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The IMF Blowdown Tunnel SH is a hypersonic wind tunnel. However, the tunnel has not been used since 1980.

Testing Capabilities: The tunnel had the capability to conduct heat transfer, force balance, pressure, surface visualization, and laser anemometry tests.

Data Acquisition: The tunnel currently has no channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: The tunnel has not been used since 1980.

Photograph/Schematic Available: No

ONERA R2Ch Blowdown Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Chalais-Meudon, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre

International Cooperation: Not available

Point of Contact: M.C. Capelier, Office National d'Etudes et de Recherches Aerospatiales, Chalais-Meudon Centre, Tel.: [33]-(1)-46-57-11-60

Test Section Size: 0.19 m (nozzle exit diameter) at Mach 3 and 4, and 0.33 m (nozzle exit diameter) at Mach 5, 6, and 7.

Operational Status: Active

Utilization Rate: 4 tests per day

Performance
Mach Number: 3, 4, 5, 6, and 7 (contoured)
Reynolds Number: 3×10^6/m at Mach 3 (maximum) and 3.5×10^6/m at Mach 7
Total Pressure: 0.4 to 80 bars
Dynamic Pressure: Not available
Total Temperature: 300 to 650 degrees Kelvin
Run Time: 35 s (10 s at Mach 10)
Comments: Nozzle exit diameter useful core is 0.18 m to 0.30 m. Starting time is 3 ms and the sweep rate is 50 degrees/10 s.

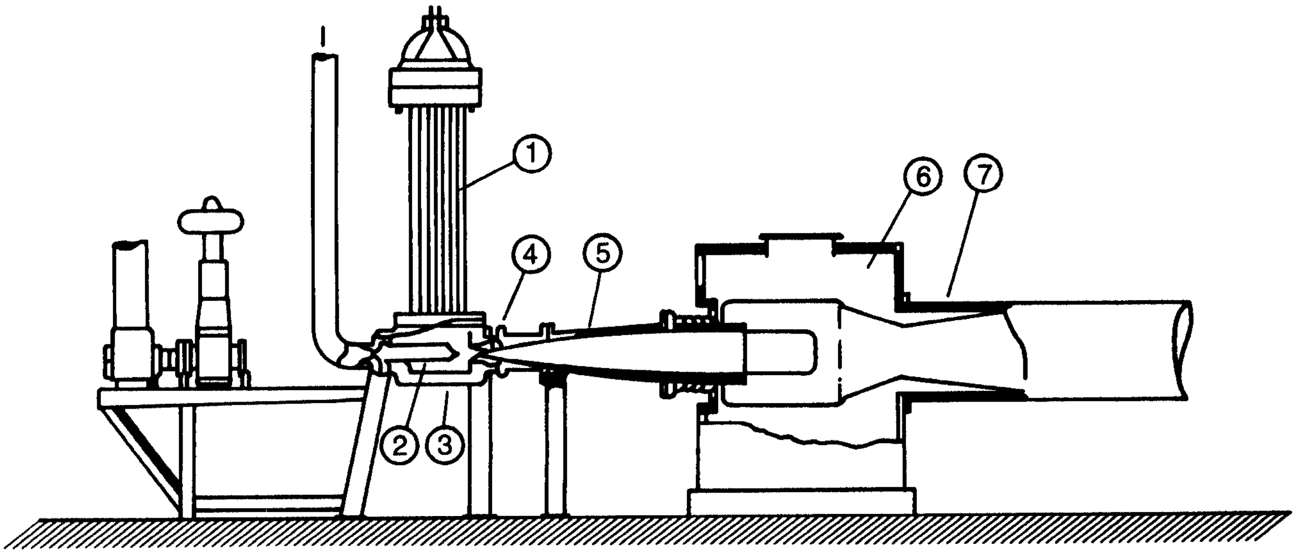
Cost Information
Date Built: 1960
Date Placed in Operation: Not available
Date(s) Upgraded: 1963
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

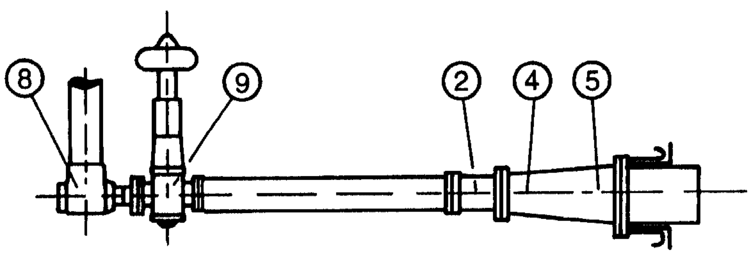
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 5

Description: The ONERA R2Ch Blowdown Wind Tunnel is a blowdown, open-jet hypersonic wind tunnel. It shares some common high pressure and vacuum equipment with ONERA's R3Ch Blowdown Wind Tunnel. Air is supplied to the R2Ch at 1,200 psi and heated to 1,100 degrees Fahrenheit in an electric accumulation heater. Run durations of under 35 s are obtained with this system. It is equipped with three contoured nozzles. Under hypersonic conditions, Reynolds Numbers of up to 3.5×10^6/m are generated on models; this is sufficient to obtain turbulent boundary layers. At lower Reynolds Numbers, fully laminar boundary layers are obtained on simple configurations; however, complex flow fields involving flow separation transition may well be embedded within the interaction region.

Testing Capabilities: The R2Ch uses conventional and component sting-mounted force balances. Temperature and pressure measurements are made with thermocouples and transducers mounted close to the model. It is used to measure pressure distributions, heat transfer, and local skin friction. It is capable of schlieren visualization, testing wall streamliness, and measuring the heat flux by thermosensitive paints. Wide-deflection

Figure V.49: Schematic Diagram of the ONERA R2Ch Blowdown Wind Tunnel





1. Heater
2. Plenum chamber
3. Inversion valve
4. Contoured nozzle (removable part)
5. Contoured nozzle (stationary part)
6. Test chamber
7. Jet recovery
8. Adjusting stagnation pressure valve
9. Adjusting stagnation pressure valve

Source: U.S. Air Force EOARD

Data Acquisition: The R3Ch has 40 channels of data and uses a SOLAR 16-45 local computer with the R2Ch.

Planned Improvements (Modifications/Upgrades): These include upgrading the data acquisition capability and systems in 1990 to 1991.

Unique Characteristics: None

Applications/Current Programs: The R3Ch is used to test boundary layer transition with roughness effects, shock boundary layer interactions on two- and three-dimensional shapes, and aerothermodynamic testing on reentry configurations. The R3Ch is also used to study hypersonic aircraft or missiles and stage separation. Since 1965, the R3Ch has been equipped with a Joule effect heater and a rapid starting device. It is particularly well-adapted to studying kinetic heating during atmospheric reentry and hypersonic flights. Many heating maps have been made on various rocket and launch vehicle models including ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation. Fundamental studies are also conducted by the R3Ch such as the effect of wall roughness and effect of protuberances on Ariane with reference to the thickness of the boundary layer. By the end of 1987, the R3Ch had conducted more than 5,000 tests.

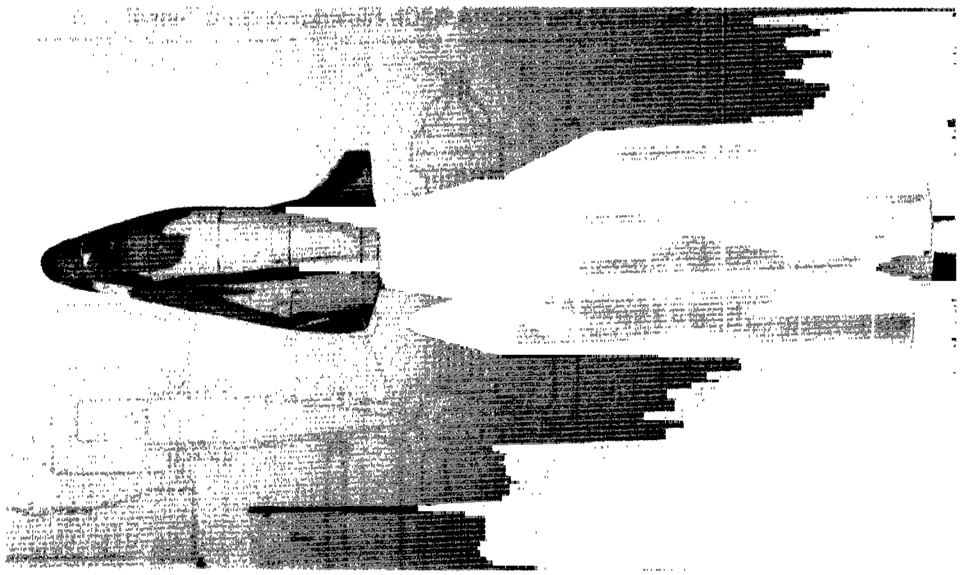
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 276. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 98 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 34-36 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 13-14.

Date of Information: September 1989

Figure V.51: Measurement of Thermal Flux Using Thermosensitive Paint on a Model of the Ariane 5 Launch Vehicle and Hermes Spaceplane in the ONERA R3Ch Blowdown Wind Tunnel



Source: ONERA

ONERA S4MA Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Modane, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator: Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre

International Cooperation: Not available

Point of Contact: Jean Laverre, Office National d'Etudes et de Recherches Aerospatiales, Modane-Avrieux Centre, Tel.: [33]-(79)-20-20-00

Test Section Size: 0.68 m diameter (Mach 6 nozzle) and 1 m diameter (Mach 10 to 12 nozzle)

Operational Status: Active

Utilization Rate: 200 to 300 hours per year

Performance
Mach Number: 6 and 10 to 12
Reynolds Number: 3 to 27 x 10^6/m
Total Pressure: 40 bars at Mach 6 and 150 bars at Mach 10 to 12
Dynamic Pressure: 7 to 67 kN/m^2
Total Temperature: 493 to 1,843 degrees Kelvin
Run Time: 30 to 100 s
Comments: None

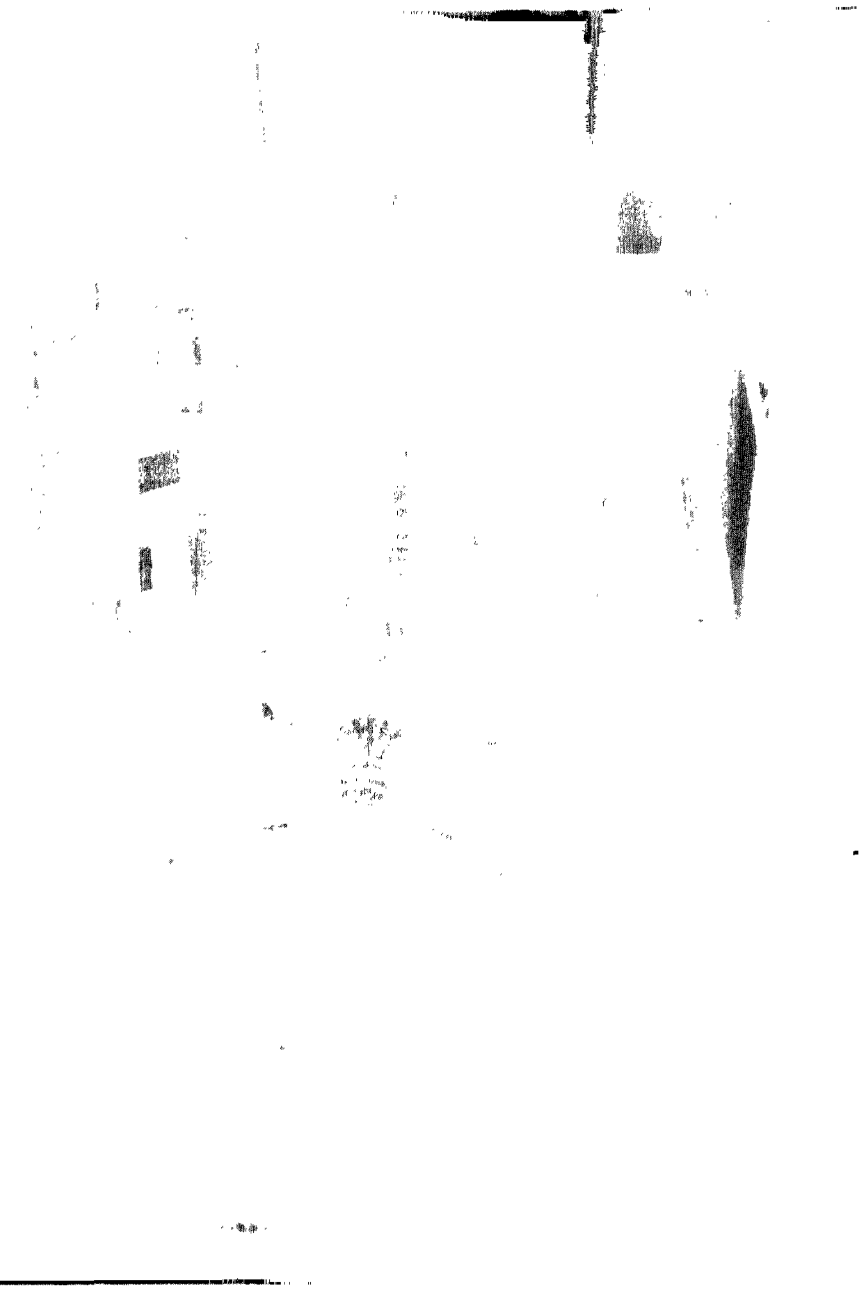
Cost Information
Date Built: 1967
Date Placed in Operation: 1970
Date(s) Upgraded: 1987 to 1989
Construction Cost: Not available
Replacement Cost: $33.5 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 12

Description: The ONERA S4MA Wind Tunnel is an intermittent, blowdown hypersonic wind tunnel. The S4MA has an alumina pebble bed heater. It has a Mach 6 nozzle with a 0.68-m diameter outlet and a Mach 10 to 12 nozzle with a 1-m diameter outlet. The throat is water-cooled. The tunnel is fed from the Modane-Avrieux Centre's store of compressed air (29 m^3 at a pressure of 270 or 400 bars), which exhausts either into the atmosphere or into vacuum spheres (3,000 or 4,000 m^3). A propane-heated pebble bed heater 2 m in diameter and 10 m high, containing 12 tons of alumina pebbles, can be raised to a maximum temperature of about 1,850 degrees Kelvin by propane combustion. The air from the heater passes through a 10-micrometer filter upstream of the nozzle.

Testing Capabilities: The test chamber is cubic in shape (3 × 3 × 2.8 m) and is equipped with an angle of incidence table and a sideslip table. A rapid introduction device is used to protect the model from flow initiation and de-initiation effects. The S4MA systems are also used as a hot gas generator supplying ramjet air intakes.

Figure V.53: ONERA S4MA Wind Tunnel



Source: ONERA

Figure V.56: Ramjet Test in the ONERA S4MA Wind Tunnel

Source: ONERA

ISL Hypersonic Shock Tunnel

Country: France

Location: Institut de Saint-Louis, St. Louis, France

Owner(s):
Institut de Saint-Louis
12, Rue de l'Industrie
Boite Postale No. 301
F-68301 St. Louis Cedex
France

Operator(s): Institut de Saint-Louis

International Cooperation: Not available

Point of Contact: G. Smeets, Institut de Saint-Louis, Tel.: [33]-(89)-69-50-00

Test Section Size: 20 x 20 cm (nozzle exit diameter)

Operational Status: Active

Utilization Rate: 4 tests per day

Performance
Mach Number: 4 to 11 (conical)
Reynolds Number: Not available
Total Pressure: 400 bars (maximum)
Dynamic Pressure: Not available
Total Temperature: 7,000 degrees Kelvin (maximum)
Run Time: Less than 1 ms
Comments: Test gas used is air.

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ISL Hypersonic Shock Tunnel is a hypervelocity facility.

Testing Capabilities: The tunnel is capable of conducting interferometry and heat transfer tests.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): The tunnel will be transformed for aeroballistic studies, but the performance characteristics indicated will be attainable, if desired.

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

LRBA C_2 Reflected Shock Tunnel

Country: France

Location: Laboratoire de Recherches Balistiques et Aerodynamiques, Vernon, France

Owner(s):
Laboratoire de Recherches Balistiques et Aerodynamiques
Boite Postale 914
F-27207 Vernon Cedex
France

Operator(s): Laboratoire de Recherches Balistiques et Aerodynamiques

International Cooperation: None

Point of Contact: M. Desgardin, Laboratoire de Recherches Balistiques et Aerodynamiques, Tel.: [33]-(32)-21-43-24

Test Section Size: 1.2 m diameter

Operational Status: Active

Utilization Rate: 3 to 4 tests per day

Performance
Mach Number: 8 to 16 (conical) and 16 (contoured)
Reynolds Number: 0.26 to 2.9 x 10^6/m
Total Pressure: 30 to 350 bars
Dynamic Pressure: Not available
Total Temperature: 1,500 to 2,000 degrees Kelvin
Run Time: 10 to 20 ms
Comments: None

Cost Information
Date Built: 1961
Date Placed in Operation: 1974 (at LRBA)
Date(s) Upgraded: 1984
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $2,500 per test (1989)
Source(s) of Funding: Ministry of Defense

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 3

Description: The LRBA C_2 Reflected Shock Tunnel is a reflected blowdown shock tunnel. It can also be used with helium for very high Mach numbers (up to Mach 30). The C_2 is normally operated with the Mach 16 contoured nozzle.

Testing Capabilities: The C_2 is capable of conducting force balance, pressure distribution, and schlieren visualization tests. The tunnel is also capable of conducting heat flux measurements.

Data Acquisition: The tunnel has 40 analog channels of data at 300 kHz per channel (block sampled data) that are recorded on a Hewlett Packard 1000 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The C_2 is used intensively to measure aerodynamic coefficients of reentry shapes and force, pressure, and temperature measurements on ballistic missiles. The tunnel is also used to test models of ESA's Hermes spaceplane.

ONERA ARC 2 Hotshot Wind Tunnel

Country: France

Location: Office National d'Etudes et de Recherches Aerospatiales, Palaiseau Centre, Palaiseau, France

Owner(s):
Office National d'Etudes et de Recherches Aerospatiales
29, Avenue de la Division Leclerc
Boite Postale 72
F-92322 Chatillon Cedex
France

Operator(s): Office National d'Etudes et de Recherches Aerospatiales, Palaiseau Centre

International Cooperation: Not available

Point of Contact: C. Capelier, Office National d'Etudes et de Recherches Aerospatiales, Palaiseau Centre, Tel.: [33]-(1)-657-11-60

Test Section Size: 70 cm (nozzle exit diameter)

Operational Status: Dismantled (see General Comments)

Utilization Rate: 3 tests per day (when tunnel was operational)

Performance
Mach Number: 15 to 20
Reynolds Number: 4.2 x 10^6/m at Mach 15
Total Pressure: 20 to 1,500 bars
Dynamic Pressure: Not available
Total Temperature: 2,000 to 8,000 degrees Kelvin
Run Time: 50 to 200 ms
Comments: Useful core diameter was 0.25 m. Test gas used was nitrogen.

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not applicable
Unit Cost to User: Not applicable
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

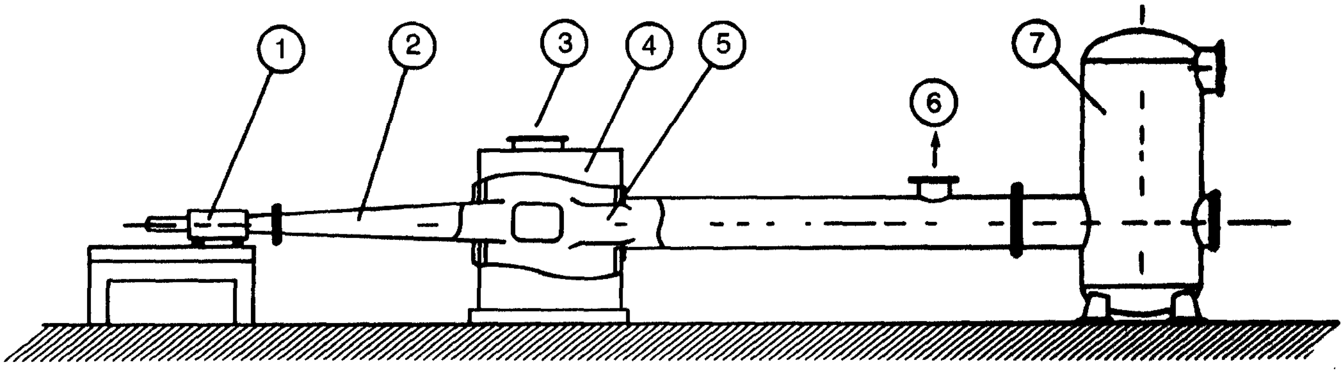
Description: The ONERA ARC 2 Hotshot Wind Tunnel was a low-density hypervelocity wind tunnel that has been dismantled. Elements of the ONERA ARC 2 Hotshot are being used in the construction of ONERA's F4 Wind Tunnel. When it was operational, the ONERA ARC 2 Hotshot used a 10-MJ, 80-kA heater powered by the French National Electrical Network. It was equipped with contoured nozzles to generate speeds from Mach 15 to 20. The exit plane of the nozzle was 24 in. The tunnel could accommodate models up to 18 in. long. Reservoir temperatures of up to 8,000 degrees Kelvin were projected and pressures of up to 20,000 psi were predicted.

Testing Capabilities: The ONERA ARC 2 Hotshot was capable of testing force balance, pressure distribution, heat transfer, and skin friction. An electron beam, coupled with a spectrometer mounted on a three-directional traversing mechanism, was used to measure density and rotational temperatures.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not applicable

Figure V.59: Schematic Drawing of the ONERA ARC 2 Hotshot Wind Tunnel



1. Arc chamber (2.5 dm^3)
2. Conical nozzle (half angle 4° 45')
3. Vertical observation axis
4. Test chamber
5. Jet recovery
6. To vacuum pumping system
7. Vacuum tank

Source: U.S. Air Force EOARD

Applications/Current Programs: Planned programs include ESA's Hermes spaceplane.

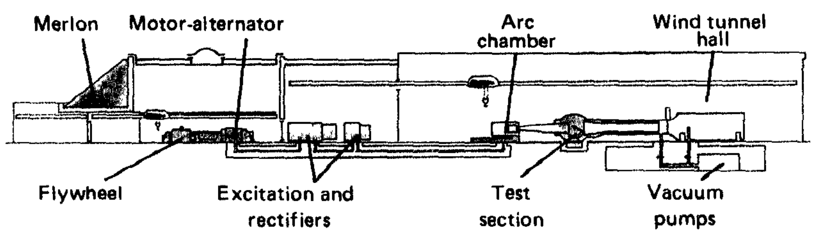
General Comments: A decision was made by ONERA in early 1988 to initiate the high-enthalpy F4 Hotshot Wind Tunnel project to conduct tests for ESA's Hermes spaceplane program. The F4 Hotshot will be a "short arc" type of facility like the wind tunnels ONERA used to have at Fontenay aux Roses near ONERA headquarters in Chatillon. Elements of ONERA's dismantled ARC 2 Hotshot Wind Tunnel are being used in the construction of the F4 Hotshot. The F4 Hotshot is scheduled to become operational in 1990.

Photograph/Schematic Available: Yes

References: ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, p. 85.

Date of Information: September 1989

Figure V.60: Schematic Diagram of the ONERA F4 Hotshot Wind Tunnel



Source: ONERA

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 89.

Date of Information: December 1985

CEPr R-4 Altitude Engine Test Facility

Country: France

Location: Centre d'Essais des Propulseurs de Saclay, Orsay, France

Owner(s):
Centre d'Essais des Propulseurs de Saclay
F-91406 Orsay Cedex
France

Operator(s): Centre d'Essais des Propulseurs de Saclay

International Cooperation: Not available

Point of Contact: M. Fayot, Centre d'Essais des Propulseurs de Saclay, Tel.: [33]-(6)-941-81-50

Test Cell Size: 11.5 ft diameter x 60 ft long

Operational Status: Not available

Utilization Rate: Not available

Performance
Mass Flow: 441 lb/s
Altitude Range: 65,600 ft
Temperature Range: −85 to 370 degrees Fahrenheit
Pressure Range: 30 psia
Speed Range: Mach 0 to 2.4
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The CEPr R-4 is an altitude engine test facility with both free-jet and direct-connect testing capability. The thrust level is 45,000 lb/ft.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: These include medium and small turbojets.

General Comments: None

Photograph/Schematic Available: No

CEPr R-5 Altitude Engine Test Facility

Country: France

Location: Centre d'Essais des Propulseurs de Saclay, Orsay, France

Owner(s):
Centre d'Essais des Propulseurs de Saclay
F-91406 Orsay Cedex
France

Operator(s): Centre d'Essais des Propulseurs de Saclay

International Cooperation: Not available

Point of Contact: M. Fayot, Centre d'Essais des Propulseurs de Saclay, Tel.: [33]-(6)-941-81-50

Test Cell Size: 18 ft diameter x 100 ft long

Operational Status: Not available

Utilization Rate: Not available

Performance
Mass Flow: 825 lb/s
Altitude Range: 65,600 ft
Temperature Range: 1,200 degrees Fahrenheit
Pressure Range: 100 psia
Speed Range: Mach 0 to 4
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The CEPr R-5 is an altitude engine test facility with both free-jet and direct-connect testing capability. The capacity of the installed thrust stand is about 67,500 lb/ft.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

CEPr S-1 Altitude Engine Test Facility

Country: France

Location: Centre d'Essais des Propulseurs de Saclay, Orsay, France

Owner(s):
Centre d'Essais des Propulseurs de Saclay
F-91406 Orsay Cedex
France

Operator(s): Centre d'Essais des Propulseurs de Saclay

International Cooperation: Not available

Point of Contact: M. Fayot, Centre d'Essais des Propulseurs de Saclay, Tel.: [33]-(6)-941-81-50

Test Cell Size: 12 ft diameter x 51 ft long

Operational Status: Not available

Utilization Rate: Not available

Performance
Mass Flow: 221 lb/s
Altitude Range: 62,000 ft
Temperature Range: 661 degrees Fahrenheit
Pressure Range: 29 psia
Speed Range: Mach 2
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The CEPr S-1 is an altitude engine test facility. The thrust level is 22,500 lb/ft.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 90.

Date of Information: December 1985

Testing Capabilities: Test stand no. 1 is used for the full analysis of a 430 mm diameter operational ramjet. It is capable of continuous thrust measurement, perfect flight simulation between Mach 1.8 and 4.5 at any altitude below 30 km, and simulation of both the external kinetic heating and air supply asymmetries as a function of the missile attitude in flight. Test stand no. 2 is less heavily equipped and is used for basic research. The maximum simulated Mach number is only 3.5 for altitudes below 15 km. Test stand no. 3 is specially equipped for supplying ramjets fuelled by a semipropellant, usually called ramrockets. The test stand characteristics are identical to those of test stand no. 1, except that the combustor diameter is limited to 200 mm. The maximum weight of semipropellant is limited to 20 kg. It has an 18 bar gaseous propane supply with a mass flow rate of 1 kg/s. Test stand no. 4 is used for research on materials, particularly thermal protection. It can simulate flight at Mach 1.8 to 4.5 at altitudes below 17 km and with engines having diameters less than 100 mm.

Data Acquisition: The cells use a digital data acquisition system.

Planned Improvements (Modifications/Upgrades): These include increasing air storage and improving safety and data acquisition.

Unique Characteristics: The cells can simulate all useful trajectories, including simulation of external aerodynamic heating. Direct measurement of the thrust can also be made.

Applications/Current Programs: Work is only devoted to missiles through 6.1, 6.2, 6.3, and 6.4 studies.

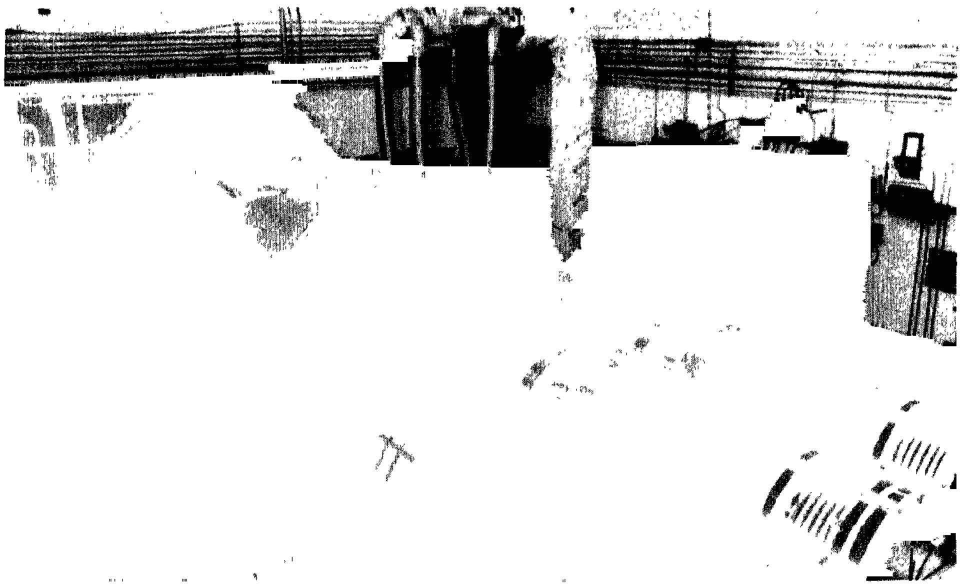
General Comments: Sources of funding include General Delegate for Armament of the French Ministry of Defense through the Direction for Engines.

Photograph/Schematic Available: Yes

References: ONERA. Missions, Tools. Chatillon, France: ONERA, 1988. ONERA. Resources, Facilities. Chatillon, France: ONERA, 1989, pp. 30-31.

Date of Information: September 1989

Figure V.63: Test With Simulation of External Kinetic Heating in Test Stand No. 2 of the ONERA ATD Ramjet Cells Nos. 8 and 9



Source: ONERA

Figure V.64: Tests on 180-mm Caliber Ramrocket in Test Stand No. 3 of the ONERA ATD Ramjet Cells Nos. 8 and 9

Source: ONERA

Aerospace Test Facilities in Italy

Figure VI.1: Map of Test Facilities in Italy

Source: GAO

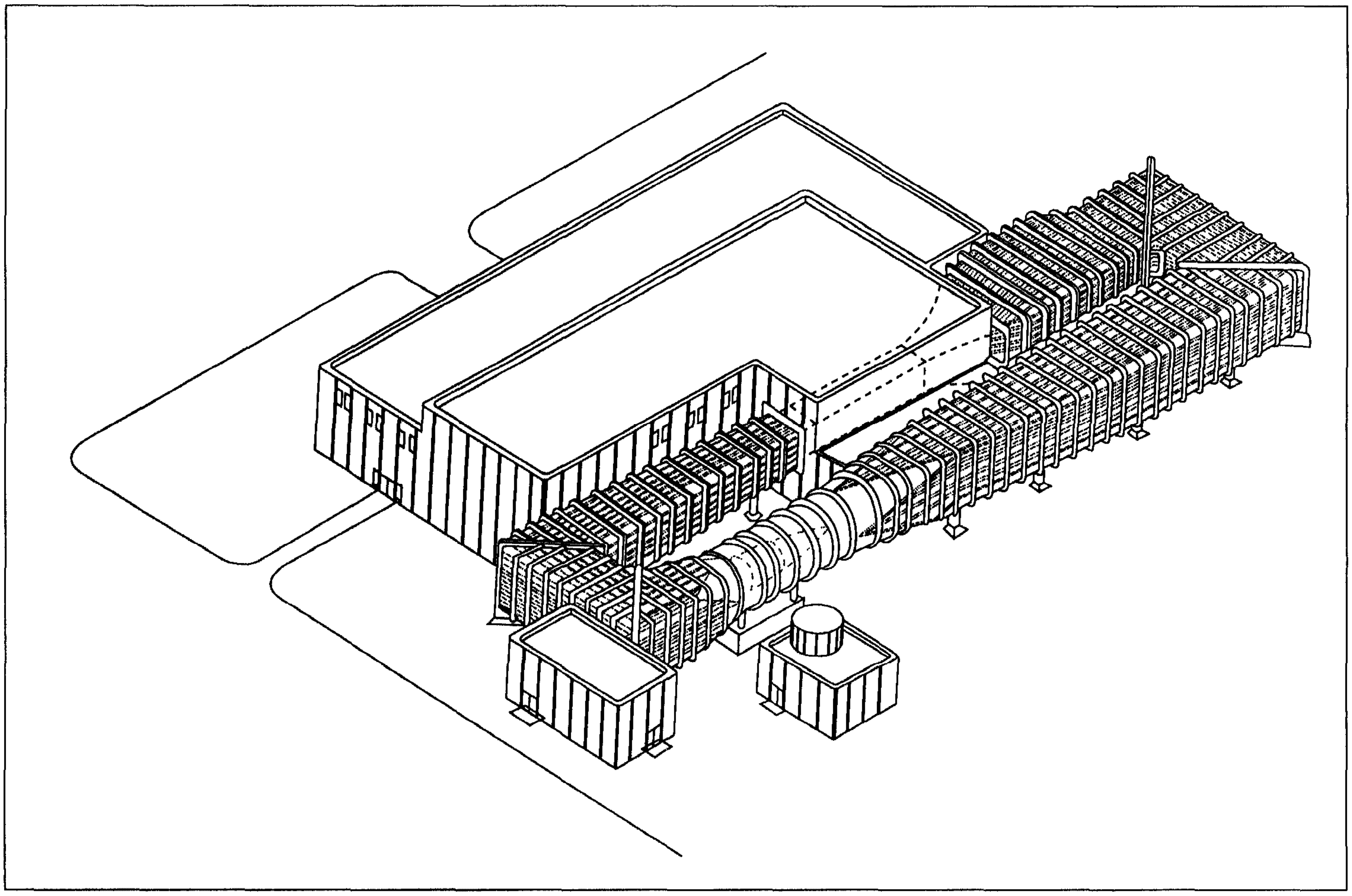
General Comments: The S1 test section will be the same size as the CIRA High Reynolds Transonic Wind Tunnel to allow the testing of the same aircraft models.

Photograph/Schematic Available: Yes

References: None available

Date of Information: August 1989

Figure VI.2: Schematic Drawing of the CIRA Low-Speed Wind Tunnel



Source: CIRA

Planned Improvements (Modifications/Upgrades): CIRA conducted a study to enhance the maximum Mach number. The study recommended using compressed air ejectors to increase the pressure ratio across the test section to achieve a larger flow rate. The transonic extension will require adding (1) several air ejector nozzles in a section downstream of the fan, (2) an exhaust line upstream of the test section to remove the air supplied by the ejectors, (3) compressed air storage tanks, air supply piping from the tanks to the ejector nozzles, and a compressed air system to pump up the storage tanks, and (4) a second throat with adjustable wall to tune the Mach number before the test run. If these modifications are made, the tunnel could be operated at speeds up to Mach 1.4 with a useful run time of 45 s.

Unique Characteristics: The flow qualities required in the tunnel specifications will exceed NATO AGARD specifications. The tunnel is expected be one of the largest pressurized wind tunnels in the western world.

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

References: None available

Date of Information: August 1989

General Comments: CIRA has conducted a feasibility study in cooperation with FluiDyne Engineering Corporation and Aerospatiale under the "Scirocco Project" to define the requirements for the arc plasma wind tunnel. The tunnel is presently scheduled to become operational in the first half of 1992.

Photograph/Schematic Available: No

References: CIRA. "Phase A2." In: Final Report. Capua, Italy: CIRA, 1989. (No. DLC/COP-HER-TN-011) Mattei, A., and G. Russo. "Space activities at CIRA." In: Euromech Colloquium. Turin, Italy: CIRA, 1989 (No. 246).

Date of Information: August 1989

FHI Low-Speed Wind Tunnel

Country: Japan

Location: Fuji Heavy Industries, Utsunomiya, Tochigi Prefecture, Japan

Owner(s):
Fuji Heavy Industries
Aircraft Engineering Division
1-1-11 Yonan
Utsunomiya
Tochigi Prefecture 320
Japan

Operator(s): Fuji Heavy Industries

International Cooperation: None

Point of Contact: Akitoshi Nagao, Fuji Heavy Industries, Tel.: [81]-(286)-58-1111

Test Section Size: 6.56 x 6.56 x 9.5 ft

Operational Status: Active

Utilization Rate: Essentially 1 shift per day

Performance
- **Mach Number:** 0 to 0.176 or 0 to 197 ft/s
- **Reynolds Number:** 0 to 1.5 x 10^6/ft
- **Total Pressure:** Atmospheric
- **Dynamic Pressure:** 0 to 46 lb/ft^2
- **Total Temperature:** Ambient
- **Run Time:** Not available
- **Comments:** None

Cost Information
- **Date Built:** 1969
- **Date Placed in Operation:** 1969
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** $2 million (1985)
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** 2

Description: The FHI Low-Speed Wind Tunnel is a continuous-flow, closed-circuit, single-return subsonic wind tunnel. The tunnel has an open throat.

Testing Capabilities: The three-model support systems are equipped for static tests and tandem strut with a six-component balance, wire suspension with balance, and sting with internal balance. Auxiliary equipment consists of 5-hp model motors for power supply to the models, a 30 kg/cm^2 10m^3 compressed air supply, and pressure measurements (scanivalves). The tunnel is available for static tests (force and pressure measurement test), low-speed flutter tests, airfoil tests (with end-plate), and external store ejection tests. It can accommodate models with a span of 5.3 ft and a weight of 200 lb. Powering-up of the drive motor of the fan to achieve speeds of 80 m/s was completed in 1986.

Data Acquisition: A Hewlett Packard 1000 series computer and front-end are used for data acquisition of up to 16-analog input channels. On-line data acquisition/reduction programs provide almost instantaneous numerical and graphical results.

Planned Improvements (Modifications/Upgrades): None

KHI 3.5 m Wind Tunnel

Country: Japan

Location: Kawasaki Heavy Industries, Kakamigahara City, Gifu Prefecture, Japan

Owner(s):
Kawasaki Heavy Industries
Gifu Works
1, Kawasaki-cho
Kakamigahara City
Gifu Prefecture 504
Japan

Operator(s): Kawasaki Heavy Industries

International Cooperation: None

Point of Contact: Jun Okumura, Kawasaki Heavy Industries, Tel.: [81]-(583)-82-5346

Test Section Size: No. 1: 3.5 x 3.5 x 6.5 m (closed); No. 2: 2.5 x 3 m (open)

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: No. 1: 0 to 0.1 (closed); No. 2: 0 to 0.19 (open)
Reynolds Number: No. 1: 0 to 0.71 x 10^6/ft (closed); No. 2: 0 to 1.33 x 10^6/ft (open)
Total Pressure: Atmospheric
Dynamic Pressure: No. 1: 0 to 15.7 lb/ft^2 (closed); No. 2: 0 to 54 lb/ft^2 (open)
Total Temperature: Ambient
Run Time: Not available
Comments: Not available

Cost Information
Date Built: 1938
Date Placed in Operation: Not available
Date(s) Upgraded: 1967
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The KHI 3.5 m Wind Tunnel is a subsonic wind tunnel with closed and open test sections.

Testing Capabilities: The tunnel's open test section has an external six-component balance with strut mount or internal six-component balance with sting mount. The tunnel's closed test section has an external six-component balance with strut mount. Compressed air is supplied at 4 lb/s at 300 psi. The model propeller/helicopter blade driving systems are powered by 10- and 100-hp motors.

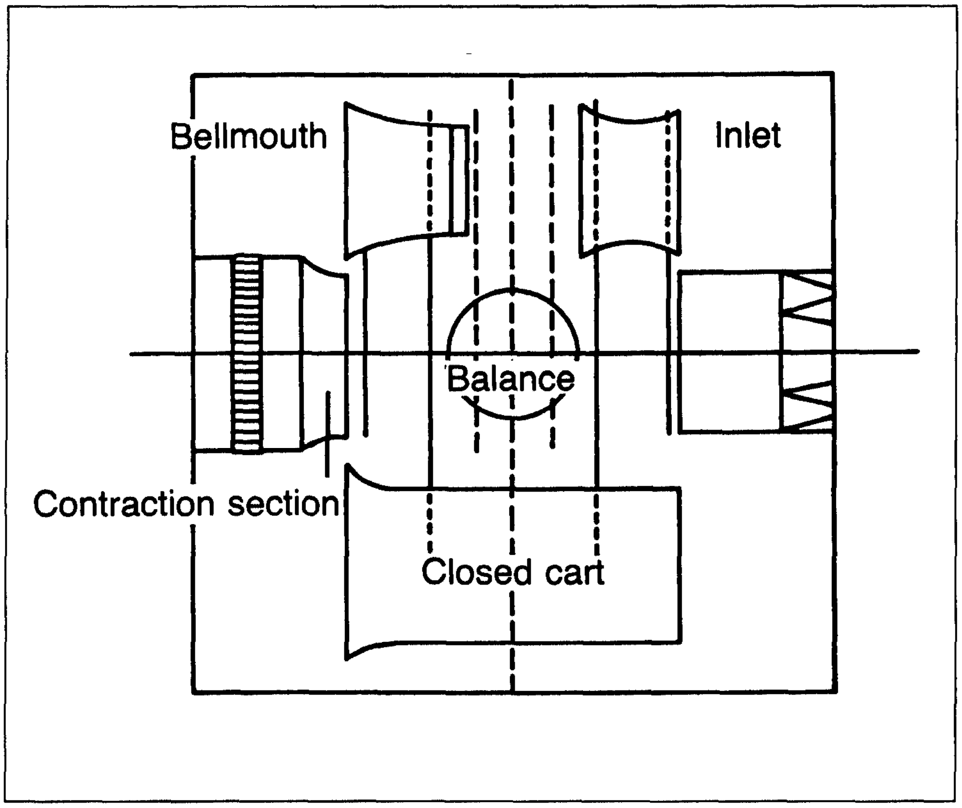
Data Acquisition: The tunnel has 40 on-line channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current programs include low-speed aerodynamic research, static stability control, and airplane, helicopter, and missile development programs.

Figure VII.3: Test Section Configuration of the KHI 3.5 m Wind Tunnel



Source: KHI

Series 1 computer processes the data on-line with output by plotter, printer, graphic display, and character display. The IBM computer is connected to the host IBM 3090 computer for data storage and post processing.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to conduct research and development of aircraft, missiles, and helicopters.

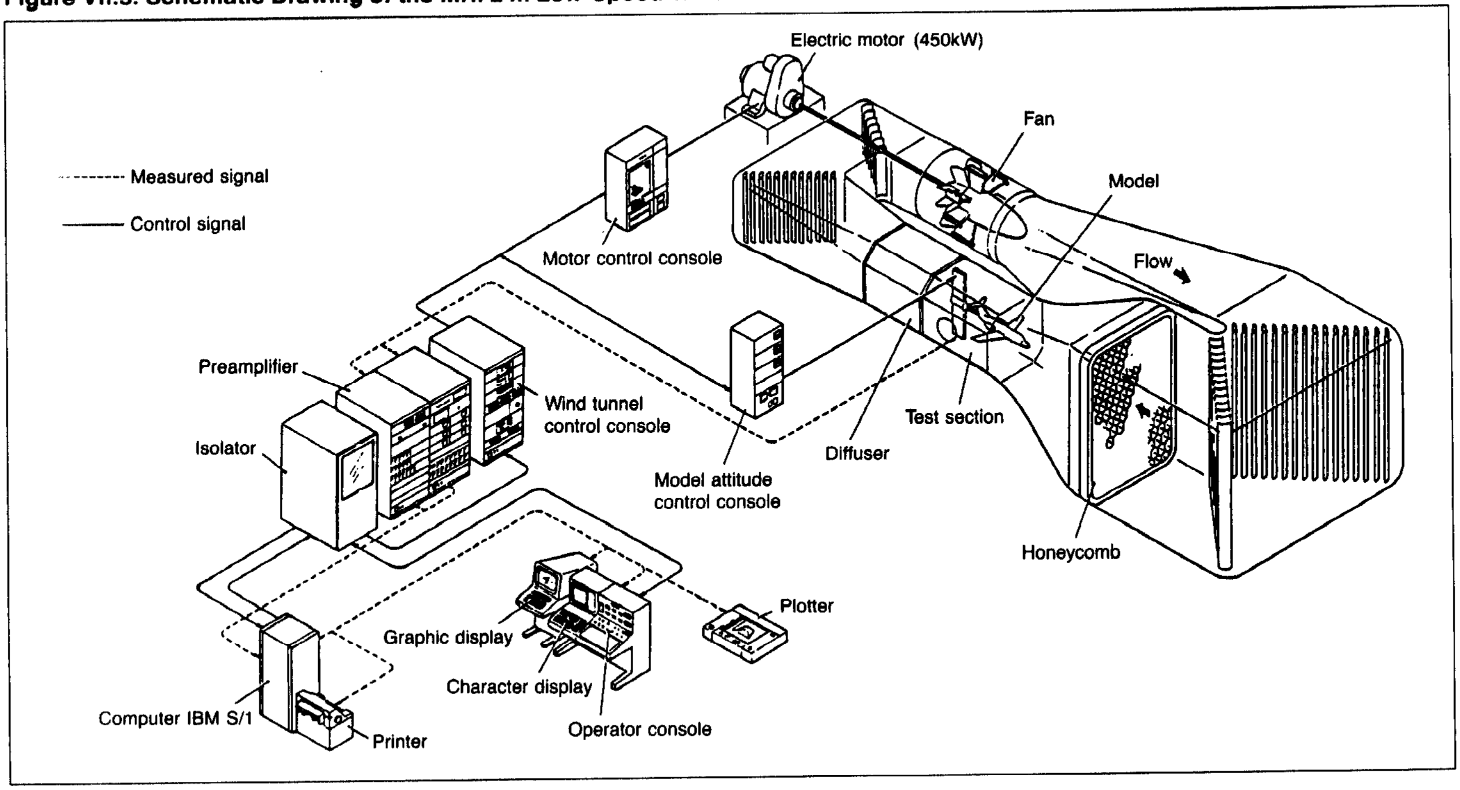
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 96.

Date of Information: October 1989

Figure VII.5: Schematic Drawing of the MHI 2 m Low-Speed Wind Tunnel



Source: MHI

MHI Smoke Tunnel

Country: Japan

Location: Mitsubishi Heavy Industries, Komaki-shi, Aichi Prefecture, Japan

Owner(s):
Mitsubishi Heavy Industries
Aircraft and Special Vehicles Headquarters
Nagoya Guidance and Propulsion Systems Works
1200, Higashi-tanaka
Komaki-shi
Aichi Prefecture 485
Japan

Operator(s): Mitsubishi Heavy Industries, Engine Engineering Department

International Cooperation: Not available

Point of Contact: Mikio Kajita, Mitsubishi Heavy Industries, Tel.: [81]-(568)-79-2111, ext. 4610

Test Section Size: 0.2 x 1.5 x 2.5 m

Operational Status: Not available

Utilization Rate: Not available

Performance
Mach Number: 0.11 or 40 m/s (pressure/force tests) and 0.05 or 18 m/s (smoke visualization tests)
Reynolds Number: Not available
Total Pressure: Not available
Dynamic Pressure: Not available
Total Temperature: Not available
Run Time: Not available
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The MHI Smoke Tunnel is a specialized induction, open-circuit subsonic wind tunnel used for flow visualization tests by the smoke technique. The tunnel's inlet is 3 × 1.5 m and the tunnel is 31 m long. The contraction ratio is 15 to 1. The test section has a window 1.2 × 2.2 m. Smoke is provided by kerosene vapor in 69 lines. The tunnel has an axial, single-stage fan 1.1 m in diameter powered by a 37-kW DC motor.

Testing Capabilities: The tunnel is capable of conducting flow visualization tests using the smoke technique. Three-dimensional flow observation is possible through side and rear windows.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: None

Applications/Current Programs: These include investigations of low-speed aerodynamic problems, testing of automobile radiators, and development of a flow meter.

NAL 6 m Low-Speed Wind Tunnel LS

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: Y. Ishida, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911

Test Section Size: No. 1: 6.5 x 5.5 m (closed); No. 2: 5.6 x 4.6 m (open)

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: No. 1: 0.18 or 60 m/s; No. 2: 0.21 or 70 m/s
Reynolds Number: No. 1: 1.2 x 10^6/m; No. 2: 1.4 x 10^6/m
Total Pressure: Atmospheric
Dynamic Pressure: No. 1: 2.3 kPa; No. 2: 3.1 kPa
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1965
Date Placed in Operation: 1965
Date(s) Upgraded: Not available
Construction Cost: $5.25 million (1965)
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: 0
Scientists: 7
Technicians: 0
Others: 0
Administrative/Management: 2
Total: 9

Description: The NAL 6 m Low-Speed Wind Tunnel LS is a continuous flow, closed-circuit, single-return subsonic wind tunnel. The tunnel has both a semiclosed and open test section.

Testing Capabilities: The tunnel has struts for the six-component pyramid-type external balance for model tests of V/STOL and conventional airplanes. Auxiliary equipment for the powered model tests consists of a 292 Nm^3/min (maximum) at 5-MPa compressed-air supply. Propeller and half-model testing are also possible. The tunnel can accommodate a model with a wing span of up to 3 m and a weight of 500 kg. It is powered by a 10-bladed, 9-m diameter blower driven by a 3,000-kW electric motor.

Data Acquisition: The tunnel has 38 channels of information that can be recorded on the data acquisition system and reduced off-site.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

TRDI Convertible Wind Tunnel

Country: Japan

Location: Technical Research and Development Institute, Tachikawa-shi, Tokyo, Japan

Owner(s):
Technical Research and Development Institute
The First Division
Third Research Center
1-2-10 Sakae-cho
Tachikawa-shi
Tokyo 190
Japan

Operator(s): Technical Research and Development Institute

International Cooperation: None

Point of Contact: Hideki Kuwano, Technical Research and Development Institute, Tel.: [81]-(425)-24-2411, ext. 130

Test Section Size: No. 1: 10.8 x 10.8 x 14.8 ft; No. 2: 19.7 x 19.7 x 20.5 ft; No. 3: 13 (octagon) x 14 ft

Operational Status: Active

Utilization Rate: 130 days per year

Performance
Mach Number: No.1: 0.04 to 0.17; No. 2: 0.03 to 0.05; No. 3: 0.04 to 0.1
Reynolds Number: 0 to 1.4 x 10^6/ft
Total Pressure: Atmospheric
Dynamic Pressure: 0 to 60 lb/ft^2
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1971
Date Placed in Operation: 1972
Date(s) Upgraded: None
Construction Cost: $880,000 (1971)
Replacement Cost: $8.6 million (1989)
Annual Operating Cost: $40,000 (1989)
Unit Cost to User: $190 per hour (1989)
Source(s) of Funding: Japan Defense Agency

Number and Type of Staff
Engineers: 3
Scientists: 0
Technicians: 3
Others: 0
Administrative/Management: 0
Total: 6

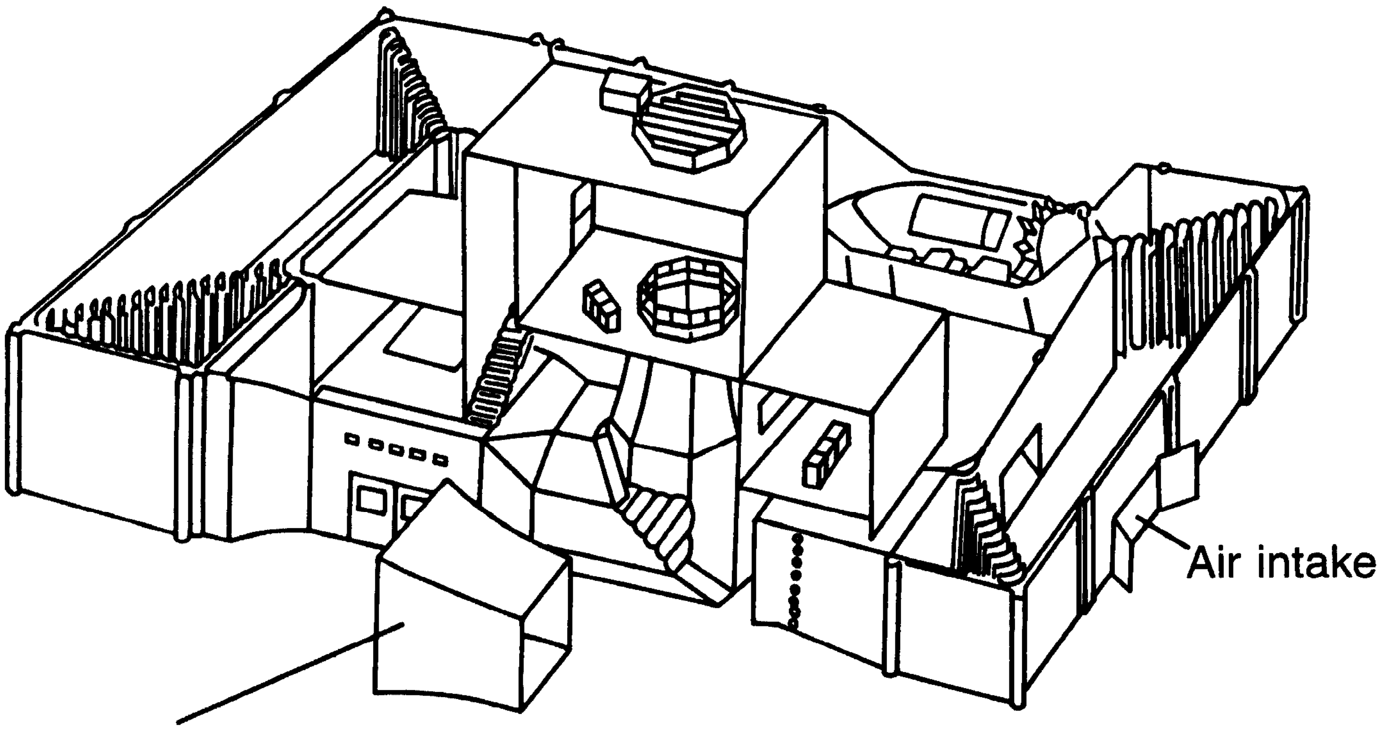
Description: The TRDI Convertible Wind Tunnel is both a continuous-flow, single-return horizontal subsonic wind tunnel and a continuous-flow, open-circuit vertical subsonic wind tunnel. The horizontal tunnel has both an open- and closed-jet test chamber which can accommodate models with a wingspan of up to 8 ft and weight of up to 1,000 lb. The vertical tunnel has an open-jet test chamber.

Testing Capabilities: The horizontal tunnel has two horizontal test sections: one uses a strut-type balance for six-component force tests; the other is used for large model tests. The vertical tunnel has a spin test section with a rotary balance apparatus. The test section is used for free-spin and aerodynamic tests. The tunnel is powered by a 10-bladed, 5.5-m diameter fan. The maximum power is 1,900 kW.

Data Acquisition: The tunnel has 10 channels of information that can be recorded on the acquisition system and reduced on-site with a minicomputer.

Planned Improvements (Modifications/Upgrades): None

Figure VII.8: Schematic Diagram of the TRDI Convertible Wind Tunnel



Source: TRDI

TRDI Low-Speed Wind Tunnel

Country: Japan

Location: Technical Research and Development Institute, Tachikawa-shi, Tokyo, Japan

Owner(s):
Technical Research and Development Institute
The First Division
Third Research Center
1-2-10 Sakae-cho
Tachikawa-shi
Tokyo 190
Japan

Operator(s): Technical Research and Development Institute

International Cooperation: None

Point of Contact: Hideki Kuwano, Technical Research and Development Institute, Tel.: [81]-(425)-24-2411, ext. 130

Test Section Size: 8.2 ft diameter x 11.5 ft long

Operational Status: Active

Utilization Rate: 230 days per year

Performance
Mach Number: 0.04 to 0.17 or 50 to 190 ft/s
Reynolds Number: 0 to 1.4 x 10^6/ft
Total Pressure: Atmospheric
Dynamic Pressure: 0 to 60 lb/ft^2
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1961
Date Placed in Operation: 1962
Date(s) Upgraded: None
Construction Cost: $273,000 (1961)
Replacement Cost: $3.5 million (1989)
Annual Operating Cost: $26,000 (1989)
Unit Cost to User: $105 per hour (1989)
Source(s) of Funding: Japan Defense Agency

Number and Type of Staff
Engineers: 3
Scientists: 0
Technicians: 3
Others: 0
Administrative/Management: 0
Total: 6

Description: The TRDI Low-Speed Wind Tunnel is a continuous-flow, single-return subsonic wind tunnel. The tunnel has open- and closed-jet test chambers that can accommodate models with a wingspan of up to 6 ft and weight of up to 250 lb.

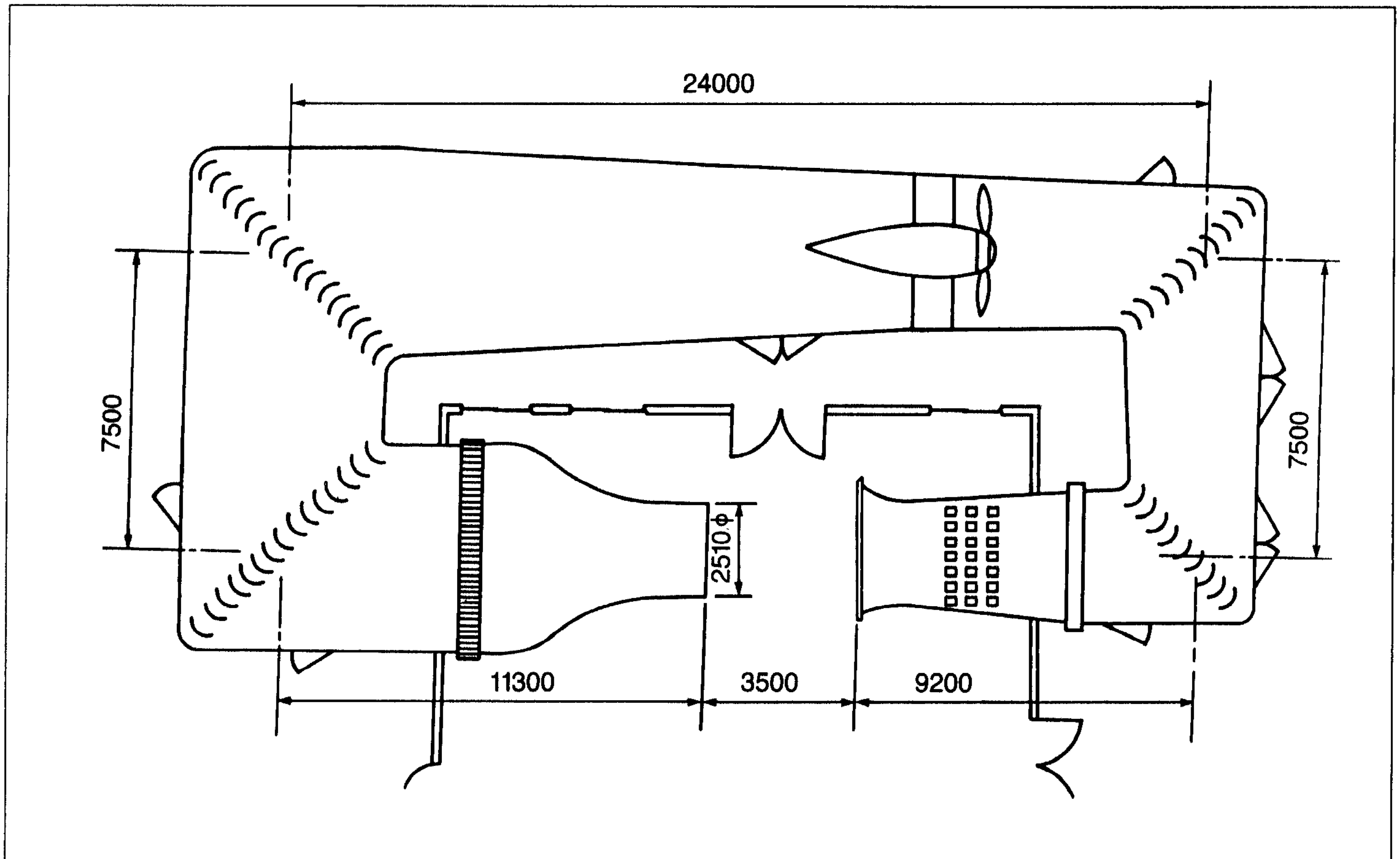
Testing Capabilities: The tunnel has two types of model-support systems: a sting support and a wire support. The sting-support system is used for six-component force tests and high angle of attack tests up to 90 degrees. The wire-support system is generally used for external store separation and flutter tests. The tunnel is powered by a 10-bladed, 3.6-m diameter fan. The maximum power is 450 kW.

Data Acquisition: The tunnel has nine channels of information that can be recorded on the data acquisition system and reduced on-site with a Hewlett Packard 9825 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Figure VII.10: Schematic Diagram of the TRDI Low-Speed Wind Tunnel



Source: TRDI

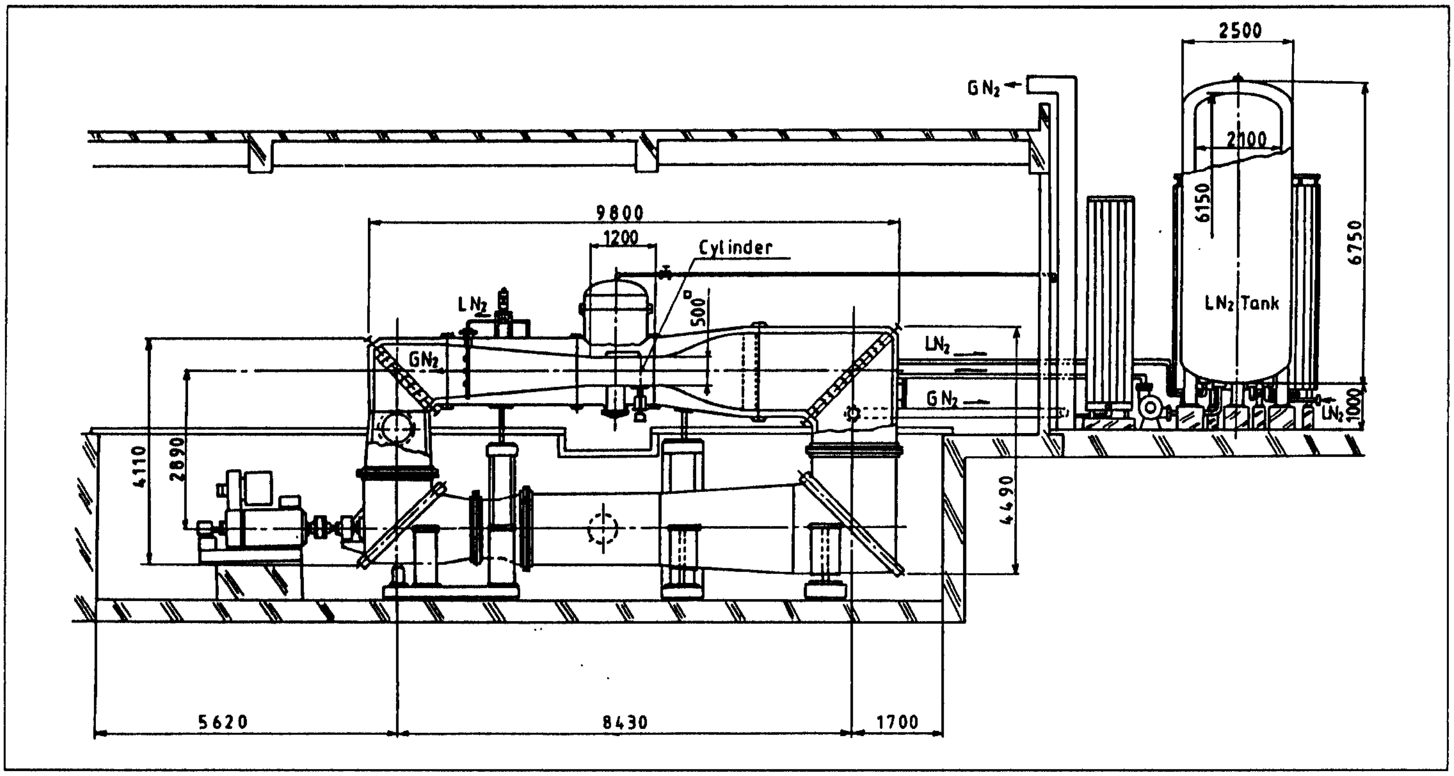
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 119. Adachi, Tsutomu, Kazuo Matsuuchi, Satoshi Matsuda, and Tatsuo Kawai. "On the Force and Vortex Shedding on a Circular Cylinder from Subcritical up to Transcritical Reynolds Numbers." In: Journal of the Japan Society of Mechanical Engineers, vol. 51, no. 461 (1985-1), pp. 295-299 (in Japanese). Adachi, Tsutomu, Kazuo Matsuuchi, and Hiroki Ono. "Characteristics of Hot-Wire Anemometer in Low Temperature Flow (Effect of Aspect Ratio)." In: Journal of the Japan Society of Mechanical Engineers, vol. 54, no. 498 (1988-2), pp. 387-392 (in Japanese). Adachi, Tsutomu, Hiroki Ono, Kazuo Matsuuchi, Tatsuo Kawai, and Tetsuo Cho. "Flow Around a Circular Cylinder in the High Reynolds Number Range (Effect of Surface Roughness)." In: Journal of the Japan Society of Mechanical Engineers, vol. 55, no. 511 (1989-3), pp. 685-692 (in Japanese). Adachi, Tsutomu, Hiroki Ono, Kazuo Matsuuchi, Tatsuo Kawai, and Tetsuo Cho. "Drag and Vortex Shedding from Circular Cylinder in the High Reynolds Number Range (Effect of Surface Roughness)." In: Journal of the Japan Society of Mechanical Engineers, vol. 55, no. 517 (1989-9), pp. 2597-2601 (in Japanese). Adachi, Tsutomu, Yoshimasa Yoshizawa, Yasunori Kobayashi, Masahide Mura Kami, Kazuo Matsuuchi, Tatsuo Kawai, Tetsuo Cho, Yasunaga Shimura, Masaya Tanaka, and Sohemon Fuchigami. "Cryogenic Wind Tunnel and Its Performance for High Reynolds Number Testing." In: Proceedings of the International Conference on Fluid Dynamic Measurement and Its Applications, Beijing, People's Republic of China, 1989.

Date of Information: October 1989

Figure VII.12: Schematic Diagram of the University of Tsukuba Cryogenic Wind Tunnel



Source: University of Tsukuba

Applications/Current Programs: These include the ISAS HIMES vehicle and flutter characteristics of a rocket tail-wing.

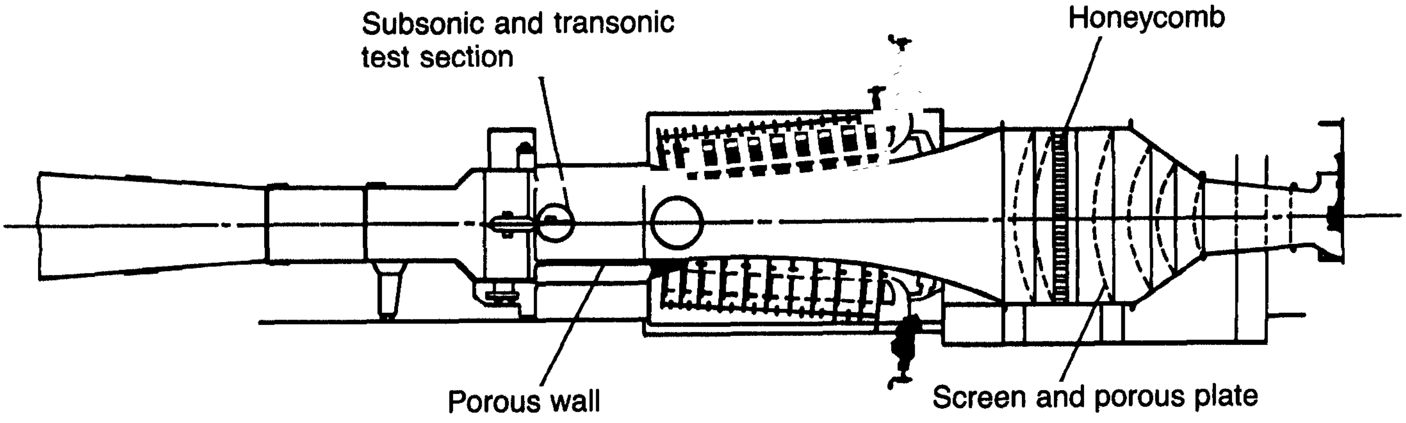
General Comments: The total construction cost of the ISAS Transonic and Supersonic Wind Tunnel system is $20 million (1988). In addition to the transonic and supersonic wind tunnels, the system also includes the air reservoir system and data acquisition system. However, the detailed cost of each component is not precisely determined.

Photograph/Schematic Available: Yes

References: No references have yet been published.

Date of Information: January 1990

Figure VII.14: Schematic Diagram of the ISAS Transonic Wind Tunnel



Source: ISAS

Applications/Current Programs: Current applications include testing models of commercial airplanes, fighter aircraft, missiles, and spaceplanes.

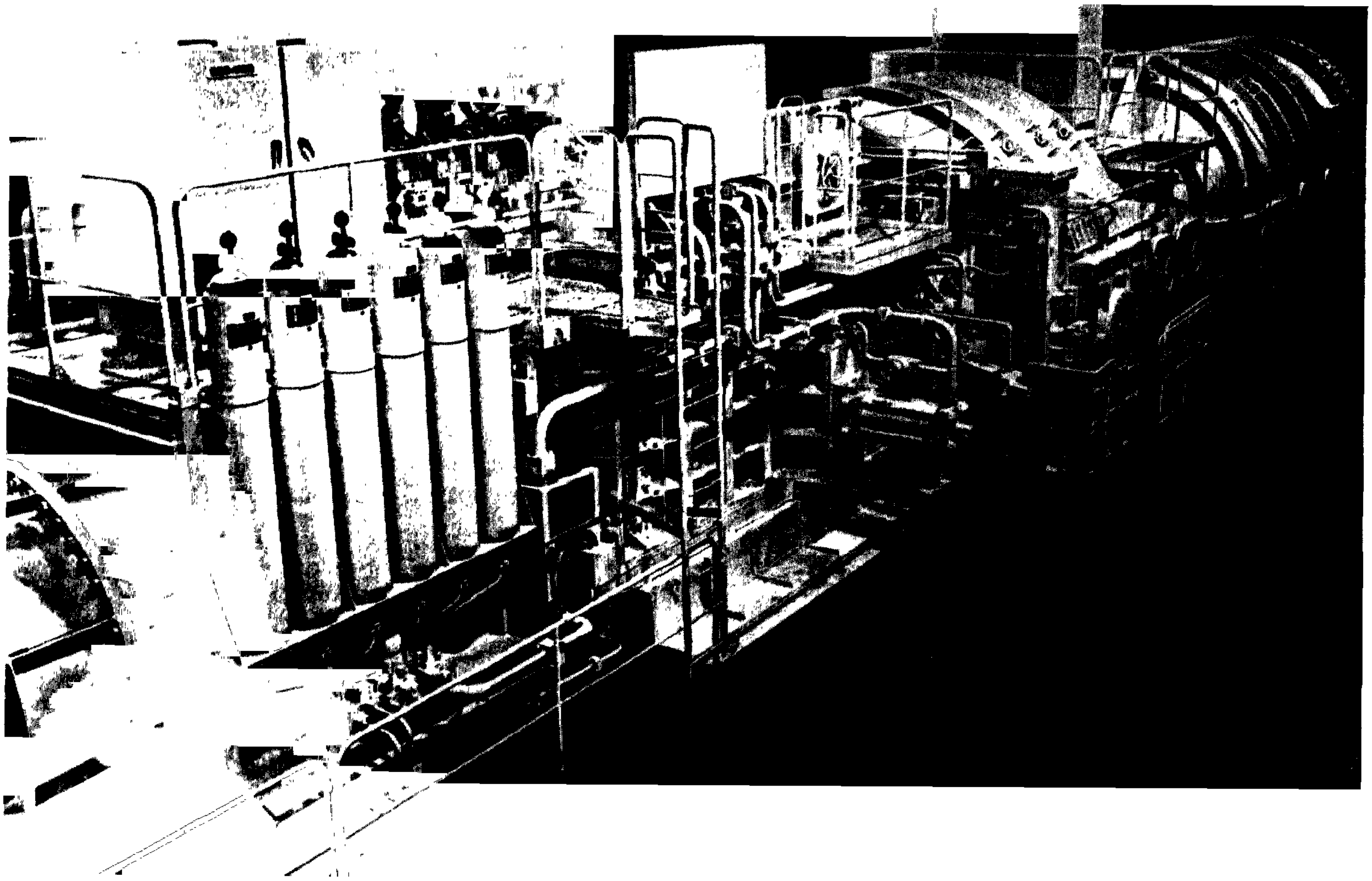
General Comments: None

Photograph/Schematic Available: Yes

References: None available

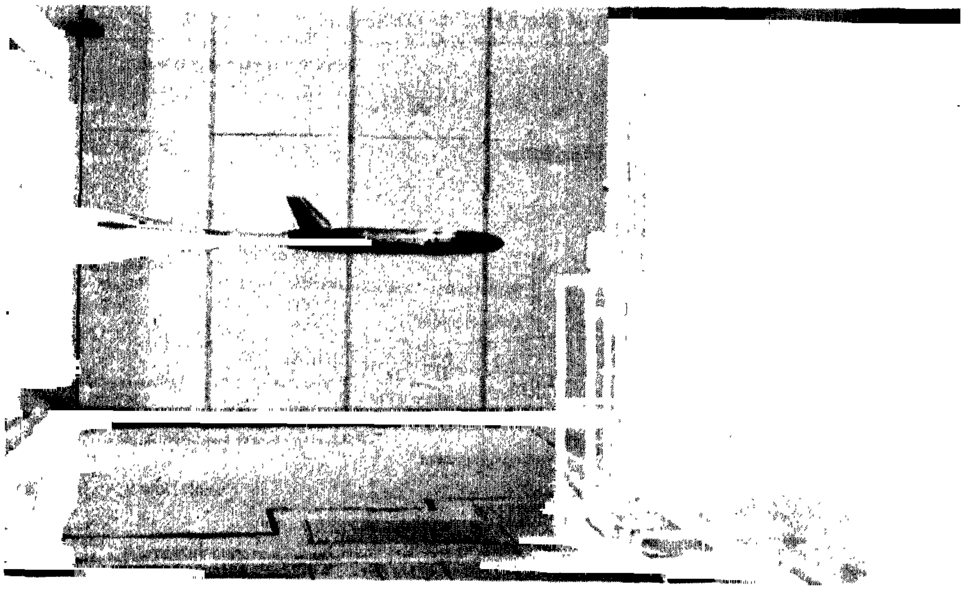
Date of Information: October 1989

Figure VII.15: KHI 1 m Transonic Wind Tunnel



Source: KHI

Figure VII.18: Sting Strut Model Supporting Equipment of the KHI 1 m Transonic Wind Tunnel

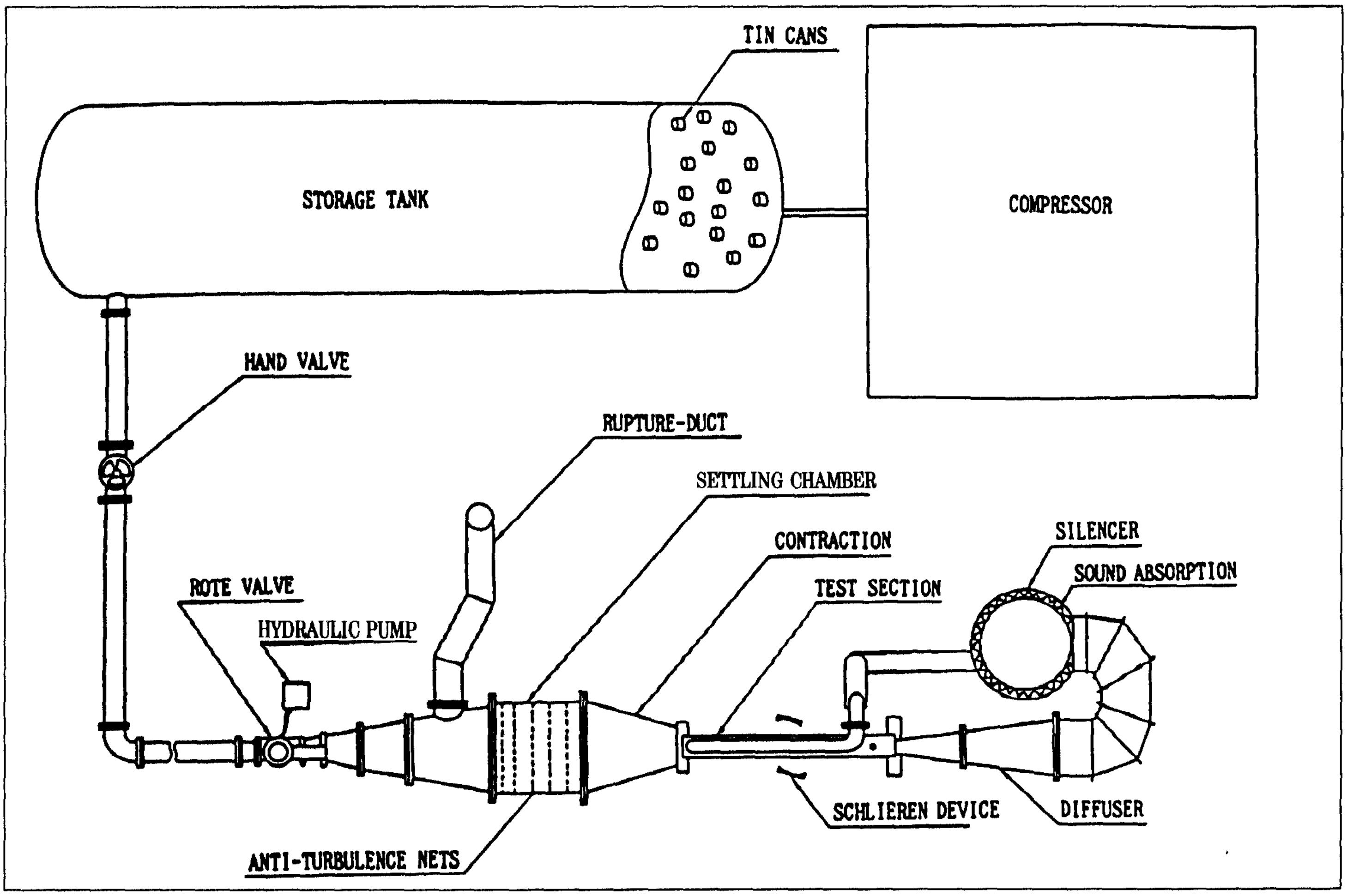


Source: KHI

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C: National Aeronautics and Space Administration, 1985, vol. 1, p. 144.

Date of Information: October 1989

Figure VII.19: Schematic Diagram of the KHI Two-Dimensional Wind Tunnel



Source: KHI

NAL 2 m Transonic Wind Tunnel HS

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: Not available

Point of Contact: M. Ebihara, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911

Test Section Size: 2 x 2 x 4.13 m

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.1 to 1.4
Reynolds Number: 1.6 to 6 x 10^6/m
Total Pressure: 40 to 130 kPa
Dynamic Pressure: 1.9 to 42 kN/m^2
Total Temperature: 318 to 333 degrees Kelvin
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1960
Date Placed in Operation: 1960
Date(s) Upgraded: 1985 (ongoing)
Construction Cost: $8,335,000 (1960)
Replacement Cost: $200 million (1985)
Annual Operating Cost: $3,638,000 to $7,275,000 for maintenance (1989)
Unit Cost to User: $7,275 per hour (1989)
Source(s) of Funding: Japanese government

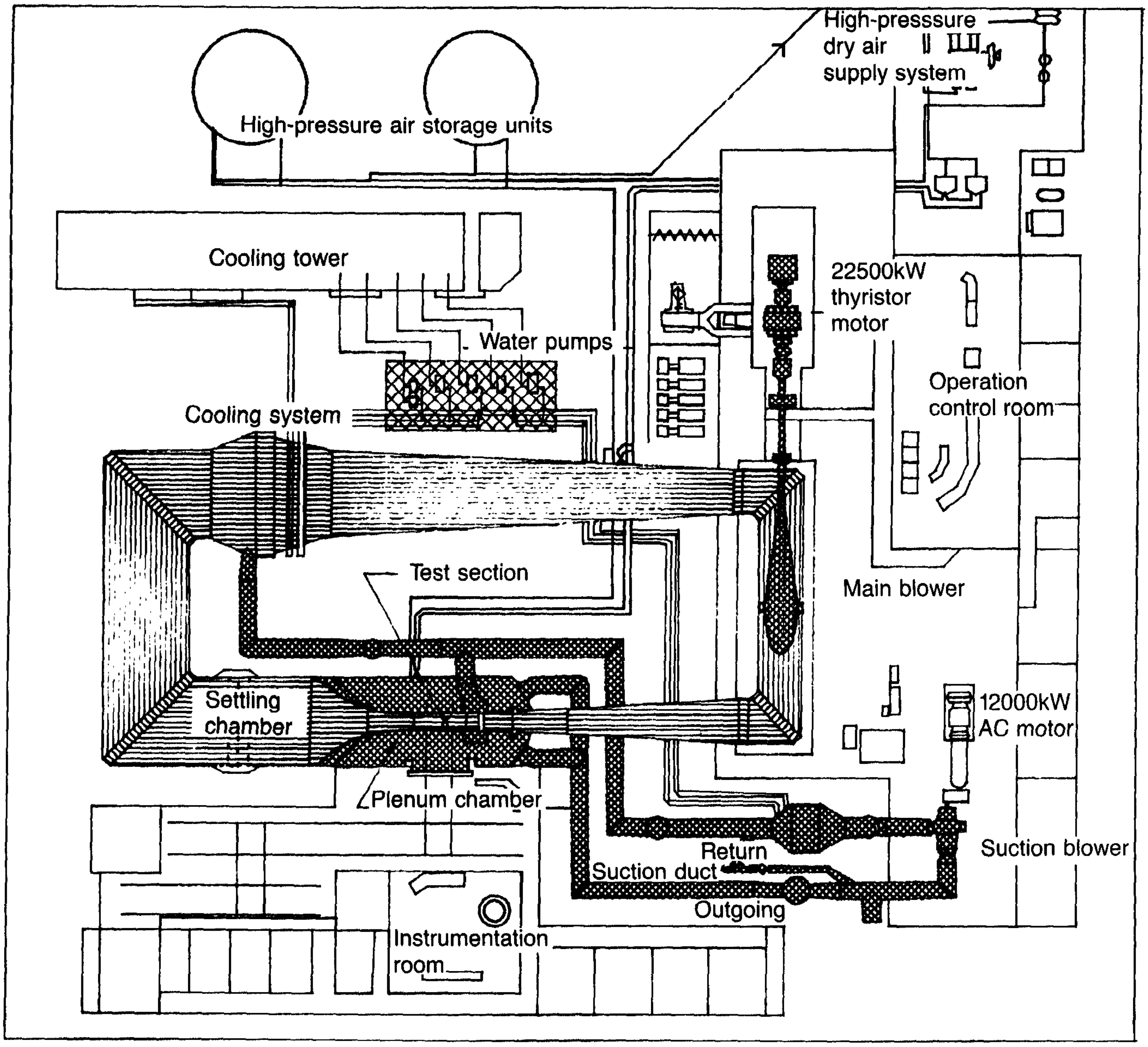
Number and Type of Staff
Engineers: 6
Scientists: 1
Technicians: 7
Others: 0
Administrative/Management: 2
Total: 16

Description: The NAL 2 m Transonic Wind Tunnel HS is a continuous-flow, closed-circuit, single-return transonic wind tunnel. It is driven by a 22.5-MW thyrister motor, controllable to a Mach number accuracy of 0.0005. It has a settling chamber-to-test section contraction ratio of 20 to achieve a turbulence level of 0.2 percent in the mass flow fluctuation.

Testing Capabilities: The NAL 2 m is equipped with three test section carts. The first cart uses a sting-strut support for complete-model testing. This cart has four walls that are perforated at 20-percent open-area ratio with 12-mm diameter normal holes. The second cart is used for semispan-model testing and has the same wall configuration as the first cart. The third cart is used for complete-model testing, but it has 60-degree slant holes at 8 percent open-area ratio. For near-sonic and supersonic tests, an auxiliary suction system with a 12-MW power unit is used in combination with a flexible wall nozzle and second throat settings to establish desired Mach numbers.

Data Acquisition: The tunnel has 96 A/D converter channels in 3 data acquisition speed ranges: 16 channels for high-speed (200 kHz) acquisition, 32 channels for medium-speed (50 kHz) acquisition, and 48 channels

Figure VII.21: Schematic Diagram of the NAL 2 m Transonic Wind Tunnel HS



Source: NAL

Planned Improvements (Modifications/Upgrades): The Hewlett Packard 2113B data acquisition and processing system computer was expected to be replaced by a DG ECLIPSE MV/7800XP computer in Japan fiscal year 1989.

Unique Characteristics: None

Applications/Current Programs: Development tests on a transonic wing section are being conducted.

General Comments: The NAL Two-Dimensional Transonic Wind Tunnel was formally known as the NAL RENO Wind Tunnel.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 145. National Aerospace Laboratory. NAL 1988. Chofu-shi, Tokyo: National Aerospace Laboratory, 1988, p. 16.

Date of Information: October 1989

FHI 2 × 2 ft High-Speed Wind Tunnel

Country: Japan

Location: Fuji Heavy Industries, Utsunomiya, Tochigi Prefecture, Japan

Owner(s):
Fuji Heavy Industries
Aircraft Engineering Division
1-1-11 Yonan
Utsunomiya
Tochigi Prefecture 320
Japan

Operator(s): Fuji Heavy Industries

International Cooperation: None

Point of Contact: Akitoshi Nagao, Fuji Heavy Industries, Tel.: [81]-(286)-58-1111

Test Section Size: 2 x 2 ft

Operational Status: Active

Utilization Rate: 20 to 30 tests per day

Performance
Mach Number: 0.2 to 4
Reynolds Number: 3.2 to 3.5 x 10^6/ft
Total Pressure: Atmospheric
Dynamic Pressure: 140 to 800 lb/ft^2
Total Temperature: Atmospheric at stagnation
Run Time: 10 to 30 s (10 s for supersonic)
Comments: Intermittent run time is 20 min.

Cost Information
Date Built: 1981
Date Placed in Operation: 1981
Date(s) Upgraded: Not available
Construction Cost: $2,267,000 (1981)
Replacement Cost: $5.5 million (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Fuji Heavy Industries

Number and Type of Staff
Engineers: 0
Scientists: 0
Technicians: 2
Others: 0
Administrative/Management: 0
Total: 2

Description: The FHI 2 × 2 ft High-Speed Wind Tunnel is an intermittent, indraft, open-circuit, trisonic wind tunnel. It has a supersonic closed test section and a six-percent perforated transonic test section.

Testing Capabilities: The tunnel is equipped with both sting and sidewall model support systems. The sting support system has a six-component internal balance for full-model tests, and the sidewall support system has a three-component balance for half-model tests. Oil flow and schlieren techniques are available for flow visualization tests, and a 10 kg/cm^2, 2.5 m^3 compressed air supply is equipped to simulate exhaust jet flow and pressure measurement equipment (scanivalves). When test Mach numbers are varied over the supersonic region, the fixed nozzle blocks can be changed. This takes about 1 hour. Three supersonic nozzle blocks (Mach 2, 3 and 4) are available for supersonic tests. Additional supersonic nozzles have been installed.

Data Acquisition: A Hewlett Packard 1000 series computer and front-end are used for data acquisition of up to 17 analog channels. Two programmable logic controllers are used for wind tunnel and model position control. On-line data acquisition/reduction programs provide almost instantaneous numerical and graphical results.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: The tunnel's vacuum system is unique because it uses a large collapsible, rubberized storage bag for the air supply.

Applications/Current Programs: The tunnel is used to study transonic and supersonic aerodynamics of military and transport aircraft and rocket configurations.

General Comments: The Canadian firm Dilworth, Secord, Meagher Associates, Ltd. designed the tunnel and sold the wind tunnel technology to FHI.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, pp. 185 and 221.

Date of Information: November 1988

MHI 60 cm Trisonic Wind Tunnel

Country: Japan

Location: Mitsubishi Heavy Industries, Nagoya, Aichi Prefecture, Japan

Owner(s):
Mitsubishi Heavy Industries
Nagoya Aerospace Systems Works
10 Oye-cho, Minato-ku
Nagoya
Aichi Prefecture 455
Japan

Operator(s): Mitsubishi Heavy Industries, Nagoya Aerospace Systems Works

International Cooperation: Council for Scientific and Industrial Research (South Africa)

Point of Contact: Haruhiko Arakawa, Mitsubishi Heavy Industries, Tel.: [81]-(52)-611-8011

Test Section Size: 0.6 x 0.6 x 2.8 m

Operational Status: Active

Utilization Rate: 10 hours per day

Performance
Mach Number: 0.4 to 4
Reynolds Number: 15 to 65 x 10^6/m
Total Pressure: 11.77 bars (maximum)
Dynamic Pressure: 29.4 to 156 kN/m^2
Total Temperature: Ambient
Run Time: 20 s at Mach 1 and 35 s at Mach 2.5
Comments: None

Cost Information
Date Built: 1968
Date Placed in Operation: 1968
Date(s) Upgraded: 1979, 1982, 1987, and 1989
Construction Cost: $3.6 million (1968)
Replacement Cost: $13 million (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The MHI 60 cm Trisonic Wind Tunnel is an intermittent blowdown trisonic wind tunnel. The tunnel is capable of conducting tests in the subsonic, transonic, and supersonic speed ranges. The test gas is exhausted to the atmosphere.

Testing Capabilities: The tunnel is used to conduct six-component force tests; pressure distribution tests; half-model tests; flutter tests (half-wing and empennage); static aeroelastic tests; air intake tests, including unsteady pressure measurements; power effect tests; and flow visualization tests. Angle of attack range is from −15 to 30 degrees when the sting support system is used. An internal six-component balance is used for force measurement of complete aircraft model tests, and a sidewall five-component balance is used for half-model tests. The air storage sphere is 8 m in diameter with air pressure up to 15 kg/cm^2. Tunnel upgrades in 1982 improved the flow uniformity and turbulence level as well as precise control of Mach number. Upgrades in 1987 replaced tunnel control, data acquisition, and processing systems with MX computers. In 1989, a new air compressor was added, which doubled the test capability.

Data Acquisition: The tunnel has 32 channels of data that can record force and pressure data simultaneously. The Mitsubishi Electric MX 2000/MX 3000 computers process data on-line with output by plotter, printer, graphic display, and character display. These computers are connected to the host IBM 3090 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current programs include research and development of aircraft, missiles, and rockets.

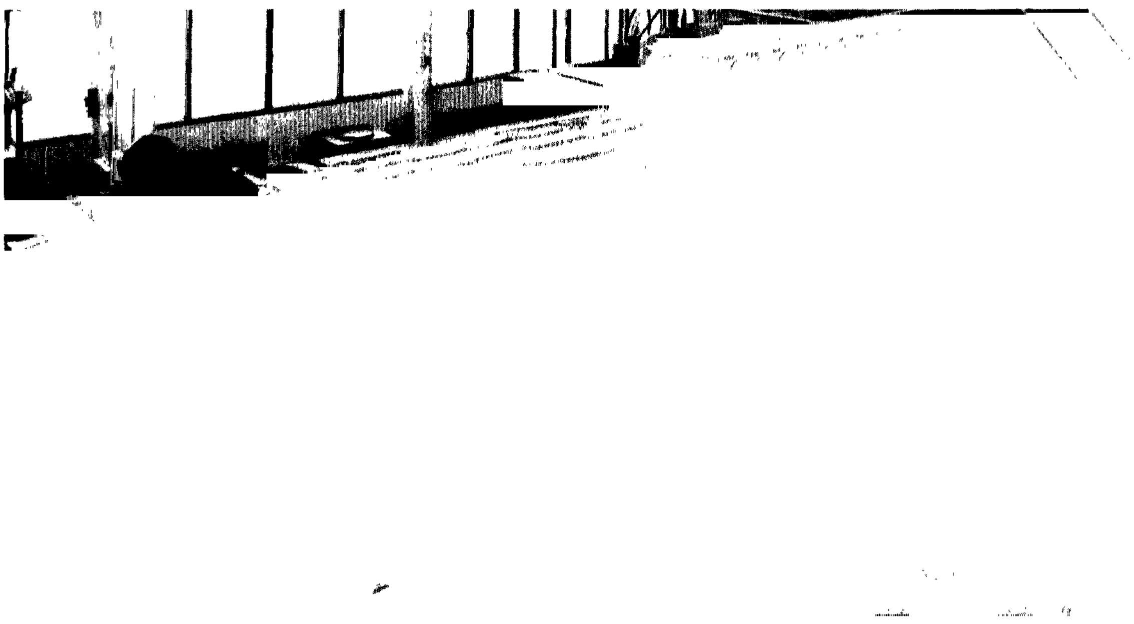
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 184.

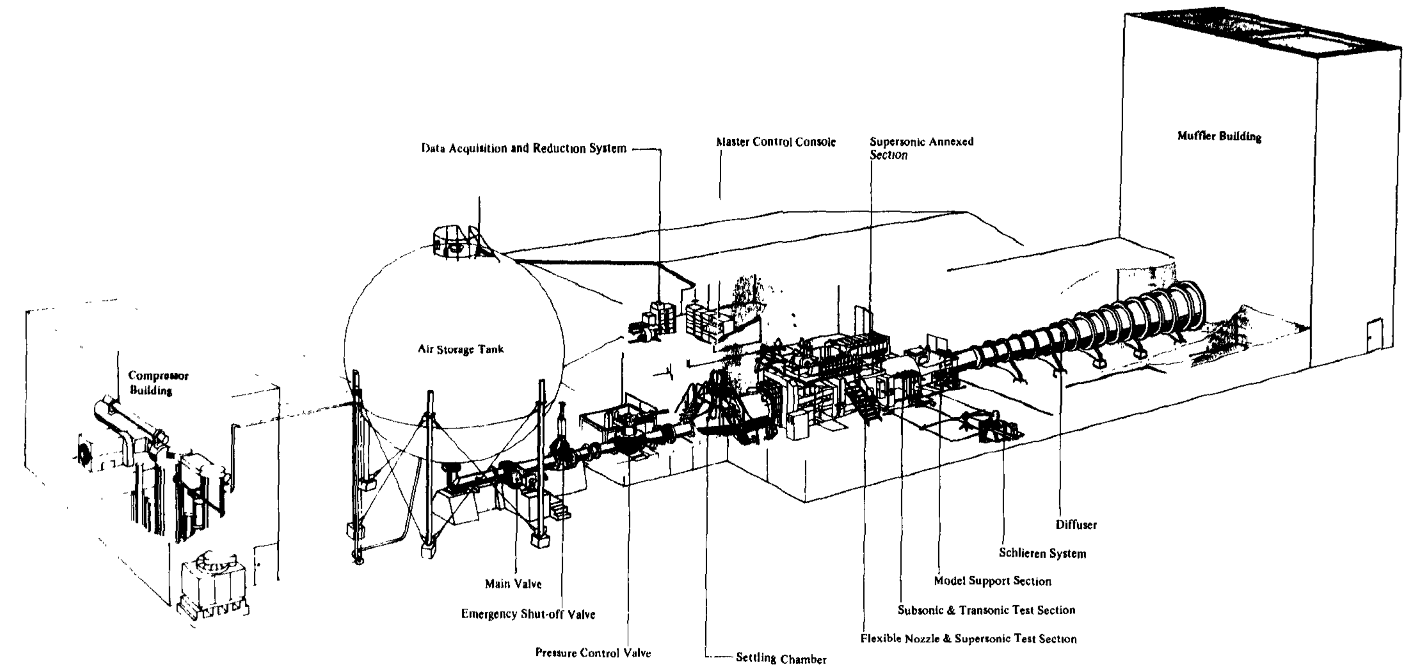
Date of Information: October 1989

Figure VII.22: MHI 60 cm Trisonic Wind Tunnel



Source: MHI

Figure VII.23: Schematic Diagram of the MHI 60 cm Trisonic Wind Tunnel



Source: MHI

ISAS Supersonic Wind Tunnel

Country: Japan

Location: Institute of Space and Astronautical Science, Sagamihara-shi, Kanagawa Prefecture, Japan

Owner(s):
Institute of Space and Astronautical Science
3-1-1 Yoshinodai
Sagamihara-shi
Kanagawa Prefecture 229
Japan

Operator(s): Institute of Space and Astronautical Science

International Cooperation: None

Point of Contact: Professor Keiichi Karashima, Institute of Space and Astronautical Science, Tel.: [81]-(427)-57-3911, ext. 2812

Test Section Size: 0.6 x 0.6 x 0.8 m

Operational Status: Under construction

Utilization Rate: Not yet operational

Performance
Mach Number: 1.5 to 4 (maximum)
Reynolds Number: 1.08 x 10^6/m
Total Pressure: 6 atm (maximum)
Dynamic Pressure: 260 kN/m^2 (maximum)
Total Temperature: Atmospheric
Run Time: 30 s (minimum)
Comments: None

Cost Information
Date Built: 1988
Date Placed in Operation: 1990
Date(s) Upgraded: Not applicable
Construction Cost: $10 million (1988) (See General Comments)
Replacement Cost: Not available
Annual Operating Cost: $220,000 (1990)
Unit Cost to User: $1,000 per hour (1990)
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: 1
Scientists: 0
Technicians: 1
Others: 0
Administrative/Management: 1
Total: 3

Description: The ISAS Supersonic Wind Tunnel is a blowdown supersonic wind tunnel. The tunnel covers Mach numbers 1.5 to 4 nearly continuously by use of a supersonic nozzle with variable throat geometry. The nozzle geometry is regulated before tunnel operation so that the Mach number is fixed during the test.

Testing Capabilities: The tunnel has various testing capabilities including six-component force tests, pressure measurement at 120 points, and optical observation using schlieren and laser interferometry as well as a high-speed video system. In addition, the tunnel has another testing block designed for general uses. These uses may include simulation of free flight, separation of boosters from the vehicle, and opening tests of supersonic parachutes.

Data Acquisition: A high-speed and multi-channel data acquisition system is available, which consists of a computer and the associated measurement devices. Data acquisition is obtained automatically.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: The tunnel is designed particularly for combustion simulation tests.

Applications/Current Programs: These include the aerodynamic characteristics of the ISAS HIMES vehicle, simulation tests of the air-intake of air-breathing propulsion systems, and opening characteristics of supersonic parachutes.

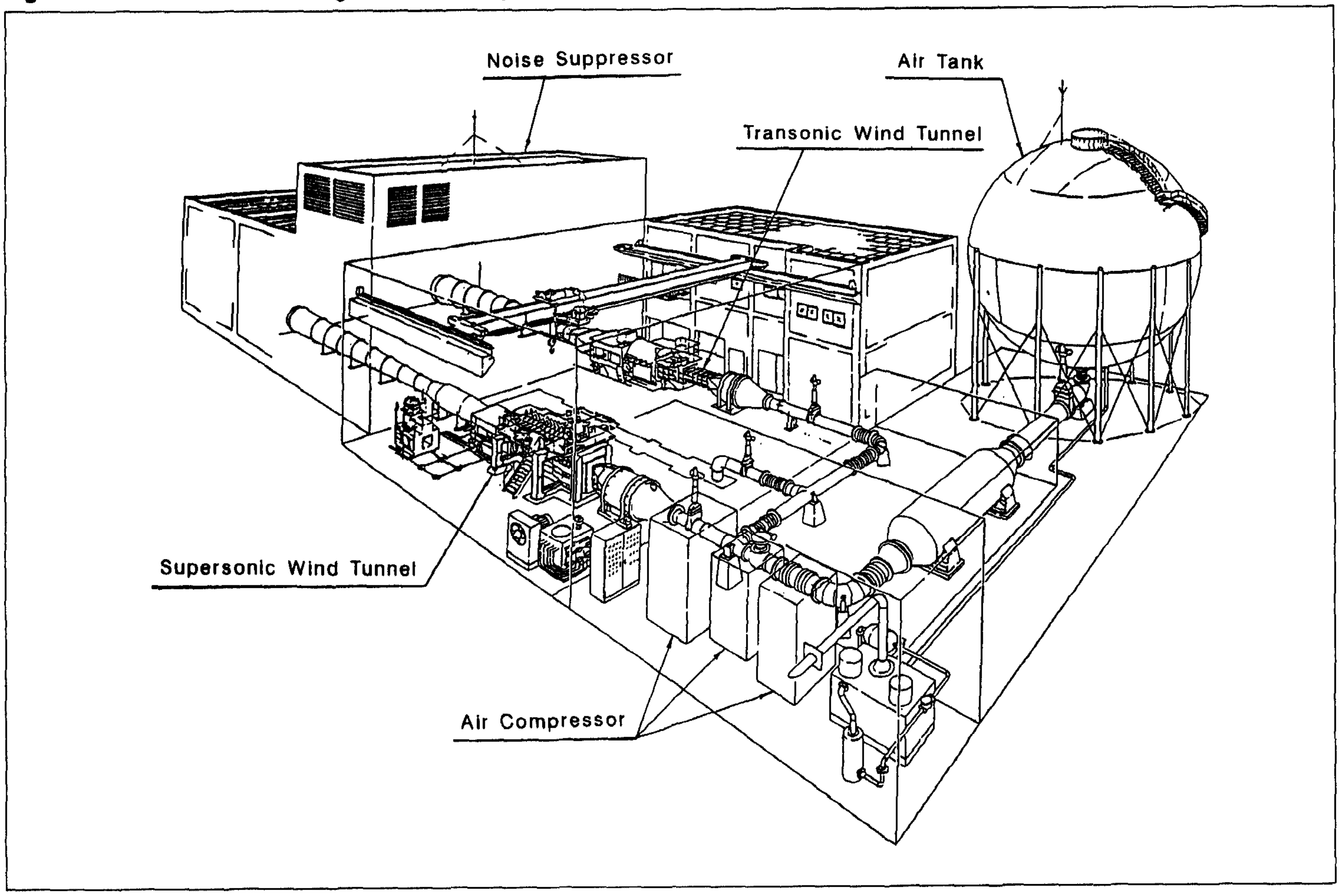
General Comments: The total construction cost of the ISAS Transonic and Supersonic Wind Tunnel system is $20 million (1988). In addition to the transonic and supersonic wind tunnels, the system also includes the air reservoir system and data acquisition system. However, the detailed cost of each component is not precisely determined.

Photograph/Schematic Available: Yes

References: No references have yet been published.

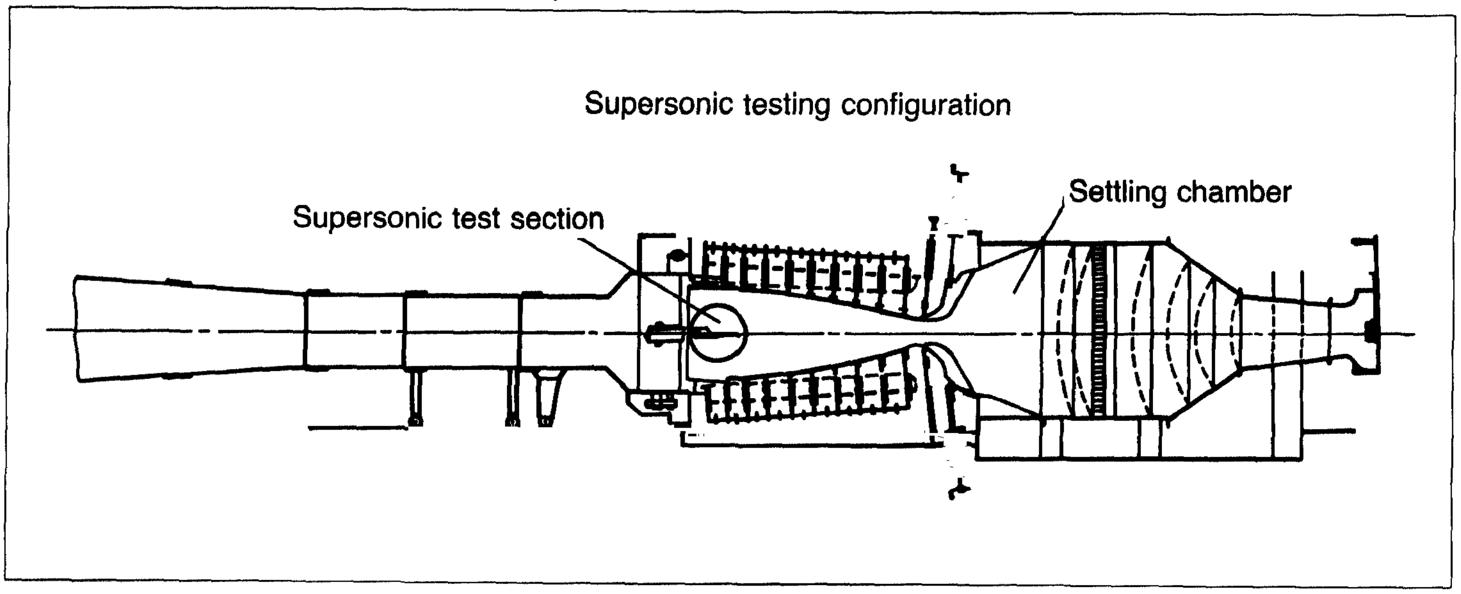
Date of Information: January 1990

Figure VII.24: Schematic Drawing of the ISAS Supersonic Wind Tunnel



Source: ISAS

Figure VII.25: Schematic Diagram of the ISAS Supersonic Wind Tunnel



Source: ISAS

NAL 1 m Wind Tunnel

Country: Japan

Location: National Aerospace Laboratory, Choufu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: S. Sakakibara, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911

Test Section Size: 1 x 1 m

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 1.4 to 4
Reynolds Number: 0.6 to 1.8 x 10^7/ft
Total Pressure: 152 to 1,275 kPa
Dynamic Pressure: 65 to 155 kPa
Total Temperature: Ambient
Run Time: 30 to 60 s with varying model incidence
Comments: None

Cost Information
Date Built: 1961
Date Placed in Operation: 1961
Date(s) Upgraded: 1977, 1980, and 1988
Construction Cost: $6.7 million (1961)
Replacement Cost: $50 million (1989)
Annual Operating Cost: $360,000 (1989)
Unit Cost to User: $1,800 per run (1989)
Source(s) of Funding: None

Number and Type of Staff
Engineers: 5
Scientists: 0
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 6

Description: The tunnel 1 m Wind Tunnel is an intermittent, blowdown supersonic wind tunnel.

Testing Capabilities: The tunnel is capable of conducting (1) force measurements using six-component strain-gauge balances, (2) pressure measurements using scanivalves and electric scanning pressure transducers, (3) other measurements using dynamic stability parameters by the forced oscillation method and free-flight technique, and (4) flow visualization using color schlieren, vapor screen, and oil streaks. Other equipment includes jet simulation with air up to 2 MPa.

Data Acquisition: The tunnel has 32 A/D channels and 12 digital inputs that are recorded and reduced in an on-line operation using an ECLIPSE-S 140 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: The NAL 1 m Wind Tunnel is the largest supersonic wind tunnel in Japan.

Applications/Current Programs: These include basic and projected research for airplanes, space vehicles and other fundamental configurations. Measurements of aerodynamic characteristics for NAL's spaceplane and NASDA's H-II Orbiting Plane (HOPE) are currently underway. The tunnel is also used for investigations of aerodynamic components (such as engine intakes) at supersonic speeds between Mach 1.4 and 4.

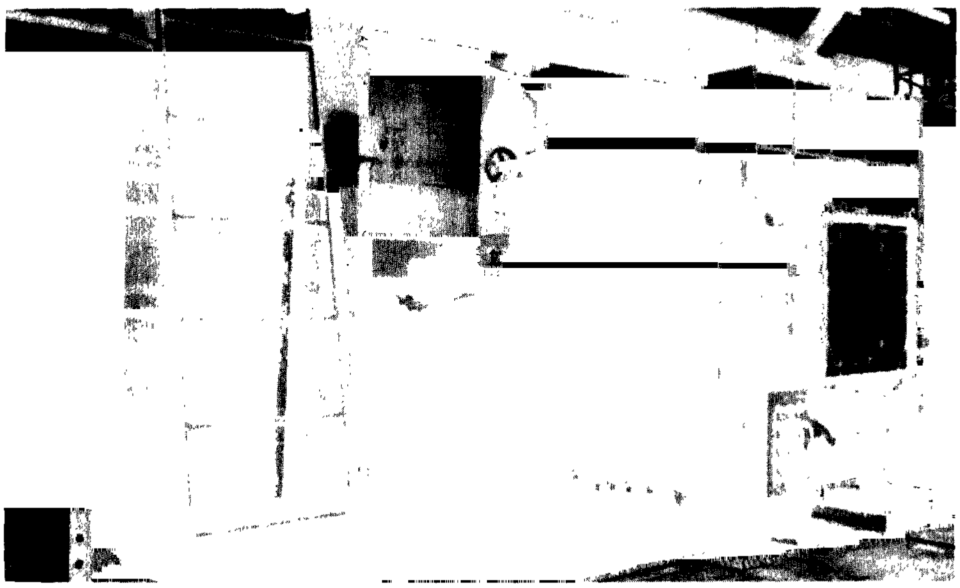
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 225. National Aerospace Laboratory. NAL 1988. Chofu-shi, Tokyo: National Aerospace Laboratory, 1988, p. 11.

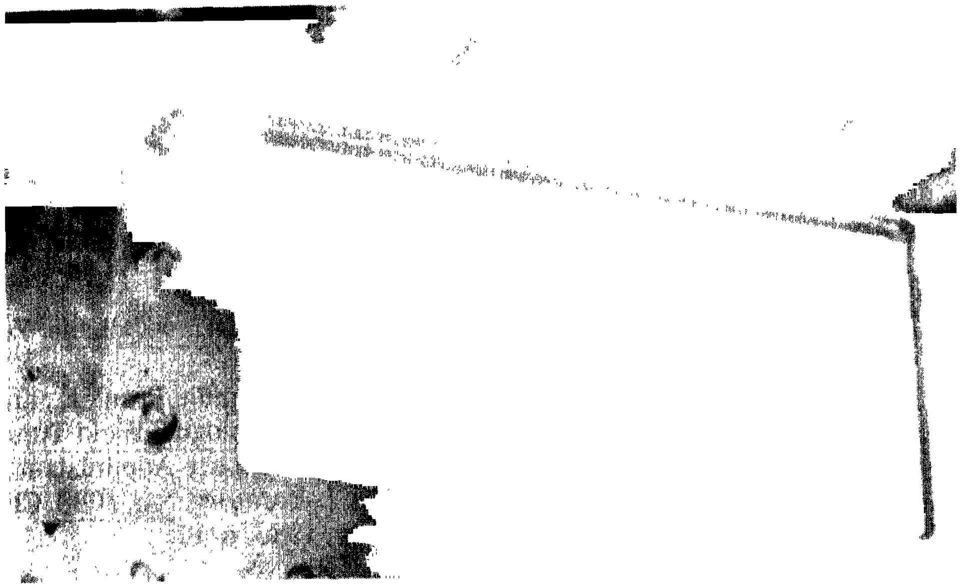
Date of Information: October 1989

Figure VII.26: Test Section of the NAL 1 m Wind Tunnel



Source: NAL

Figure VII.27: Test of a Scramjet Intake in the NAL 1 m Wind Tunnel



Source: NAL

NAL 50 cm Hypersonic Wind Tunnel

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: K. Hozumi, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911

Test Section Size: 50 cm diameter (axisymmetric)

Operational Status: Active

Utilization Rate: 3 runs per day

Performance
Mach Number: 5, 7, 9, and 11
Reynolds Number: 0.3 to 7.2 x 10^6/m
Total Pressure: 1 to 10 MPa
Dynamic Pressure: 7.8 to 78 kPa
Total Temperature: 600 to 1,500 degrees Kelvin
Run Time: 120 s (maximum)
Comments: None

Cost Information
Date Built: 1965
Date Placed in Operation: 1966
Date(s) Upgraded: Not available
Construction Cost: $2,766,000 (1965)
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $2,910 per run (1989)
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 6

Description: The NAL 50 cm Hypersonic Wind Tunnel is an intermittent blowdown hypersonic wind tunnel. The tunnel has four interchangeable axisymmetric contoured nozzles and is equipped with an alumina pebble-bed heater.

Testing Capabilities: The tunnel is capable of six-component force tests, pressure tests using a parallel operation of three scanivalves, and heat transfer tests using a Calorimeter and infrared ray methods. Schlieren, oil flow, and thermographic flow visualization techniques are available.

Data Acquisition: The tunnel has 64 channels of data and 10,000 samples per second can be acquired and reduced off-line on an ECLIPSE-S 140 computer system.

Planned Improvements (Modifications/Upgrades): These include construction of a new test section with a 1.2-m exit diameter Mach 10 nozzle parallel to the existing 50-cm test section.

Unique Characteristics: Currently, the NAL 50 cm Hypersonic Wind Tunnel is the only hypersonic wind tunnel in Japan.

Applications/Current Programs: Measurements of aerodynamic characteristics and heat transfer distributions for NAL's spaceplane and NASDA's HOPE are currently underway. The tunnel is also used to investigate the aerodynamic and aerothermodynamic characteristics of hypersonic transports.

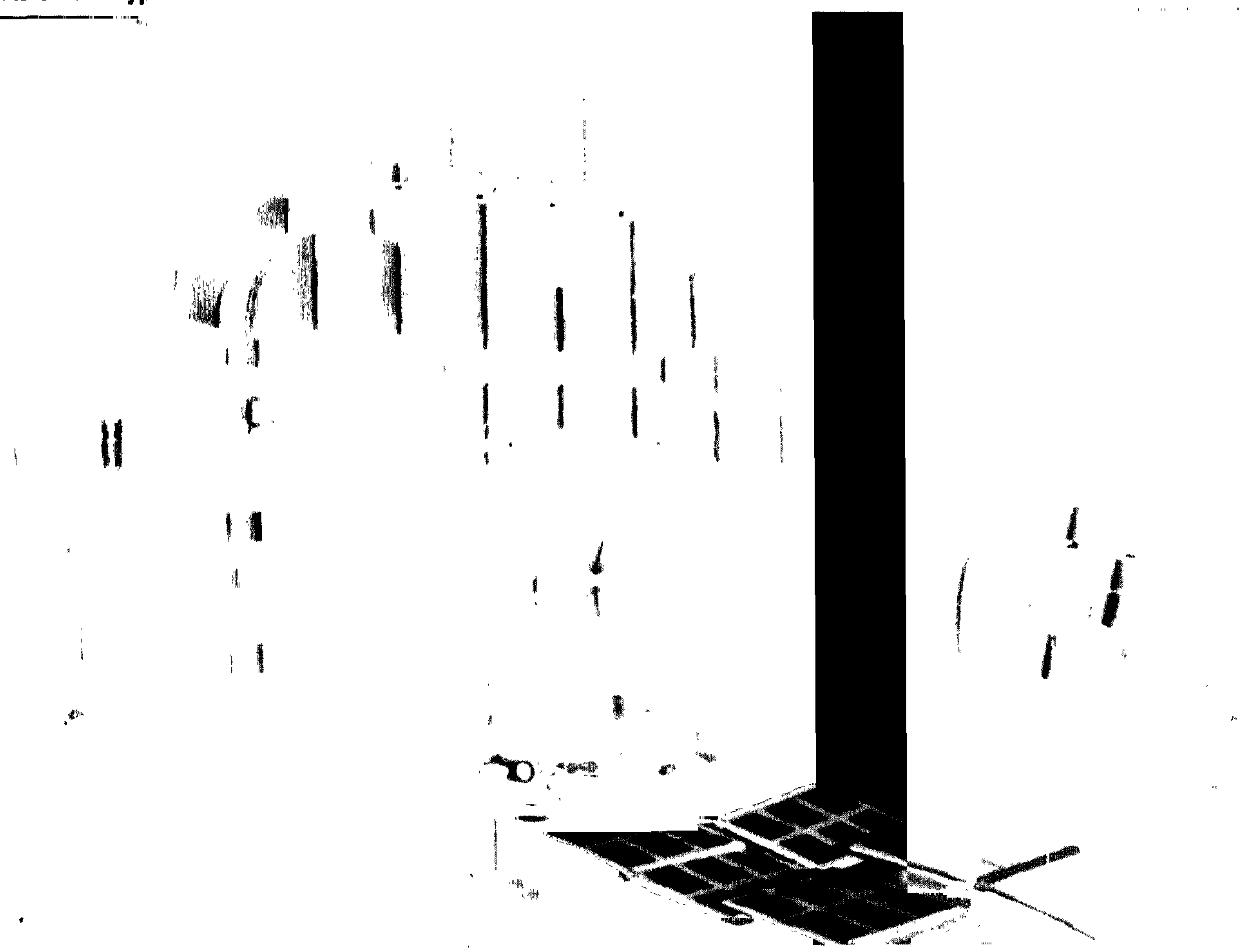
General Comments: None

Photograph/Schematic Available: Yes

References: National Aerospace Laboratory. NAL 1988. Chofu-shi, Tokyo: National Aerospace Laboratory, 1989, p. 11. National Aerospace Laboratory. Design and Construction of the 50 cm Hypersonic Wind Tunnel at National Aerospace Laboratory. Chofu-shi, Tokyo: National Aerospace Laboratory, 1969 (NAL Technical Report No. 116 (in Japanese).

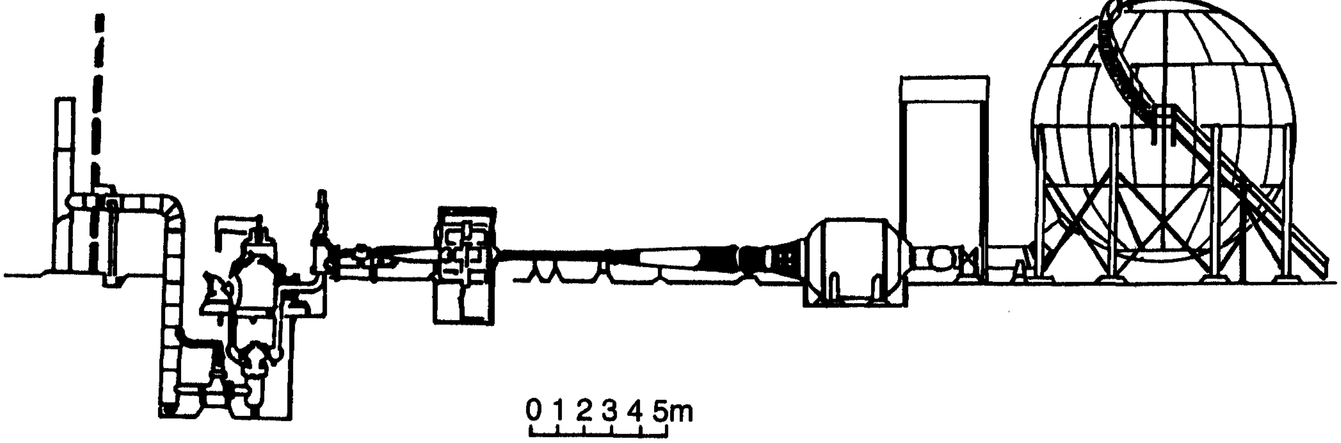
Date of Information: October 1989

Figure VII.28: NAL 50 cm Hypersonic Wind Tunnel



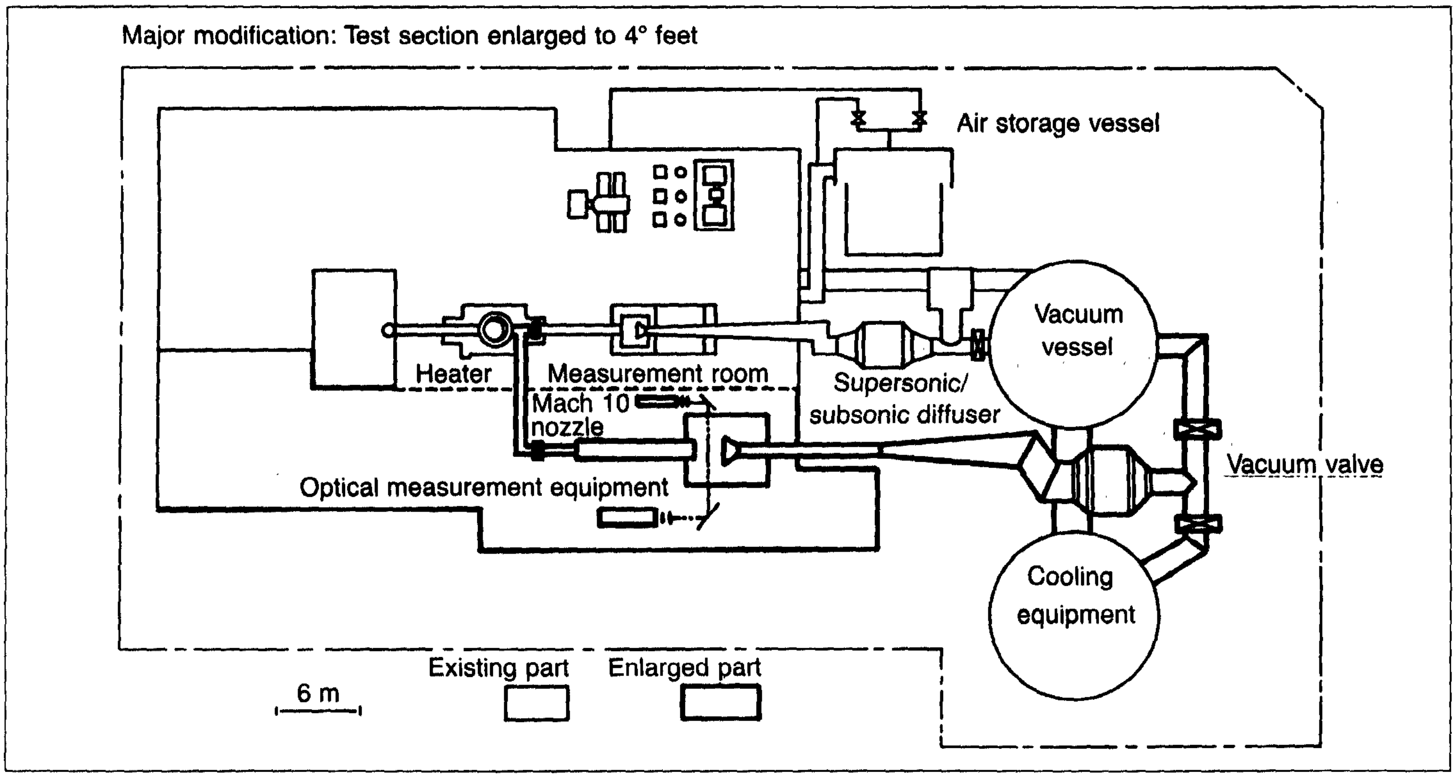
Source: GAO

Figure VII.29: Schematic Drawing of the NAL 50 cm Hypersonic Wind Tunnel



Source: NAL

Figure VII.30: Schematic Diagram of the NAL 50 cm Hypersonic Wind Tunnel



Source: NAL

MHI Small Turbojet Development Test Cell (1007)

Country: Japan

Location: Mitsubishi Heavy Industries, Komaki-shi, Aichi Prefecture, Japan

Owner(s):
Mitsubishi Heavy Industries
Aircraft and Special Vehicles Headquarters
Nagoya Guidance and Propulsion Systems Works
1200, Higashi-tanaka
Komaki-shi
Aichi Prefecture 485
Japan

Operator(s): Mitsubishi Heavy Industries, Engine Engineering Department

International Cooperation: None

Point of Contact: Mikio Kajita, Mitsubishi Heavy Industries, Tel.: [81]-(568)-79-2111, ext. 4610

Test Cell Size: 8 in. diameter (direct connect); 18 x 18 x 40 ft

Operational Status: Active

Utilization Rate: 10 to 20 tests per month

Performance
Mass Flow: 12 lb/s for sea level conditions
Altitude Range: Sea level to 20,000 ft
Temperature Range: –30 to 180 degrees Fahrenheit
Pressure Range: 33 psia
Speed Range: Mach 0 to 1.2
Comments: None

Cost Information
Date Built: 1980
Date Placed in Operation: 1980
Date(s) Upgraded: 1983
Construction Cost: $1 million (1980)
Replacement Cost: Not available
Annual Operating Cost: $400,000 per year (1989)
Unit Cost to User: Not available
Source(s) of Funding: Mitsubishi Heavy Industries

Number and Type of Staff
Engineers: 6
Scientists: 0
Technicians: 12
Others: 2
Administrative/Management: 2
Total: 22

Description: The MHI Small Turbojet Development Test Cell (1007) is an altitude engine test facility. It was originally set up as a sea level flight condition simulator. For altitude simulation tests, air is used for the ejector. For inlet temperature tests, liquid nitrogen/liquid oxygen is used. The capacity of the installed thrust stand is about 1,100 lb. The thrust level is 600 lb.

Testing Capabilities: The test cell is used mainly for performance and mission-simulated testing of small turbojets for missiles and target drones. It also has the environmental test capabilities for high and low temperature and water ingestion.

Data Acquisition: A minicomputer-controlled digital data acquisition system (MEC MELCOM MX3000 X2) is available for high-speed general-purpose data acquisition (384 channels and 100 kHz). A personal computer-controlled system is also available for lower speed data acquisition (170 channels). Analog recording devices such as magnetic tape, strip chart, and oscillograph are prepared.

Planned Improvements (Modifications/Upgrades): In 1989, the capacity of the air source compressors were expected to be tripled. The compressors can be used as exhausters for altitude simulation up to 40,000 ft pressure altitude. An inlet air cooling system will also be added to realize full-altitude testing of 700-lb class turbojet/fan or 1,500-hp class turboshaft engines up to 30,000 ft at Mach 1.

Unique Characteristics: None

Applications/Current Programs: Current applications include testing small- and medium-sized turbojets.

General Comments: Start simulation is only for altitude tests.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 92.

Date of Information: October 1989

Figure VII.31: MHI Small Turbojet Development Test Cell (1007)

Source: MHI

NAL Ram/Scramjet Engine Test Facility

Country: Japan

Location: National Aerospace Laboratory, Kakuda Branch, Kimigaya, Kakuda, Miyagi Prefecture, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory, Kakuda Branch

International Cooperation: Not applicable

Point of Contact: Hiroshi Miyajima, National Aerospace Laboratory, Kakuda Branch, Tel.: [81]-(224)-68-3111

Test Cell Size: 510 x 510 mm (nozzle exit area)

Operational Status: Planned

Utilization Rate: Unknown

Performance
Mass Flow: 10.41 kg/s (case A) (See General Comments)
Altitude Range: Up to 35,000 m (case A)
Temperature Range: 2,557 degrees Kelvin (case A)
Pressure Range: 10.25 MPa (case A)
Speed Range: Mach 6.73 (case A)
Comments: Heat source is an air storage heater and vitiation heater. Air flow rate is 7.88 kg/s. See Description for flight conditions to be simulated and General Comments for additional performance characteristics.

Cost Information
Date Built: 1992
Date Placed in Operation: 1992
Date(s) Upgraded: Not applicable
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Unknown
Unit Cost to User: Unknown
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The NAL Ram/Scramjet Engine Test Facility will be an intermittent blowdown wind tunnel with steam ejectors. NAL has selected Kobe Steel Corporation for Phase I construction of the test facility for ramjet and scramjet engines, which includes a hypersonic wind tunnel. Kobe Steel Corporation will construct the facility in cooperation with FluiDyne Engineering Corporation. The tunnel will have a 510 × 510 mm nozzle capable of speeds up to Mach 6.73. It will be able to simulate flight conditions at altitudes up to 35,000 m. The facility will simulate the following flight conditions.

Case	A	B	C
Altitude	35,000 m	25,000 m	20,000 m
Free-stream conditions			
Mach number	8	6	4
Static temperature	237 degrees Kelvin	222 degrees Kelvin	217 degrees Kelvin
Static pressure	575 Pa	2,549 Pa	5,528 Pa
Air inlet conditions			
Mach number	6.73	5.3	3.41
Static temperature	324 degrees Kelvin	275 degrees Kelvin	274 degrees Kelvin
Static pressure	1,615 Pa	5,322 Pa	12,261 Pa

The heat source for case A will be a combination of a storage heater and a vitiation heater. Case B will have either a storage heater or a vitiation heater for its heat source. Case C will only have a storage heater. The facility will be built at NAL's Kakuda Propulsion Test Center at Kakuda, Miyagi Prefecture in northern Japan. The facility is scheduled for completion in 1992.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not applicable

Unique Characteristics: Not available

Applications/Current Programs: The facility will be able to test ramjets and scramjets.

General Comments: The facility will have the following capabilities to simulate flight conditions as indicated in cases A, B, and C above.

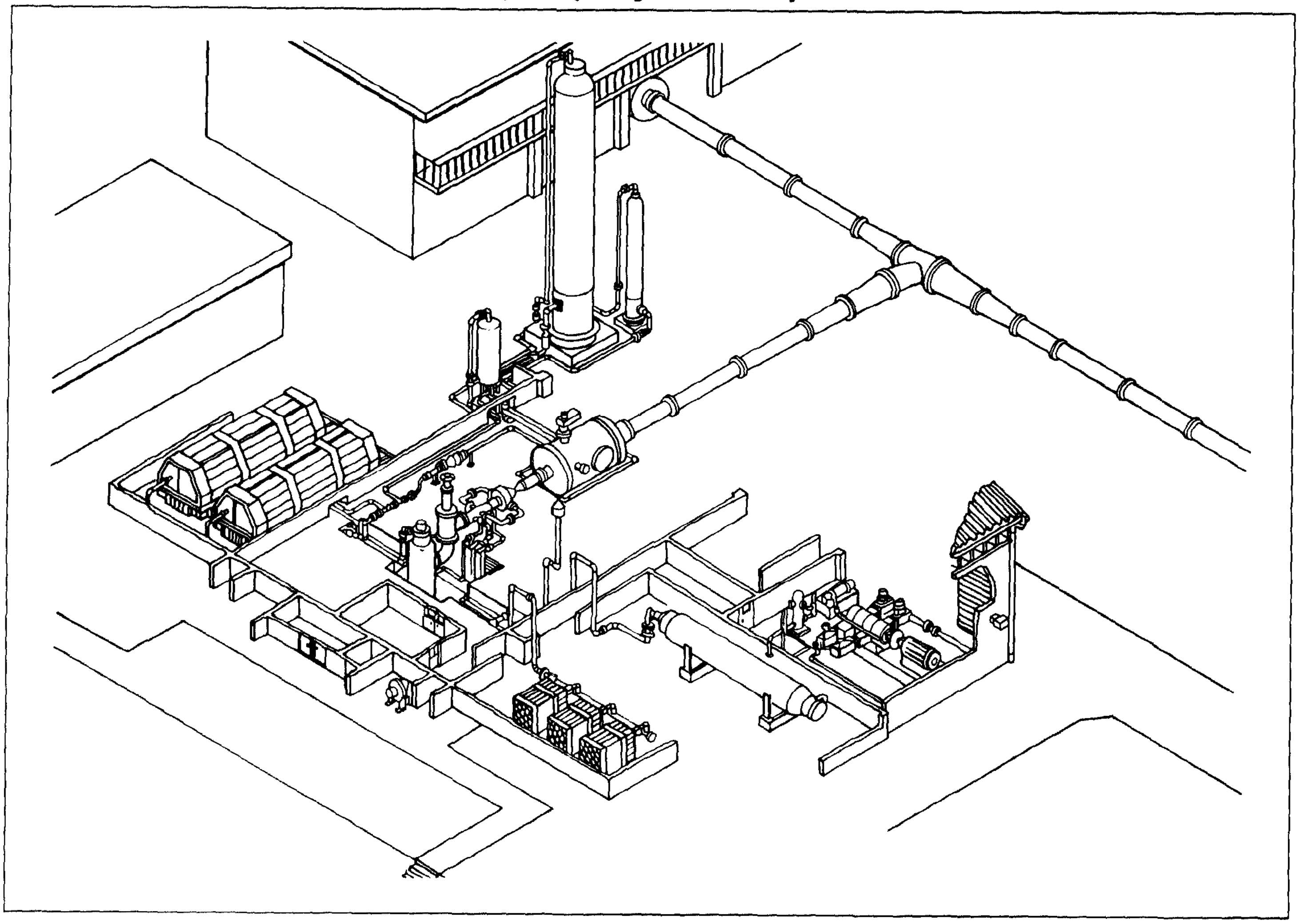
Performance	**Case**			
	A	**B**	**B**	**C**
Heat source	Air storage and vitiation	Air storage	Vitiation	Air storage
Mach number	6.73	5.3	5.3	3.41
Maximum flow rate	10.41 kg/s	30.85 kg/s	29.75 kg/s	45.88 kg/s
Air flow rate	7.88 kg/s	30.85 kg/s	24.26 kg/s	45.88 kg/s
Total temperature	2,557 degrees Kelvin	1,655 degrees Kelvin	1,579 degrees Kelvin	884 degrees Kelvin
Total pressure	10.25 MPa	4.78 MPa	5.27 MPa	0.85 MPa
Run time	30 s	60 s	60 s	30 s

Photograph/Schematic Available: Yes

References: None available

Date of Information: November 1989

Figure VII.32: Schematic Drawing of the NAL Ram/Scramjet Engine Test Facility



Source: NAL

IHI High-Pressure Turbine Facility

Country: Japan

Location: Ishikawajima-Harima Heavy Industries, Chiyoda-ku, Tokyo, Japan

Owner(s):
Ishikawajima-Harima Heavy Industries
Aero-Engines and Space Operations
Shin Ohtemachi Building, 2-chome
2-1 Ohtemachi, Chiyoda-ku
Tokyo 100
Japan

Operator(s): Ishikawajima-Harima Heavy Industries

International Cooperation: None

Point of Contact: S. Nagano, Ishikawajima-Harima Heavy Industries, Tel.: [81]-(425)-56-7241

Test Cell Size: 28 in. diameter

Operational Status: Active

Utilization Rate: 1 shift per day; 2 to 3 runs per month

Performance
- **Maximum Flow Rate:** 40 lb/s
- **Pressure Level:** 3.5 atm (maximum)
- **Inlet Temperature Range:** 2,500 degrees Fahrenheit
- **Speed Range:** 15,000 rpm
- **Power Level:** 6,000 hp
- **Comments:** None

Cost Information
- **Date Built:** 1981
- **Date Placed in Operation:** Not available
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** $2 million not including air supply system (1985)
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The IHI High-Pressure Turbine Facility is a turbine component research facility. Inlet pressure can be raised up to 10 atm when an alternative air supply is used, reducing the airflow to 22 lb/s.

Testing Capabilities: The facility has the capability of full-scale high-pressure turbine testing at a maximum inlet pressure level of 3.5 atm and an inlet temperature level of 2,500 degrees Fahrenheit. A water dynamometer is used for power absorption and speed control.

Data Acquisition: The facility can automatically measure 100 temperature data points above 100 atm pressure.

Planned Improvements (Modifications/Upgrades): An increase in the air supply system has been considered for the multistage turbine rig test. A fully automated inlet air temperature control will be installed.

Unique Characteristics: None

Applications/Current Programs: High-loaded, high-efficiency single-stage turbine (with blade cooling systems) rotating tests are currently being conducted.

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 121.

Date of Information: November 1989

NAL High-Temperature Turbine Cooling Facility

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi
Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: T. Yoshida, National Aerospace Laboratory,
Tel.: [81]-(422)-47-5911, ext. 477

Test Section Size: 20 x 10 x 10 m

Operational Status: Active

Utilization Rate: 1 shift per day; 3 runs per week

Performance
Maximum Flow Rate: 1.5 kg/s
Pressure Level: 900 kPa (maximum)
Inlet Temperature Range: 1,500 degrees Kelvin
Speed Range: Not available
Power Level: Not available
Comments: None

Cost Information
Date Built: 1979
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $600,000 (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: 5
Scientists: 4
Technicians: 0
Others: 0
Administrative/Management: 0
Total: 9

Description: The NAL High-Temperature Turbine Cooling Facility is a turbine component research facility. Heat exchanger tests and supersonic engine intake flow tests can also be performed by using modified test sections.

Testing Capabilities: The facility has the capability of testing cooled turbine airfoils. The coolant can be any kind of air bypassed from the unheated mainstream, water from a reservoir, or steam from a boiler. Electric heaters in a coolant air line can arrange a temperature ratio. Facility operation and data acquisition can be handled by one specialist.

Data Acquisition: A PC-9800 minicomputer system provides fully automated data acquisition, processing, and recording.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current applications include cooling performance tests of full-coverage film-cooled turbine vanes and blades, heat transfer characteristic tests of thermal barrier coatings, and tests of high temperature heat exchangers. Supersonic engine intake flow tests are also performed.

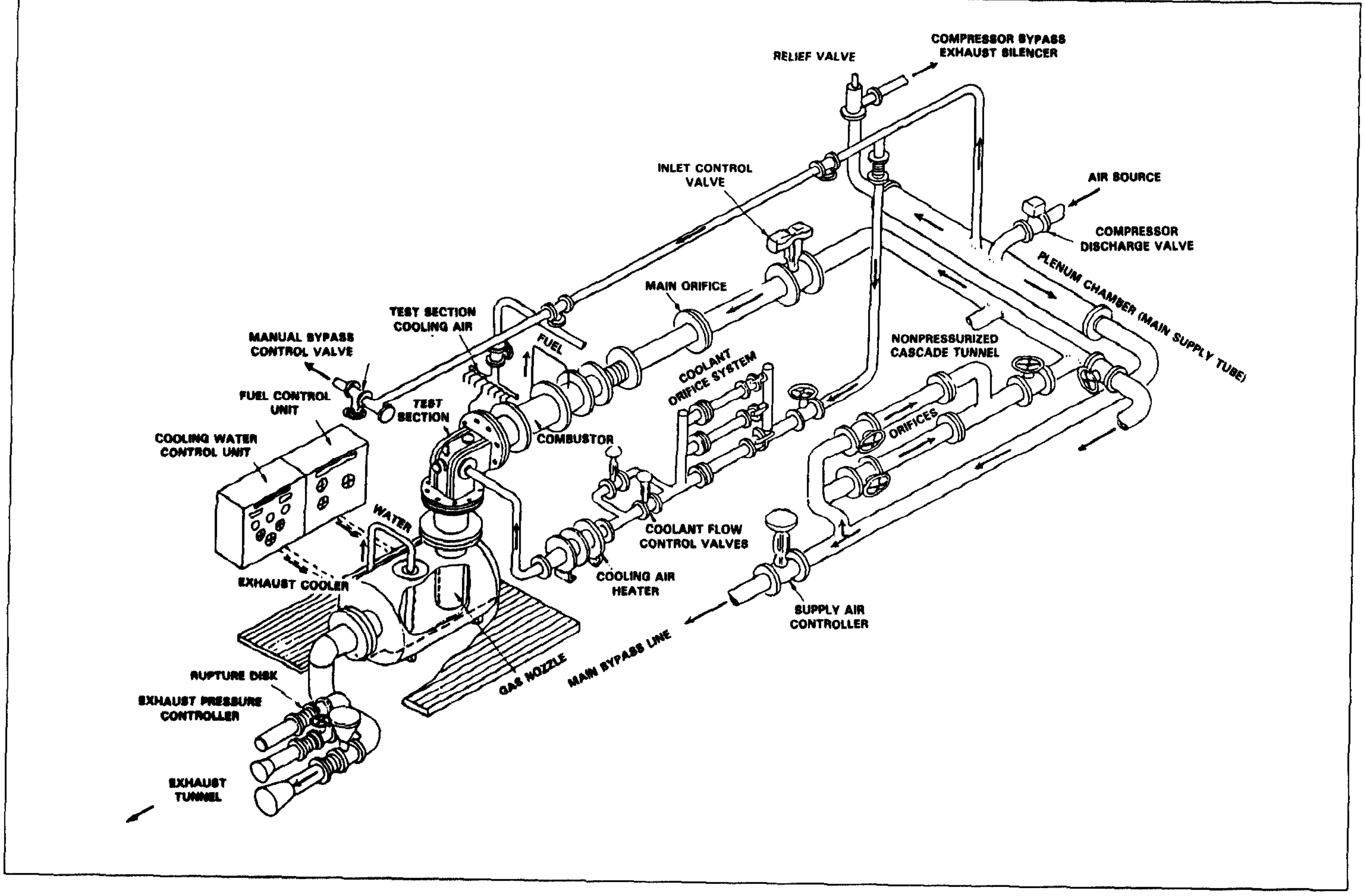
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 122.

Date of Information: October 1989

Figure VII.33: Schematic Drawing of the NAL High-Temperature Turbine Cooling Facility



Source: NASA

IHI Large-Scale Aero-Engine Compressor Facility

Country: Japan

Location: Ishikawajima-Harima Heavy Industries, Chiyoda-ku, Tokyo, Japan

Owner(s):
Ishikawajima-Harima Heavy Industries
Aero-Engine and Space Operations
Shin Ohtemachi Building, 2-chome
2-1 Ohtemachi, Chiyoda-ku
Tokyo 100
Japan

Operator(s): Ishikawajima-Harima Heavy Industries

International Cooperation: None

Point of Contact: S. Nagano, Ishikawajima-Harima Heavy Industries, Tel.: [81]-(425)-56-7241

Test Cell Size: 34 in. diameter x 40 in. long

Operational Status: Active

Utilization Rate: 1 shift per day; 4 to 5 runs per month

Performance
Maximum Flow Rate: 310 lb/s
Pressure Level: 2 atm (maximum)
Inlet Temperature Range: Ambient
Speed Range: 13,000 rpm
Power Level: 18,000 hp
Comments: None

Cost Information
Date Built: 1980
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $3.5 million (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The IHI Large-Scale Aero-Engine Compressor Facility is a compressor component research facility.

Testing Capabilities: The facility has the capability of full-scale and large bypass ratio fan rotating tests at a maximum pressure ratio of 3 atm. It is capable of testing compressors up to 18,000 hp with a maximum speed of 13,000 rpm.

Data Acquisition: The facility has 380 pressure measurement points and 120 temperature measurement points.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: High-loaded, high-efficiency, single-stage fan rotating tests are currently being conducted.

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautical and Space Administration, 1985, vol. 2, p. 148.

Date of Information: November 1989

NAL Fan/Compressor/Turbine Facility 1600-kW DC Electric Dynamometer

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: Y. Saito, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911

Test Cell Size: 5-m shaft center from floor and 4.5 m length

Operational Status: Active

Utilization Rate: 10 runs per year

Performance
Maximum Flow Rate: Not available
Pressure Level: Ambient (maximum)
Inlet Temperature Range: Ambient
Speed Range: 15,000 rpm
Power Level: Not available
Comments: None

Cost Information
Date Built: 1963
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $5 million (1988)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The NAL Fan/Compressor/Turbine Facility 1600-kW DC Electric Dynamometer is a compressor component research facility.

Testing Capabilities: The facility has the capability of testing fans, compressors, and turbines at a maximum speed of 15,000 rpm and a maximum absorbable/driving power of 1,800/1,600 kW. No air supply system for turbine testings is currently available.

Data Acquisition: No exclusive system is available.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The facility is used for testing a scaled ultrahigh bypass ratio engine fan.

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 147.

Date of Information: October 1989

IHI Medium-Pressure Combustor Facility

Country: Japan

Location: Ishikawajima-Harima Heavy Industries, Chiyoda-ku, Tokyo, Japan

Owner(s):
Ishikawajima-Harima Heavy Industries
Aero-Engines and Space Operations
Shin Ohtemachi Building, 2-chome
2-1 Ohtemachi, Chiyoda-ku
Tokyo 100
Japan

Operator(s): Ishikawajima-Harima Heavy Industries

International Cooperation: None

Point of Contact: S. Nagano, Ishikawajima-Harima Heavy Industries, Tel.: [81]-(425)-56-7241

Test Cell Size: 18 in. diameter x 9 in. long

Operational Status: Active

Utilization Rate: 1 shift per day; 300 hours per year

Performance
Maximum Flow Rate: 24 lb/s
Pressure Level: 7 atm (maximum)
Inlet Temperature Range: 180 to 780 degrees Fahrenheit
Speed Range: Not available
Power Level: Not available
Comments: None

Cost Information
Date Built: 1979
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $3.5 million (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The IHI Medium-Pressure Combustor Facility is a combustor component research facility.

Testing Capabilities: The facility has the capability of full annular combustor testing at a maximum pressure level of 7 atm, a flow rate of 24 lb/s, and an inlet air temperature range of 180 to 780 degrees Fahrenheit.

Data Acquisition: The facility has a full annular exhaust rotating rake system, 80 total channels of data, and fully automated data acquisition, recording, and processing.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current applications include improvement of combustion performance and durability and exit temperature distribution of combustors.

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 161.

Date of Information: November 1989

NAL High-Pressure Annular Combustor Test Facility

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: Takashi Tamaru, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911, ext. 429

Test Cell Size: 60 cm diameter x 2 m long

Operational Status: Standby (not operational)

Utilization Rate: No tests are conducted

Performance
- **Maximum Flow Rate:** 13.5 kg/s
- **Pressure Level:** 900 kPa (maximum)
- **Inlet Temperature Range:** 660 degrees Kelvin
- **Speed Range:** Not available
- **Power Level:** Not available
- **Comments:** None

Cost Information
- **Date Built:** 1977
- **Date Placed in Operation:** 1977
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** $4 million (1988)
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Japanese government

Number and Type of Staff
- **Engineers:** 1
- **Scientists:** 2
- **Technicians:** 0
- **Others:** 0
- **Administrative/Management:** 0
- **Total:** 3

Description: The NAL High-Pressure Annular Combustor Test Facility is a combustor component research facility. However, the facility is not operational at this time.

Testing Capabilities: The facility originally had the capacity for testing full annular combustors at a maximum pressure level of 1.5 MPa with an inlet temperature of 720 degrees Kelvin and flow rate of 25 kg/s. The facility, when operational, is limited to the above values because of the decommission of the first-stage compressor.

Data Acquisition: Data processing was performed by the PDP 11/35 Hewlett Packard 86 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The facility is not currently operational.

General Comments: The facility's instrumentation and data acquisition systems are in a decommissioned operational status.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 162.

Date of Information: October 1989

NAL High-Pressure Combustor Test Facility

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: Takashi Tamaru, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911, ext. 429

Test Cell Size: 23 cm diameter x 4 m long

Operational Status: Active

Utilization Rate: 2 to 3 runs per month

Performance
Maximum Flow Rate: 4 kg/s
Pressure Level: 5 MPa (maximum)
Inlet Temperature Range: Ambient to 730 degrees Kelvin
Speed Range: Not available
Power Level: Not available
Comments: None

Cost Information
Date Built: 1983
Date Placed in Operation: 1983
Date(s) Upgraded: Not available
Construction Cost: $3.3 million (1983)
Replacement Cost: $2 million (1988)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: 2
Scientists: 2
Technicians: 0
Others: 0
Administrative/Management: 0
Total: 4

Description: The NAL High-Pressure Combustor Test Facility is a combustor component research facility. The available fuels for the facility are natural gas and kerosene. Natural gas is provided by bundles of high-pressure bottles or truck-mounted large-capacity bottles.

Testing Capabilities: The facility has the capability of testing can-type combustors with a 7- to 15-cm liner at a maximum pressure level of 5 MPa. The inlet air temperature can be changed independently by a heat exchanger prior to its entering the combustor.

Data Acquisition: Data processing is performed by a Hewlett Packard 86 computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current applications include studies of the effect of pressure on combustor design features.

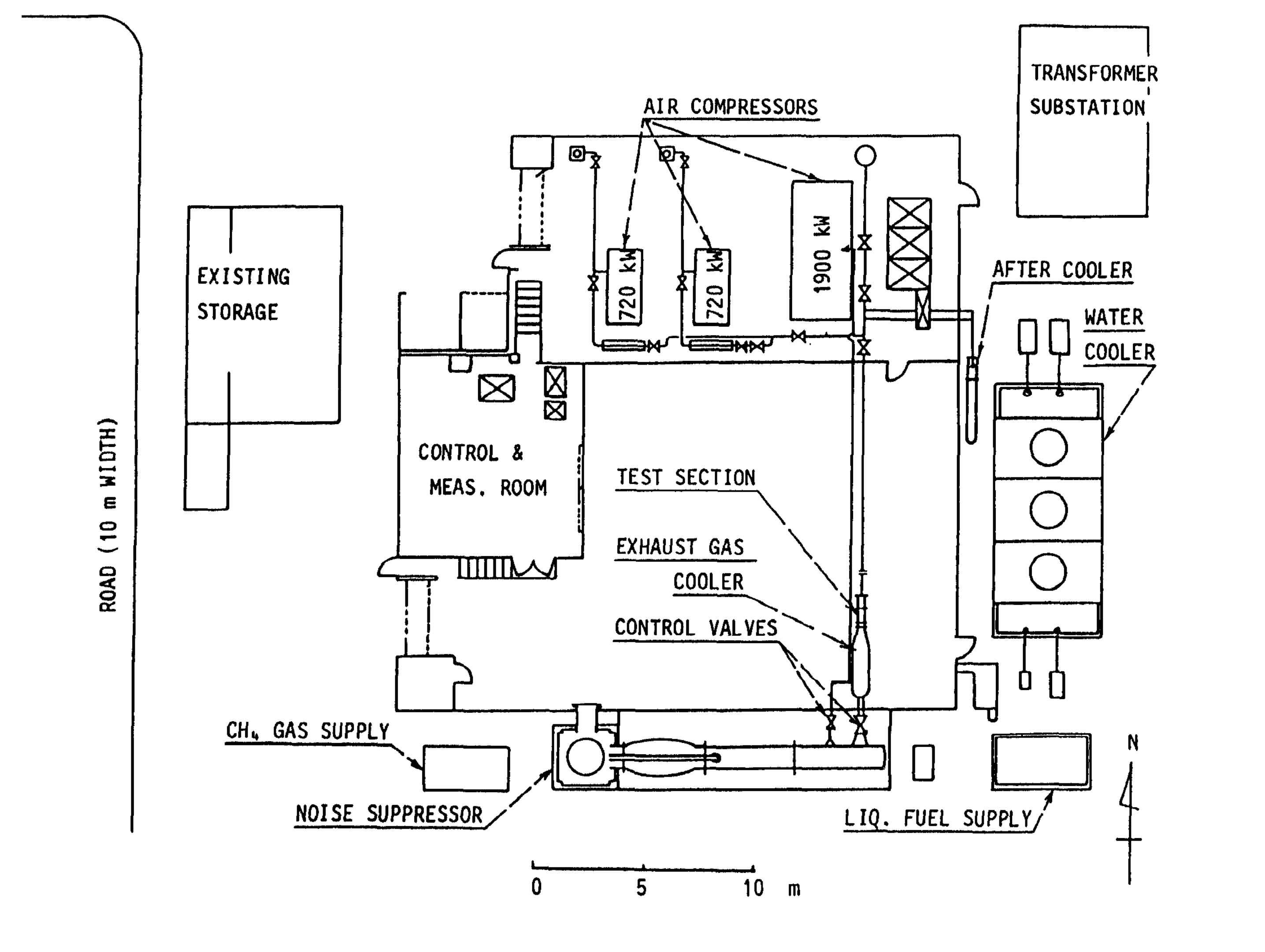
General Comments: The facility is capable of continuous operation.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 163.

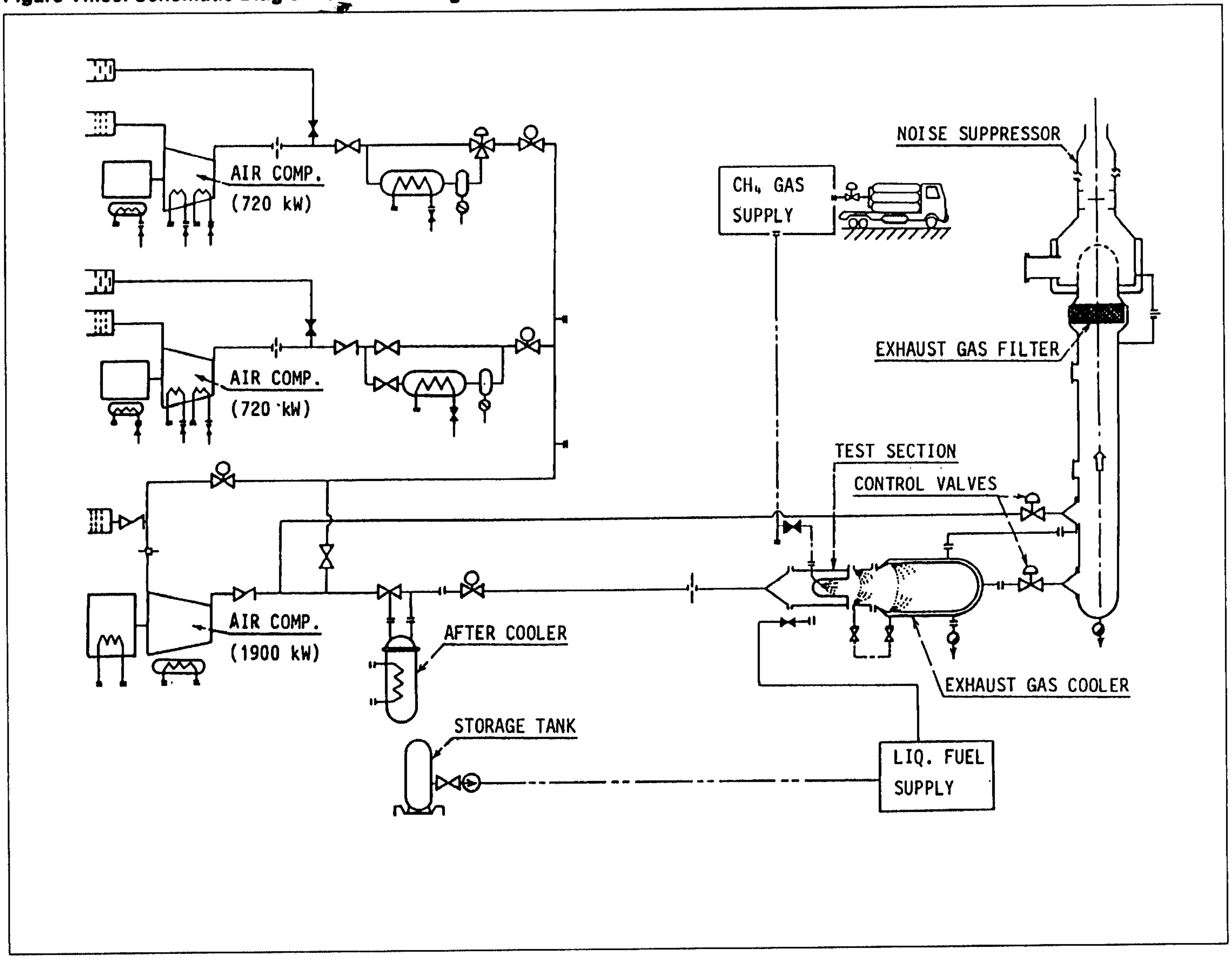
Date of Information: October 1989

Figure VII.34: Schematic Diagram of the NAL High-Pressure Combustor Test Facility



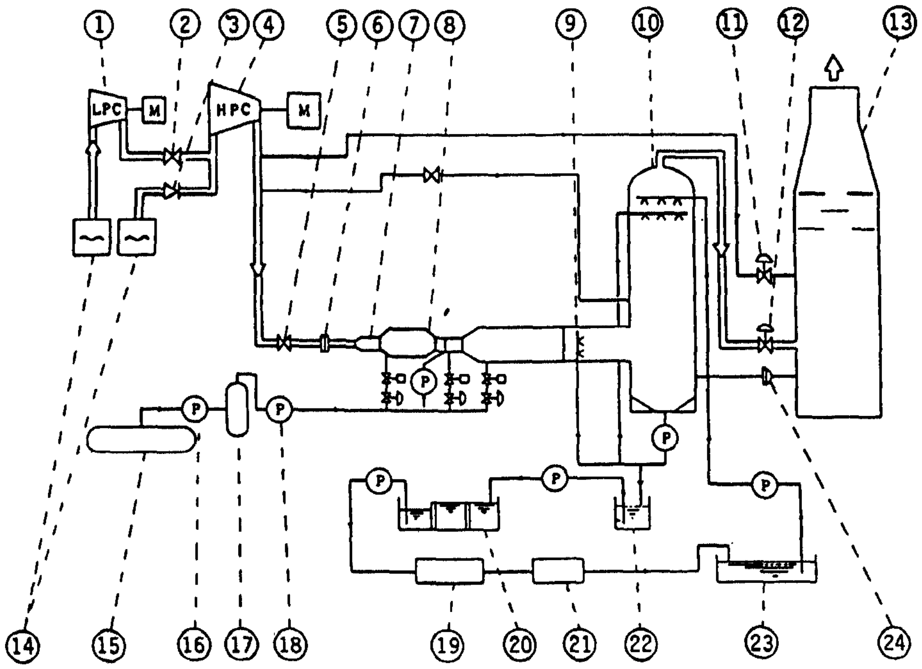
Source: NAL

Figure VII.35: Schematic Diagram of the NAL High-Pressure Combustor Test Facility



Source: NAL

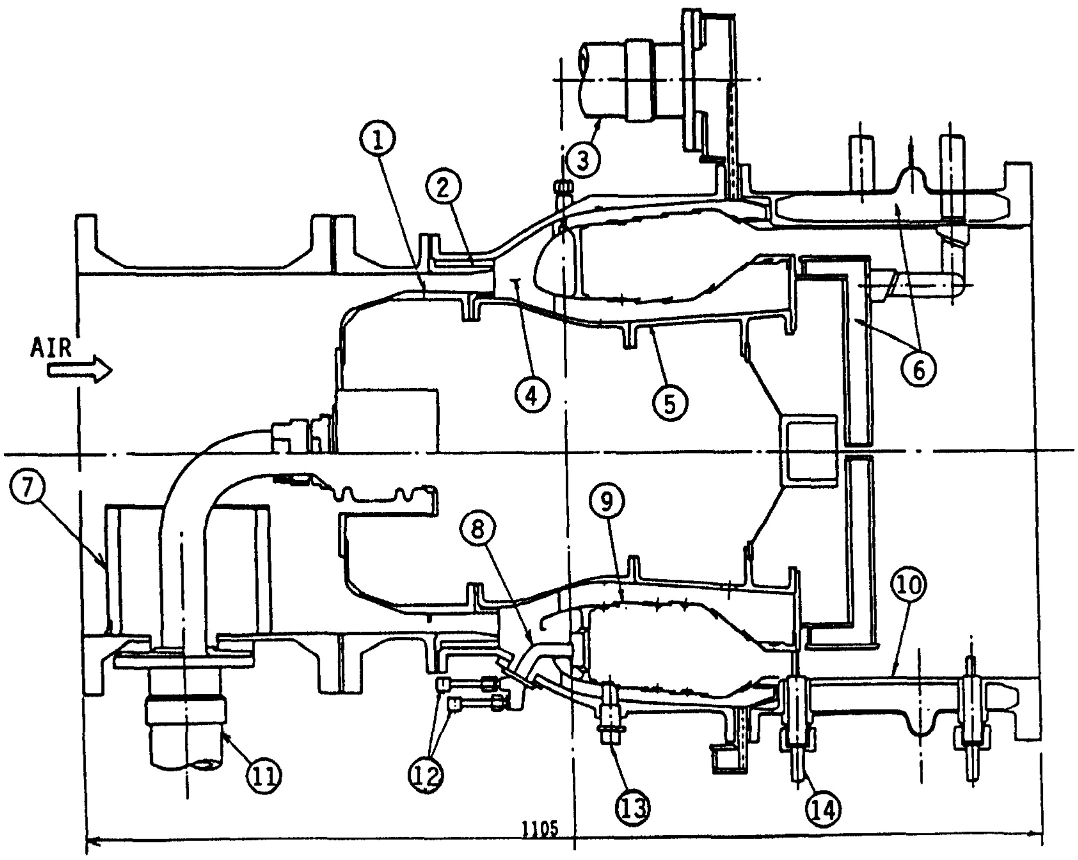
Figure VII.36: Schematic Diagram of the NAL High-Pressure Combustor Test Facility



1	3.7MW compressor	13	Exit silencer
2	Linking valve	14	Inlet silencer
3	Atmospheric inlet valve	15	Fuel storage tank
4	10MPa high press. compressor	16	Fuel feed pump
5	Flow control valve	17	Water separator
6	Orifice flow meter	18	High pressure pump
7	Flow straightner	19	Filter
8	Test section	20	Condenser
9	Cooling spray	21	Adsorbing separator
10	Exhaust gas	22	Drain well
11	Release valve	23	Cooling reservoir
12	Pressure control valve	24	Rupture disc

Source: NAL

Figure VII.37: Schematic Diagram of the Test Section of the NAL High-Pressure Combustor Test Facility



1. Inlet flow control pegs
2. Inlet diffuser
3. Outer bleed manifold
4. Casing strut
5. Inner casing
6. Cooling water jacket
7. Bleed tube fairing
8. Fuel nozzle (16)
9. Combustion liner
10. Ceramic coated duct
11. Inner bleed tube
12. Fuel manifold
13. Ignition plug (2)
14. Thermocouple rakes (32)

Source: NAL

NAL Propulsion Test Cell

Country: Japan

Location: National Aerospace Laboratory, Chofu-shi, Tokyo, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory

International Cooperation: None

Point of Contact: M. Sasaki, National Aerospace Laboratory, Tel.: [81]-(422)-47-5911

Test Cell Size: Not available

Operational Status: Active

Utilization Rate: A few runs per year

Performance
Maximum Flow Rate: Not available
Pressure Level: Ambient
Inlet Temperature Range: Ambient
Speed Range: Not available
Power Level: Not available
Comments: None

Cost Information
Date Built: 1975
Date Placed in Operation: 1975
Date(s) Upgraded: Not available
Construction Cost: $2 million (1975)
Replacement Cost: $8 million (1988)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Japanese government

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The NAL Propulsion Test Cell is a sea level engine test facility. The thrust level is 100 kN (maximum).

Testing Capabilities: The test cell has the capability of performance testing at sea level static conditions and inlet distortion testing of turbo fan engines. The test cell has no altitude simulation capability.

Data Acquisition: Fully automated data acquisition, processing, and recording are available.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current applications include tests of turbofan jet engines.

General Comments: None

Photograph/Schematic Available: No

References: None available

Date of Information: October 1989

ARA Bedford Supersonic Wind Tunnel (SWT)

Country: United Kingdom

Location: Aircraft Research Association, Bedford, United Kingdom

Owner(s):
Aircraft Research Association
Manton Lane
Bedford, Bedfordshire MK41 7PF
United Kingdom

Operator(s): Aircraft Research Association

International Cooperation: Not available

Point of Contact: Chief Executive, Aircraft Research Association, Tel.: [44]-(234)-50681

Test Section Size: 2.25 x 2.5 ft

Operational Status: Active

Utilization Rate: Low

Performance
Mach Number: 1.4 to 3
Reynolds Number: 1 to 4.3 x 10^6/ft
Total Pressure: 5.88 to 20.58 psia
Dynamic Pressure: 355 to 900 lb/ft^2
Total Temperature: 580 degrees Rankine
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1957 to 1959
Date Placed in Operation: 1959
Date(s) Upgraded: Not available
Construction Cost: $1.4 million (1960)
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: $16,500 per day (1989)
Source(s) of Funding: Commercial contracts

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ARA Bedford Supersonic Wind Tunnel is a continuous-flow, closed-circuit supersonic wind tunnel.

Testing Capabilities: The SWT is capable of conducting tests of complete models of aircraft, missiles, and intakes. It also has schlieren and shadowgraph facilities.

Data Acquisition: The tunnel has 32 channels of data, including balance components, transducers, thermocouples, and scanivalves.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: The tunnel has on-line continuous-flow Mach number variation.

Applications/Current Programs: Current programs include industry programs and research.

General Comments: The ARA Bedford Supersonic Wind Tunnel has a very high potential for productivity. A new brochure is expected to be available in December 1989.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 230.

Date of Information: October 1989

NAL Ram/Scramjet Combustor Test Facility

Country: Japan

Location: National Aerospace Laboratory, Kakuda Branch, Kimigaya, Kakuda, Miyagi Prefecture, Japan

Owner(s):
National Aerospace Laboratory
7-44-1 Jindaijihigashi-machi
Chofu-shi
Tokyo 182
Japan

Operator(s): National Aerospace Laboratory, Kakuda Branch

International Cooperation: None

Point of Contact: Nobuo Chinzei, National Aerospace Laboratory, Ramjet Performance Section, Kakuda Branch, Tel.: [81]-(224)-68-3111

Test Section Size: 80 mm (diameter); Section No. 1: 147 x 32 mm; Section No. 2: 50 x 90 mm

Operational Status: Active

Utilization Rate: 1,000 runs per year

Performance
- **Maximum Flow Rate:** Not available
- **Pressure Level:** 1.5 MPa (maximum)
- **Inlet Temperature Range:** 800 to 2,500 degrees Kelvin
- **Speed Range:** Not available
- **Power Level:** Not available
- **Comments:** None

Cost Information
- **Date Built:** 1977
- **Date Placed in Operation:** 1977
- **Date(s) Upgraded:** 1983
- **Construction Cost:** Not available
- **Replacement Cost:** $335,000 (1989)
- **Annual Operating Cost:** $15,000 (1989)
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Japanese government

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** 6

Description: The NAL Ram/Scramjet Combustor Test Facility is an intermittent, blowdown engine/propulsion component facility. The facility is uncooled and its exhaust is to atmosphere. The facility has a vitiated air heater. The facility is capable of testing ramjets and scramjets up to speeds of Mach 2.5

Testing Capabilities: The facility is capable of conducting direct-connect tests of ramjet and scramjet combustors with circular and rectangular cross sections. The facility is capable of achieving Reynolds Numbers from 3 to 30 $\times 10^6$/m and dynamic pressure of 0.4 MPa (maximum). The run time is 7 s.

Data Acquisition: The facility has 32 channels of data with 12-bit resolution of the analog-to-digital convertor. The sampling rate is 200 to 800 Hz. The facility uses a NEC PC-9801 E processor.

Planned Improvements (Modifications/Upgrades): These include the addition of a water-cooled air heater and nozzle in 1990 and Mach 1.7 and 3.5 nozzles.

Unique Characteristics: None

Applications/Current Programs: These include direct-connect ramjet and scramjet combustor testing.

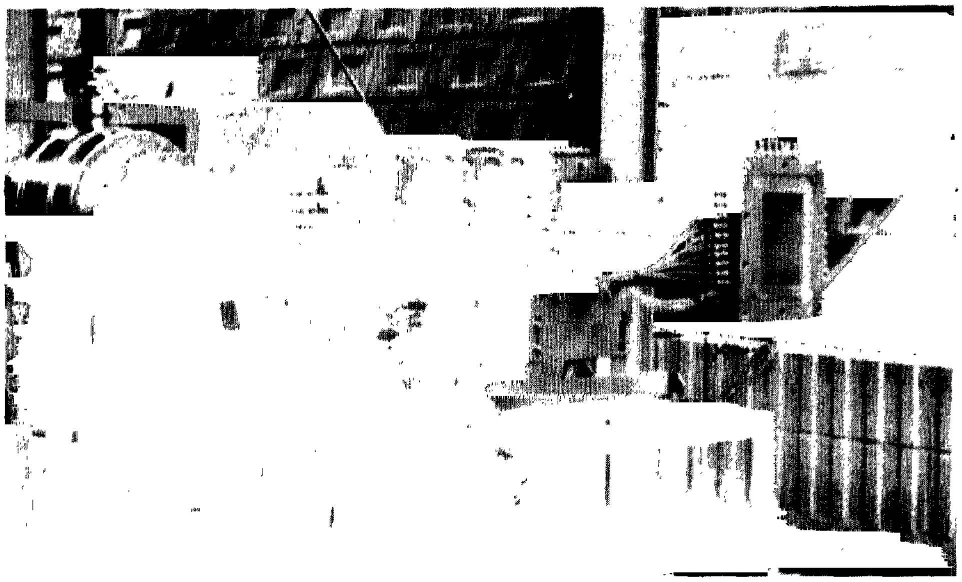
General Comments: The NAL Ram/Scramjet Combustor Test Facility is primarily a small research facility.

Photograph/Schematic Available: Yes

References: National Aerospace Laboratory. NAL Technical Report No. 912. Chofu-shi, Tokyo: National Aerospace Laboratory, 1986. National Aerospace Laboratory. NAL Technical Memorandum No. 561. Chofu-shi, Tokyo: National Aerospace Laboratory, 1986. National Aerospace Laboratory. NAL 1988. Chofu-shi, Tokyo: National Aerospace Laboratory, 1988, pp. 23-25.

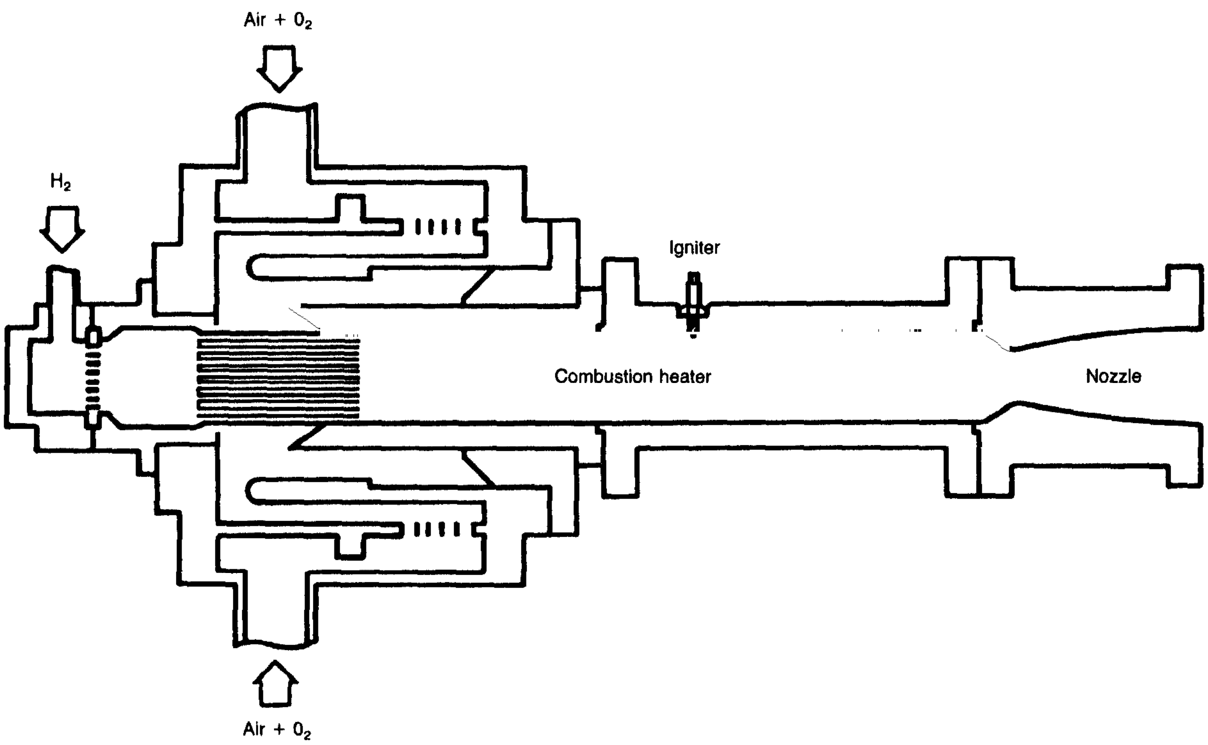
Date of Information: January 1990

Figure VII.38: NAL Ram/Scramjet Combustor Test Facility



Source: NAL

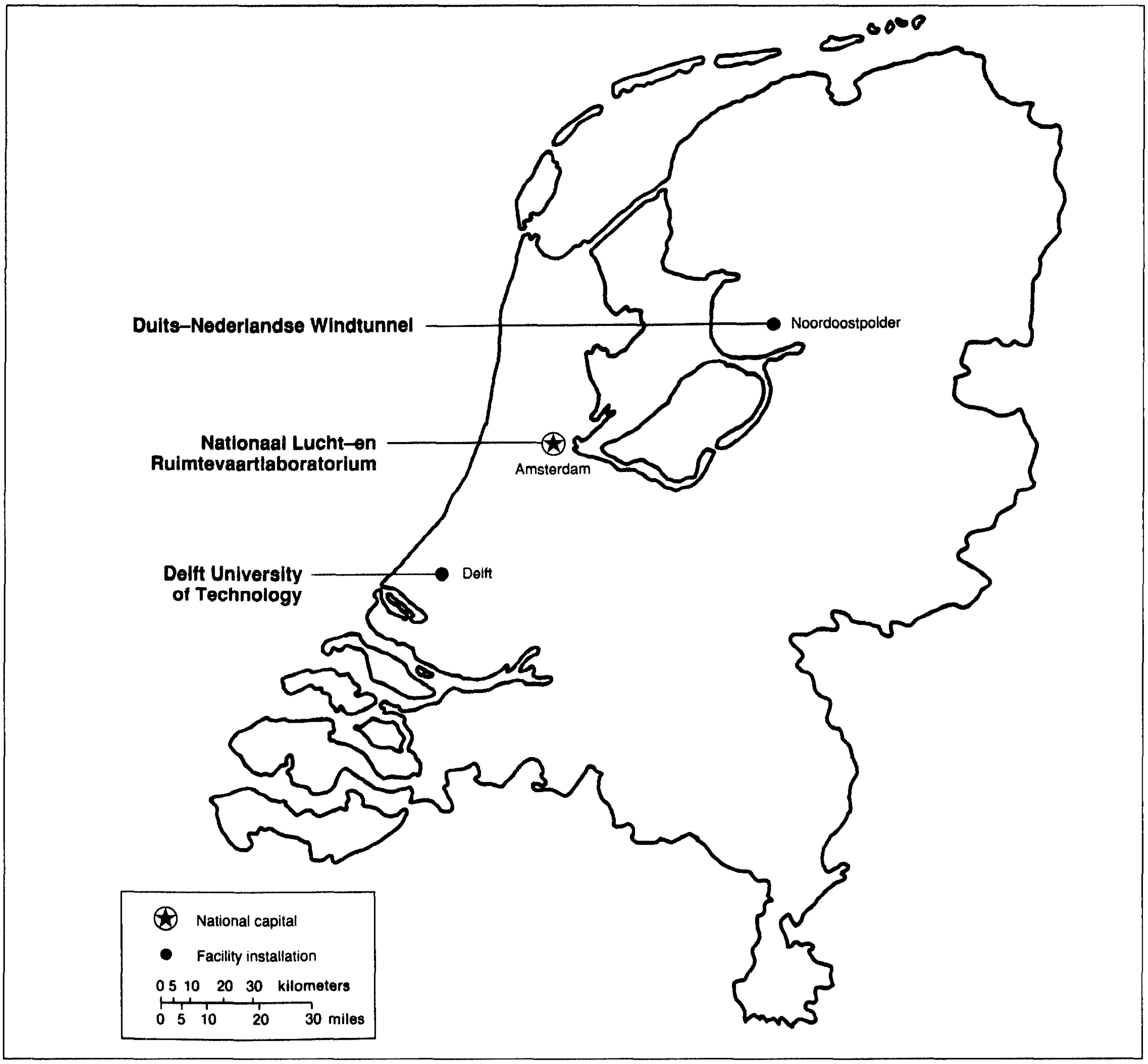
Figure VII.39: Schematic Diagram of the Vitiated Heater/Nozzle of the NAL Ram/Scramjet Combustor Test Facility



Source: NAL

Aerospace Test Facilities in The Netherlands

Figure VIII.1: Map of Test Facilities in The Netherlands



Source: GAO

DNW Low-Speed Wind Tunnel

Country: The Netherlands

Location: Duits-Nederlandse Windtunnel, Noordoostpolder, Marknesse, The Netherlands

Owner(s):
Nationaal Lucht-en Ruimtevaartlaboratorium
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands

Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Nationaal Lucht-en Ruimtevaartlaboratorium and Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: The Netherlands and West Germany

Point of Contact: J.C.A. van Ditshuizen, Duits-Nederlandse Windtunnel, Tel.: [31]-(5274)-8562

Test Section Size: 9.5 x 9.5 m, 6 x 8 m (closed and open), and 6 x 6 m

Operational Status: Active

Utilization Rate: 2,000 hours per year

Performance
- **Mach Number:** 0.18, 0.34, and 0.45
- **Reynolds Number:** 3.9 to 5.8 x 10^6/m
- **Total Pressure:** Atmospheric
- **Dynamic Pressure:** 0 to 1.3 kN/m^2
- **Total Temperature:** Ambient
- **Run Time:** Continuous
- **Comments:** None

Cost Information
- **Date Built:** 1976 to 1979
- **Date Placed in Operation:** 1980
- **Date(s) Upgraded:** Not available
- **Construction Cost:** $62,877,263 (1980)
- **Replacement Cost:** Not available
- **Annual Operating Cost:** $4,668,900 (1988)
- **Unit Cost to User:** Available upon request; hourly rate depends upon test program
- **Source(s) of Funding:** NLR and DLR

Number and Type of Staff
- **Engineers:** 20
- **Scientists:** 7
- **Technicians:** 20
- **Others:** 1
- **Administrative/Management:** 4 to 5
- **Total:** 50 to 55

Description: The Duits-Nederlandse Windtunnel/Deutsch Niederlandischer Windkanal, or German-Dutch Wind Tunnel, is the largest low-speed wind tunnel of its kind in Europe. Its construction, operation, and further development are conducted on a parity basis by NLR and DLR. The tunnel is an atmospheric closed-circuit wind tunnel, in which aerodynamic and aeroacoustic measurements can be performed at reasonably high Reynolds Numbers. Three interchangeable closed test sections with slotted walls are available. In addition, a 6 × 8 m open-jet can be used.

Testing Capabilities: Forces and moments are measured with internal strain-gauge balances or an external six-component underfloor balance. Pressure plotting measurements are performed either through scanners connected to the pressure plotting holes and feeding one or more pressure transducers, or through a number of pressure transducers directly.

Data Acquisition: The tunnel is equipped with a "distributed" computer system for control, data acquisition, and on-line data reduction and presentation. An off-line system is available for test preparation and post-processing. All computer systems are connected by an Ethernet local area network providing easy interface possibilities for client systems including acoustic and dynamic data acquisition systems. The static data acquisition system is capable of sampling three data points with 128 channels per second. These data can be presented fully corrected and on-line on printers and plotters.

Planned Improvements (Modifications/Upgrades): These include a Mach 0.28 open-jet nozzle.

Unique Characteristics: Special features of the tunnel include the possibility of aeroacoustic measurements, hot- and cold-jet simulation, propeller engine simulation, real-engine testing, ground simulation, moving belt ground plane, and a compressed air system.

Applications/Current Programs: These include general low-speed aircraft aerodynamics and aeroacoustics, helicopters and V/STOL aerodynamics, engine/airframe interference, rotor aerodynamics and aeroacoustics, flutter and dynamic testing, optimization of full-scale components, real and model engine testing, full-scale ground vehicle aerodynamics, and industrial aerodynamics.

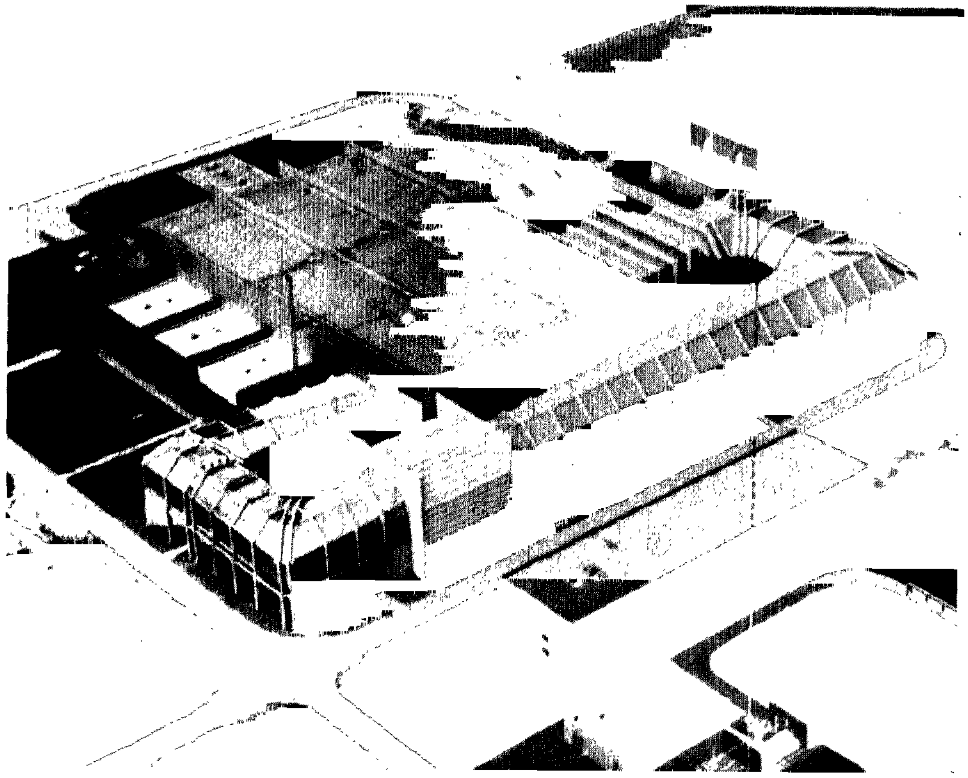
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, pp. 51-53. Seidel, M., ed. Construction 1976-1980: Design, Manufacturing, and Calibration of the German-Dutch Windtunnel (DNW). Emmeloord, The Netherlands: DNW, 1982. DNW. Annual Report 1988. Emmelrood, The Netherlands: DNW, 1988.

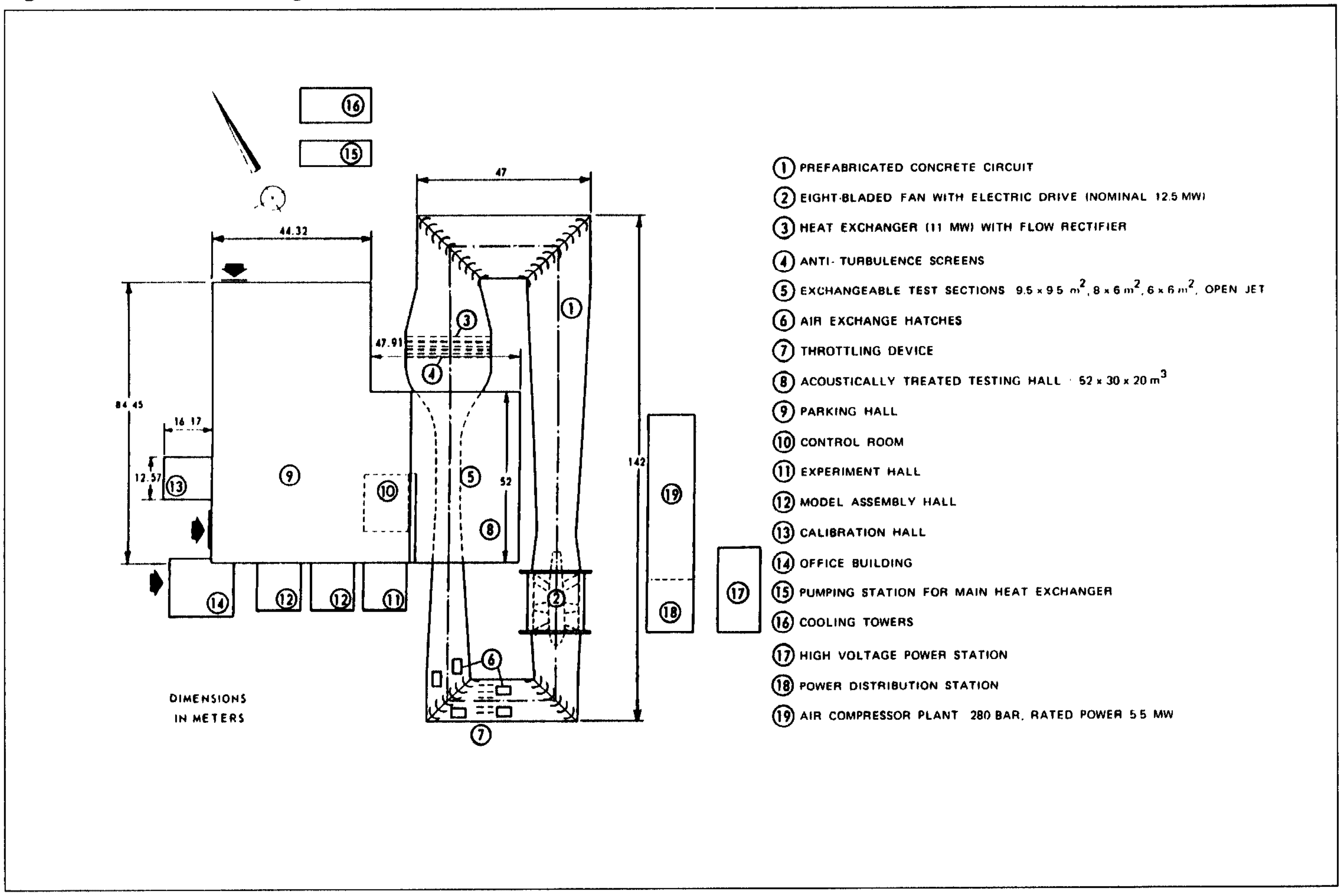
Date of Information: March 1990

Figure VIII.2: DNW Low-Speed Wind Tunnel



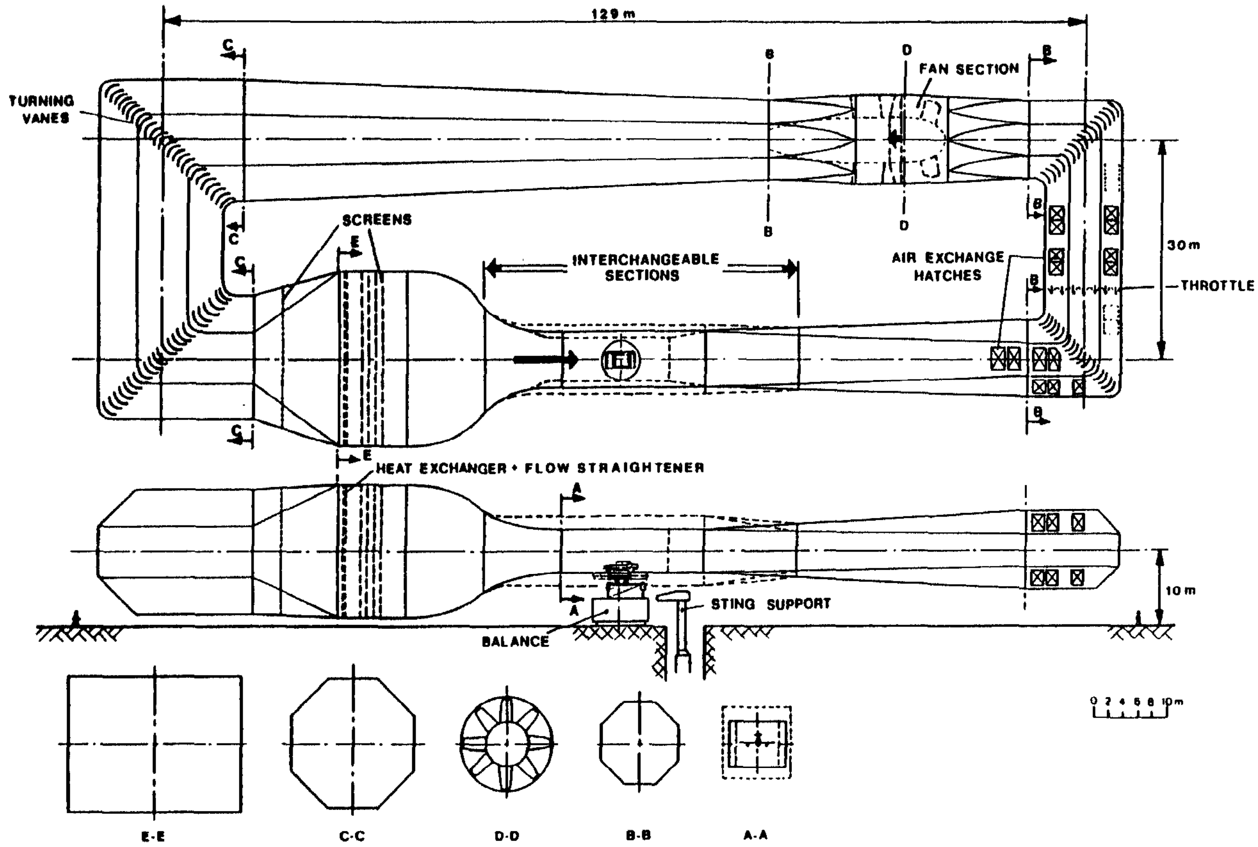
Source: DNW

Figure VIII.3: Schematic Diagram of the DNW Low-Speed Wind Tunnel



Source: DNW

Figure VIII.4: Schematic Diagram of the Airflow Circuit of the DNW Low-Speed Wind Tunnel



Source: DNW

NLR Low-Speed Wind Tunnel

Country: The Netherlands

Location: Nationaal Lucht-en Ruimtevaartlaboratorium, Amsterdam, The Netherlands

Owner(s):
Nationaal Lucht-en Ruimtevaartlaboratorium
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands

Operator(s): Nationaal Lucht-en Ruimtevaartlaboratorium

International Cooperation: Not available

Point of Contact: F. Jaarsma, Nationaal Lucht-en Ruimtevaartlaboratorium, Tel.: [31]-(5274)-2828

Test Section Size: 3 x 2.25 x 8.75 m

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.25 or 85 m/s
Reynolds Number: 0 to 6 x 10^6/m
Total Pressure: Atmospheric
Dynamic Pressure: 0 to 4 m/s
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1982
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Dutch government and research contracts

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The NLR Low-Speed Wind Tunnel is an atmospheric closed-circuit wind tunnel. The test section consists of two parts: the forward part, measuring 5.75 m in length, which is used for aeronautical testing, and the aft part, measuring 3 m in length, which is specifically used for industrial aerodynamic testing. The forward part is used to generate the simulated atmospheric boundary layer for the aft part. Two different forward parts are available: one is used only for two-dimensional testing, and the other is equipped for full-model testing and has an external six-component balance mounted on top of the test section. A thyristorized synchronous 700-kW motor powers the fan. The single-stage axial-type compressor consists of eight fixed rotor blades and seven fixed stator vanes. Wind speed is controlled through variation of the angular speed of the fan between 0 to 480 rpm.

Testing Capabilities: When a model is mounted on the six-component balance, forces and moments can be measured. Strain-gauge balances can be used in cases in which a separate portion of the model is to be tested, whether mounted on the six-component balance or in the two-dimensional test section. Forces and moments can also be measured on rudders, flaps, and ailerons, and operated by remote control, if desired.

For pressure measurements, the model is equipped with a number of pressure leads connecting each pressure hole with a pressure transducer. Other types of measurements include direction sensing, mass flow, and temperature measurements. Flow visualization techniques include the tufts and oil methods, as well as the laser screen.

Data Acquisition: The tunnel has 64 channels of data including up to 10 scanivalves for steady measurements and special-purpose system records with phase and amplitude for up to 100 analog and 100 digital channels for unsteady measurements. Data processing is performed by a Hewlett Packard 1000/45 dedicated computer.

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: The tunnel has cold- and hot-jet simulation, ground simulation, and a traversing mechanism so probes can be adjusted inside the test section.

Applications/Current Programs: These include low-speed aircraft aerodynamics, high-lift devices and V/STOL aerodynamics, engine/airframe interference, wind climate around civil structures, wind climate on board of ships (heli-decks and smoke), aerodynamics of off-shore installations, boundary layer investigations, and automotive six-component force measurements.

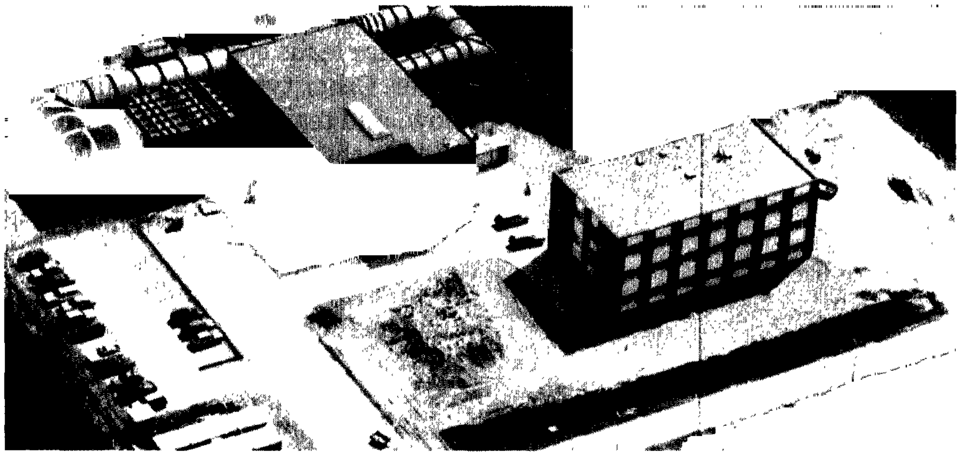
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 102. National Aerospace Laboratory. High Speed Wind Tunnel. Amsterdam: National Aerospace Laboratory, 1988.

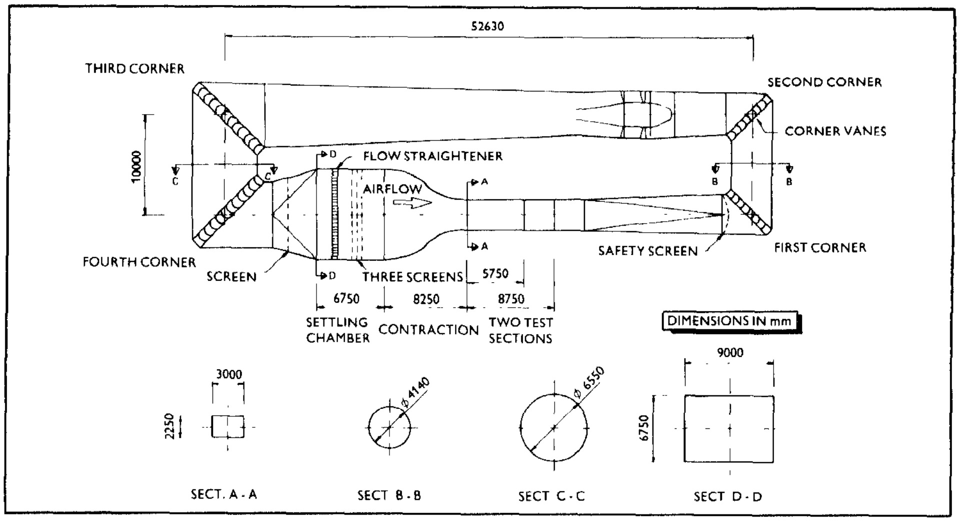
Date of Information: November 1988

Figure VIII.5: NLR Low-Speed Wind Tunnel



Source: NLR

Figure VIII.6: Schematic Diagram of the NLR Low-Speed Wind Tunnel



Source: NLR

NLR High-Speed Wind Tunnel

Country: The Netherlands

Location: Nationaal Lucht-en Ruimtevaartlaboratorium, Amsterdam, The Netherlands

Owner(s):
Nationaal Lucht-en Ruimtevaartlaboratorium
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands

Operator(s): Nationaal Lucht-en Ruimtevaartlaboratorium

International Cooperation: ESA

Point of Contact: H.A. Dambrink, Nationaal Lucht-en Ruimtevaartlaboratorium, Tel.: [31]-(20)-5-113-113

Test Section Size: 1.6 x 2 x 2.7 m

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 1.25
Reynolds Number: 10 to 15 x 10^6/m at Mach 1.25 and 31 x 10^6/m at Mach 0.7
Total Pressure: 12 to 390 kPa
Dynamic Pressure: Not available
Total Temperature: 300 to 310 degrees Kelvin
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1958
Date Placed in Operation: Not available
Date(s) Upgraded: 1980
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Dutch government and research contracts

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The NLR High-Speed Wind Tunnel is a variable-density, continuous-flow, closed-circuit transonic wind tunnel with slotted top and bottom test section walls.

Testing Capabilities: Because the tunnel's pressure can be varied considerably, a large range of Reynolds Numbers can be achieved. The tunnel has excellent flow quality over its entire velocity range. Forces and moments are measured with a six-component internal strain-gauge balance. Pressure distribution measurements are performed through one or more scanners connected to the pressure plotting holes and feeding one or more pressure transducers. The subsonic model support, the main part of which is situated under the test section floor, is used to test models on a vertical sting at subsonic speeds. The transonic model support is used to test models on a conventional sting at subsonic and transonic speeds. For the transonic model support system, various sting support booms for different testing possibilities are available. The sidewall model support is used to test half-span models and model parts. The two-dimensional model support is used to test clean or multi-element airfoils at high Reynolds Numbers. Other types of measurements include direction sensing, mass flow, and temperature measurements.

Flow visualization techniques include the tufts, oil, and acenaphtene methods and the schlieren and shadow optical systems.

Data Acquisition: The tunnel has 48 channels of data. Data processing is performed by a Hewlett Packard 1000/45 dedicated computer system.

Planned Improvements (Modifications/Upgrades): Improvements to the test section and model supports are planned. Integrated automation of the tunnel controls and test equipment are also planned.

Unique Characteristics: An important feature is the possibility of exchanging the same model between the NLR High-Speed Wind Tunnel and the NLR Supersonic Wind Tunnel. In special cases, it is also possible to test the NLR High-Speed Wind Tunnel and NLR Supersonic Wind Tunnel models in the NLR Low-Speed Wind Tunnel. This capability enables the user to test one model in different velocity regimes. Other special features include hot- and cold-jet simulation and ground simulation.

Applications/Current Programs: These include force and moment measurements; pressure measurement distribution; direction, wake, and mass flow visualization; schlieren and shadow techniques; unstationary measurements; and flutter tests. Tests of launchers and shuttles are being conducted for ESA. The NLR High-Speed Wind Tunnel is also being used to test ESA's Hermes spaceplane for Avions Marcel Dassault-Breguet Aviation.

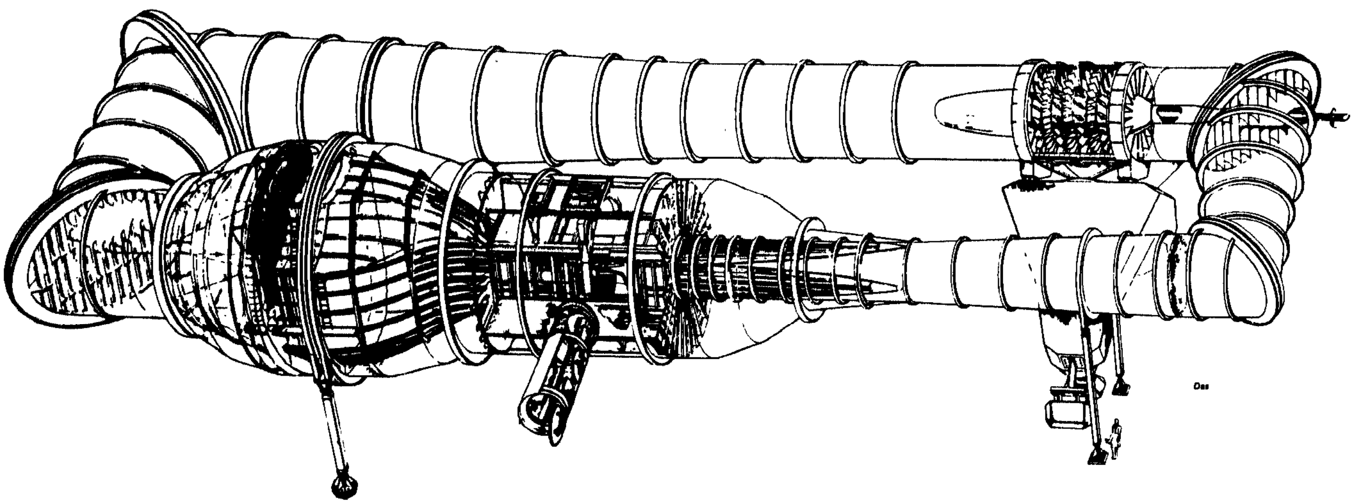
General Comments: The data acquisition system was recently updated. Also, an electronic pressure scan system is available.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 163. National Aerospace Laboratory. High-Speed Wind Tunnel. Amsterdam: National Aerospace Laboratory, 1988.

Date of Information: November 1988

Figure VIII.7: Schematic Diagram of the NLR High-Speed Wind Tunnel



Source. NLR

Figure VIII.8: Model of Fokker 100 Aircraft in the NLR High-Speed Wind Tunnel

Source: NLR

Delft University of Technology Blowdown Tunnel B (TST 27)

Country: The Netherlands

Location: Delft University of Technology, Delft, The Netherlands

Owner(s):
Delft University of Technology
Faculty of Aerospace Engineering
Kluyverweg 1
2629 HS Delft
The Netherlands

Operator(s): Delft University of Technology

International Cooperation: None

Point of Contact: W.J. Bannink, Delft University of Technology, Tel.: [31]-(15)-784500

Test Section Size: 27 x 28 x 40 to 90 cm

Operational Status: Active

Utilization Rate: 5 tests per day

Performance
Mach Number: Less than 4.2 (variable)
Reynolds Number: 37 to 130 x 10^6/m
Total Pressure: 30 bars (maximum)
Dynamic Pressure: 88 to 204 kN/m^2
Total Temperature: 300 degrees Kelvin
Run Time: 6 min
Comments: Nozzle exit height times width is 27 X 28 cm.

Cost Information
Date Built: 1971
Date Placed in Operation: 1972
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $1.4 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Typically $1,000 per day (1989)
Source(s) of Funding: Delft University of Technology

Number and Type of Staff
Engineers: 2 (part-time)
Scientists: 4 (part-time)
Technicians: 2 (part-time)
Others: 0
Administrative/Management: 1 (part-time)
Total: 9 (part-time)

Description: The Delft University of Technology Blowdown Tunnel B (TST 27) is a supersonic and transonic wind tunnel. It has a test section 280 mm wide with a height varying from 250 to 270 mm depending on the Mach number. Mach numbers range from 0.6 to 4.2. Supersonic Mach numbers are set by a continuously variable throat and flexible upper and lower nozzle walls. The Mach number may be varied during a run. Subsonic and transonic Mach numbers are controlled using a variable choke section in the outer diffuser. Small deviations of the Mach number during a run are corrected by automatic fine adjustment of the choke. Downstream of the nozzle and supersonic test section, the tunnel consists of a number of separate nozzles, supported on wheels and connected by quick-lock couplings. This allows use of the tunnel in several configurations. For transonic tests, a transonic test section with either slotted or perforated walls may be inserted downstream of the closed-wall test section. Either of two different model carts may be used. One cart is equipped with an angle of incidence mechanism for sting-mounted models. The other cart is equipped with a mechanism for traversing probes in three directions through the flow field. The comparatively long run time (up to 300 s) allows exploration in detail of the flow field over the model. The tunnel is designed for operation at high stagnation pressures; the maximum unit Reynolds Number varies from 37×10^6/m in the transonic range to 130×10^6/m at Mach 4. The TST 27 is driven by dry, oil-free air delivered by a 6,000-kW compressor plant and stored at a pressure of 40 bars in a 300-m^3 storage vessel.

Testing Capabilities: The TST 27 has computer-controlled five-hole directional pressure probes and is capable of conducting pressure distribution, surface and schlieren visualization, and interferometry tests.

Data Acquisition: The TST 27 has 26 on-line channels of data. Data are collected, stored, and processed in the central data acquisition system DRS of the Laboratory. For extensive numerical calculation, a terminal provides access to the IBM 3083 mainframe and Convex minisupercomputer at the University Computer Center.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include three-dimensional flow separation and vertical flow over delta wings.

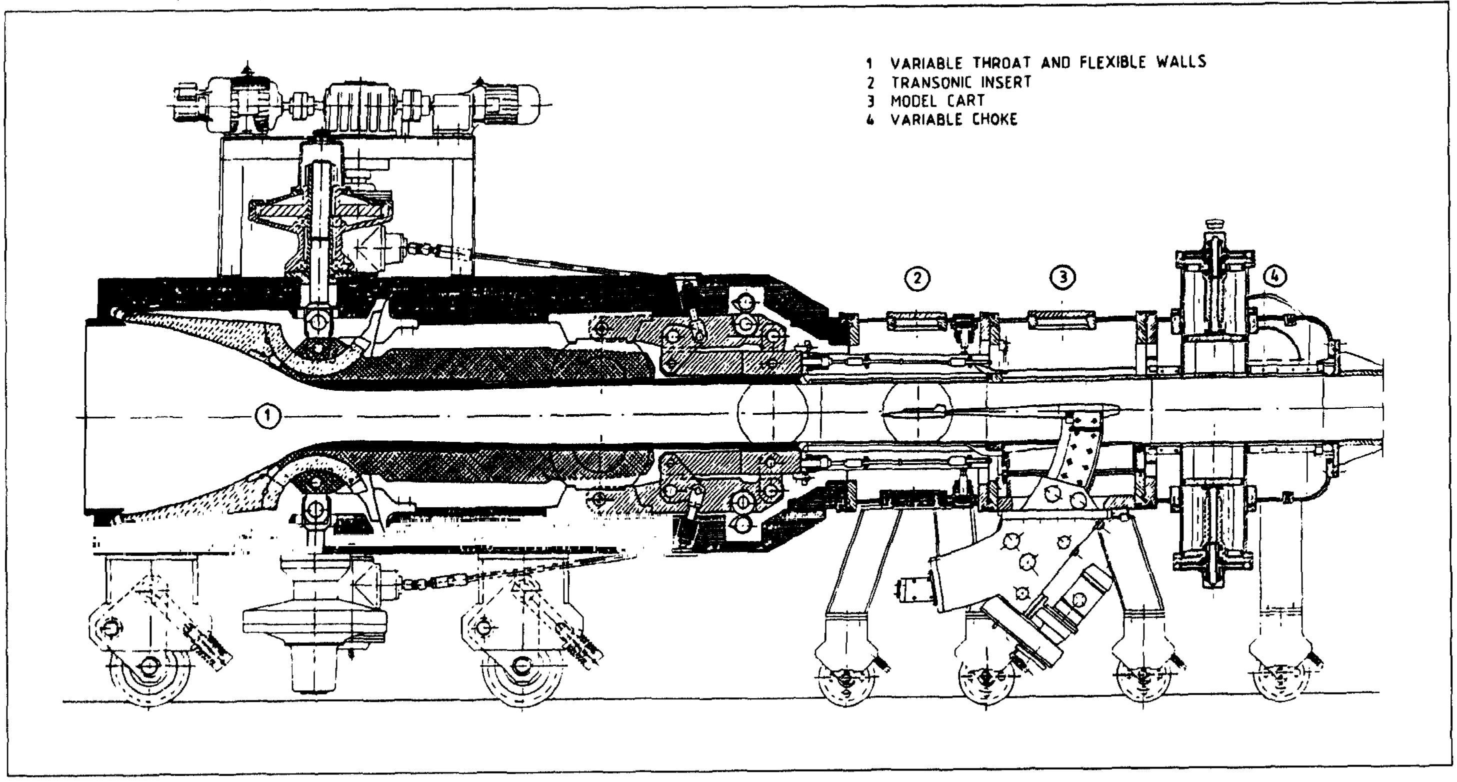
General Comments: The quoted unit cost to user increases if more than 6 min total running time per day is required.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 88 (EOARD Technical Report). Delft University of Technology. The Laboratory of High Speed Aerodynamics. Delft, The Netherlands: Delft University of Technology, 1989, pp. 1-4.

Date of Information: October 1989

Figure VIII.10: Schematic Diagram of the Transonic Test Section of the Delft University of Technology Blowdown Wind Tunnel B (TST 27)



Source: Delft University of Technology

Testing Capabilities: The tunnel will have computer-controlled five-hole directional pressure probes and hot-wire probes. It will also be capable of conducting pressure distribution, surface and schlieren visualization, and interferometry tests.

Data Acquisition: Data will be collected, stored, and processed in the central data acquisition system DRS of the Laboratory. For extensive numerical calculations, a terminal will provide access to the IBM 3083 mainframe and Convex minisupercomputer at the University Computer Center.

Planned Improvements (Modifications/Upgrades): Not applicable

Unique Characteristics: None

Applications/Current Programs: Planned applications include boundary layer research.

General Comments: None

Photograph/Schematic Available: Yes

References: Delft University of Technology. The Laboratory of High Speed Aerodynamics. Delft, The Netherlands: Delft University of Technology, 1989, pp. 1 and 3-4.

Date of Information: October 1989

Delft University of Technology Blowdown Tunnel A (ST 15)

Country: The Netherlands

Location: Delft University of Technology, Delft, The Netherlands

Owner(s):
Delft University of Technology
Faculty of Aerospace Engineering
Kluyverweg 1
2629 HS Delft
The Netherlands

Operator(s): Delft University of Technology

International Cooperation: None

Point of Contact: W.J. Bannink, Delft University of Technology, Tel.: [31]-(15)-784500

Test Section Size: 15 x 15 x 25 cm

Operational Status: Active

Utilization Rate: 10 tests per day

Performance
Mach Number: Less than 3 (nozzle blocks)
Reynolds Number: 20 x 10^6/m at Mach 3
Total Pressure: 15 bars (maximum)
Dynamic Pressure: 90 to 250 kN/m^2 at Mach 3
Total Temperature: 300 degrees Kelvin
Run Time: 20 min (maximum)
Comments: Nozzle exit height times width is 15 x 15 cm.

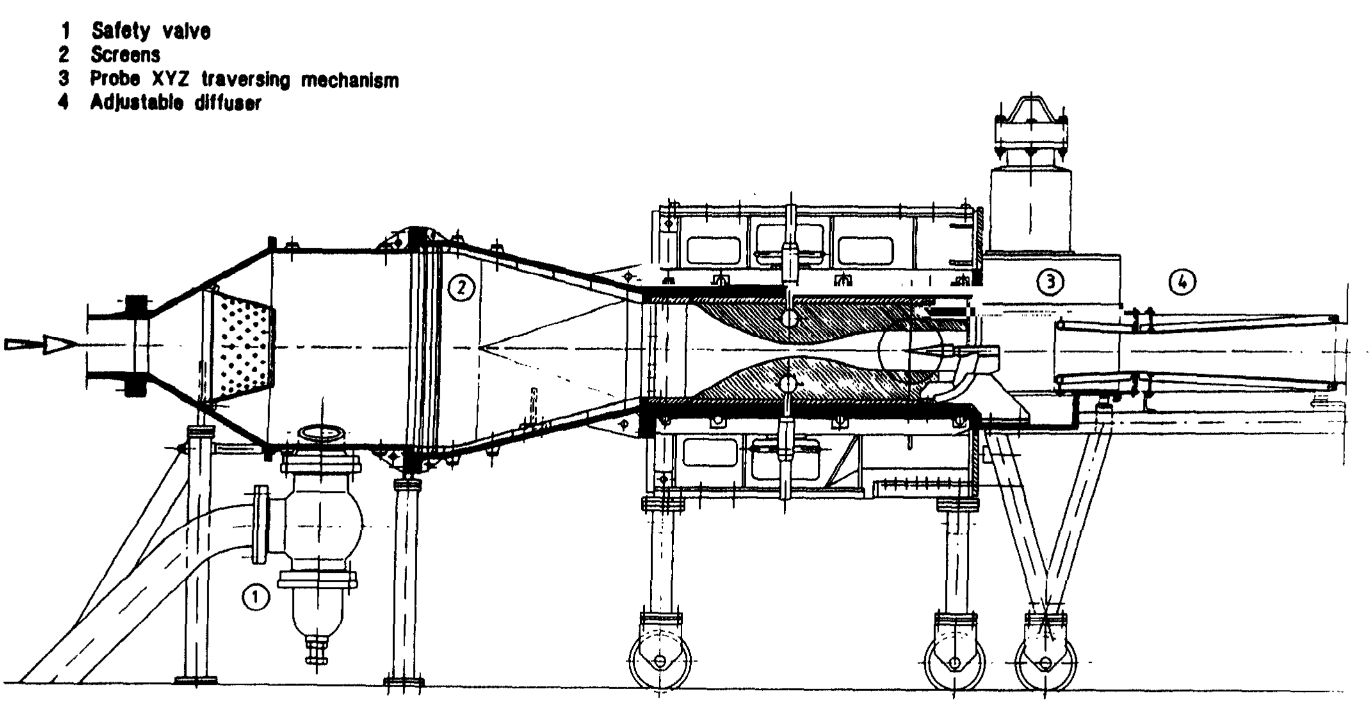
Cost Information
Date Built: 1959
Date Placed in Operation: 1960
Date(s) Upgraded: 1972
Construction Cost: Not available
Replacement Cost: $600,000 (1989)
Annual Operating Cost: Not available
Unit Cost to User: Typically $600 per day (1989)
Source(s) of Funding: Delft University of Technology

Number and Type of Staff
Engineers: 2 (part-time)
Scientists: 4 (part-time)
Technicians: 2 (part-time)
Others: 0
Administrative/Management: 0
Total: 8 (part-time)

Description: The Delft University of Technology Blowdown Tunnel A (ST 15) is a supersonic wind tunnel. Built in 1959, the ST 15 was the first supersonic wind tunnel to be operated by the Faculty of Aerospace Engineering. The tunnel is not equipped with a flexible-wall nozzle; rather, interchangeable sets of liners are used to obtain Mach numbers of either 1.5, 2, 2.5, or 3 in a 15 × 15 cm test section. Because of its long running time—20 min before recharging the pressure vessel is required—the tunnel is still in demand for tests involving flow visualization or detailed exploration of the flow field. The possibility of using specially adapted liners has proved to be an advantage for particular tests. The ST 15 is driven by dry, oil-free air delivered by a 6,000-kW compressor plant and stored at a pressure of 40 bars in a 300-m^3 storage vessel.

Testing Capabilities: The ST 15 has computer-controlled five-hole directional pressure probes and is capable of conducting pressure distribution, surface and schlieren visualization, and interferometry tests. Comparatively large windows (250 mm in diameter) provide a large field of view for nonintrusive optical measurements.

Figure VIII.12: Schematic Diagram of the Delft University of Technology Blowdown Wind Tunnel A (ST 15)



Source: Delft University of Technology

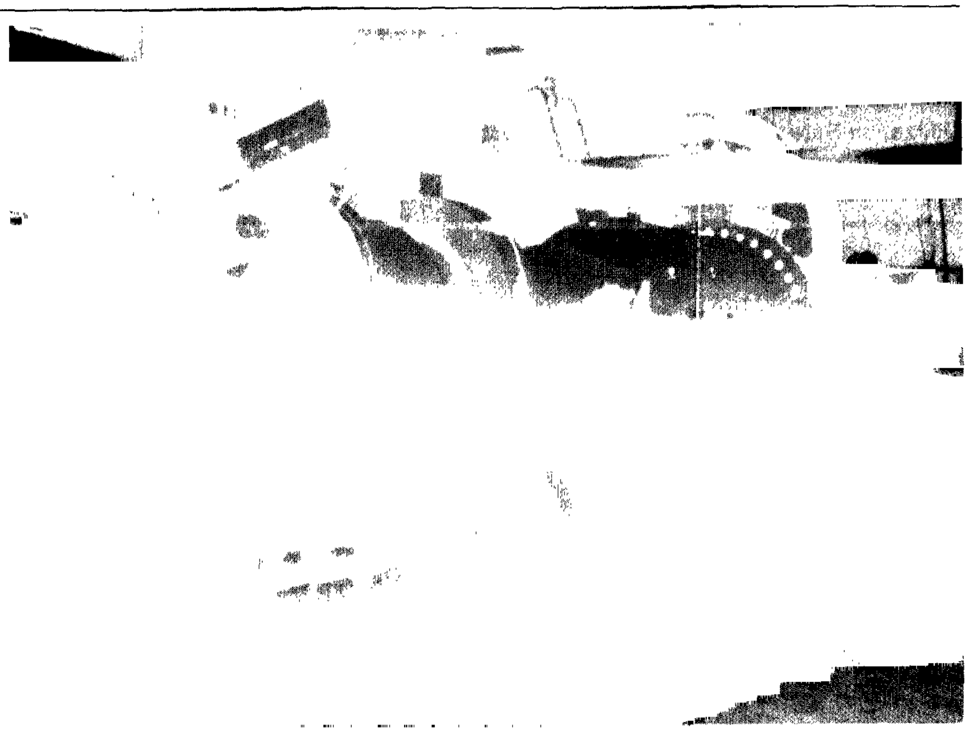
General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 97 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). National Aerospace Laboratory. Continuous Supersonic Wind Tunnel. Amsterdam: National Aerospace Laboratory, 1988.

Date of Information: November 1988

Figure VIII.13: NLR Continuous Supersonic Wind Tunnel



Source: NLR

NLR Supersonic Wind Tunnel

Country: The Netherlands

Location: Nationaal Lucht-en Ruimtevaartlaboratorium, Amsterdam, The Netherlands

Owner(s):
Nationaal Lucht-en Ruimtevaartlaboratorium
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands

Operator(s): Nationaal Lucht-en Ruimtevaartlaboratorium

International Cooperation: ESA

Point of Contact: H.A. Dambrink, Nationaal Lucht-en Ruimtevaartlaboratorium, Tel.: [31]-(20)-5-113-113

Test Section Size: 1.2 x 1.2 m

Operational Status: Active

Utilization Rate: 1 shift per day; approximately 10 blowdown runs per day

Performance
Mach Number: 1.2 to 4
Reynolds Number: 75 x 10^6/m at Mach 3.9
Total Pressure: 15 bars (maximum)
Dynamic Pressure: 75.65 to 117 kN/m^2
Total Temperature: 290 degrees Kelvin (maximum)
Run Time: 10 to 40 s (maximum)
Comments: None

Cost Information
Date Built: 1960
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Dutch government and research contracts

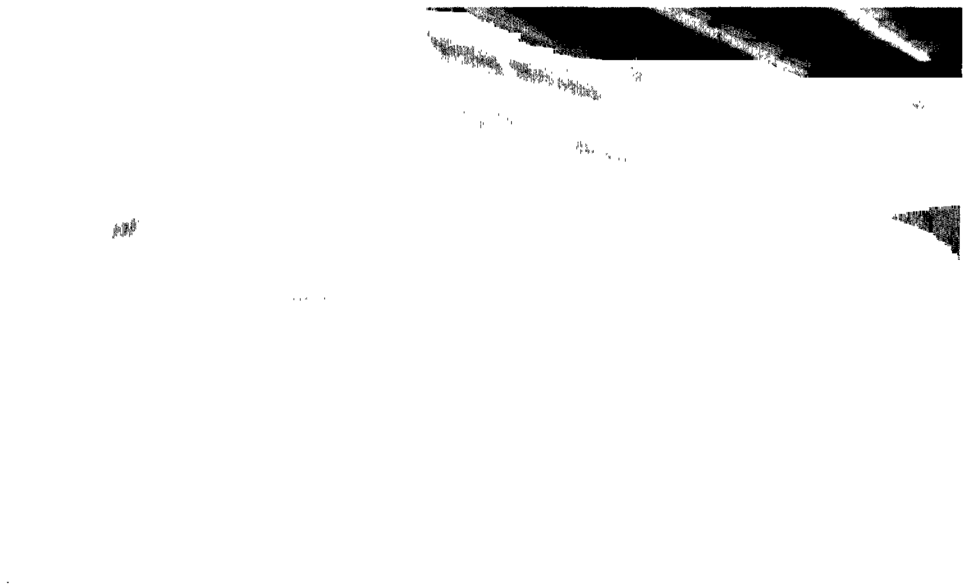
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The NLR Supersonic Wind Tunnel is a blowdown facility fed by an air storage vessel containing 600 m^3 of dry air at a maximum pressure of about 4,000 kPa.

Testing Capabilities: Forces and moments are measured with a six-component internal strain-gauge balance. More balances can be used in cases in which a separate portion of the model (e.g., aftbody) is to be tested simultaneously. Forces and moments can also be measured on rudders, flaps, and ailerons, and operated by remote control, if desired. For pressure measurements, the model is equipped with a number of pressure leads connecting each pressure plotting hole on the model with a pressure transducer. Other types of measurements include flow direction sensing, mass flow, and temperature measurements. The tunnel also has the ability to simulate propulsive jets with pressurized air and hydrogen peroxide.

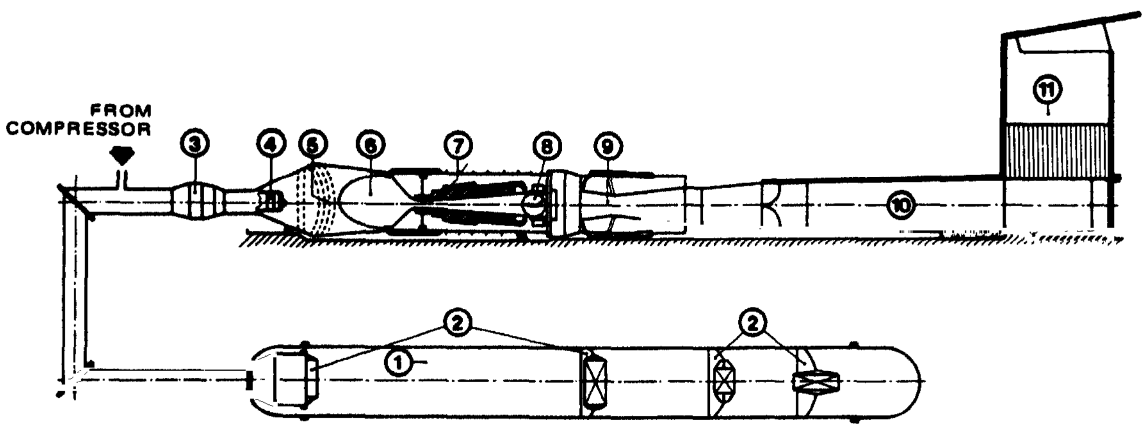
Data Acquisition: The tunnel has 24 channels of data. Data processing is performed by a Hewlett Packard 1000/45 dedicated computer system. Flow visualization techniques include the oil and naphthalene methods and the schlieren and shadow optical systems.

Figure VIII.15: NLR Supersonic Wind Tunnel



Source: NLR

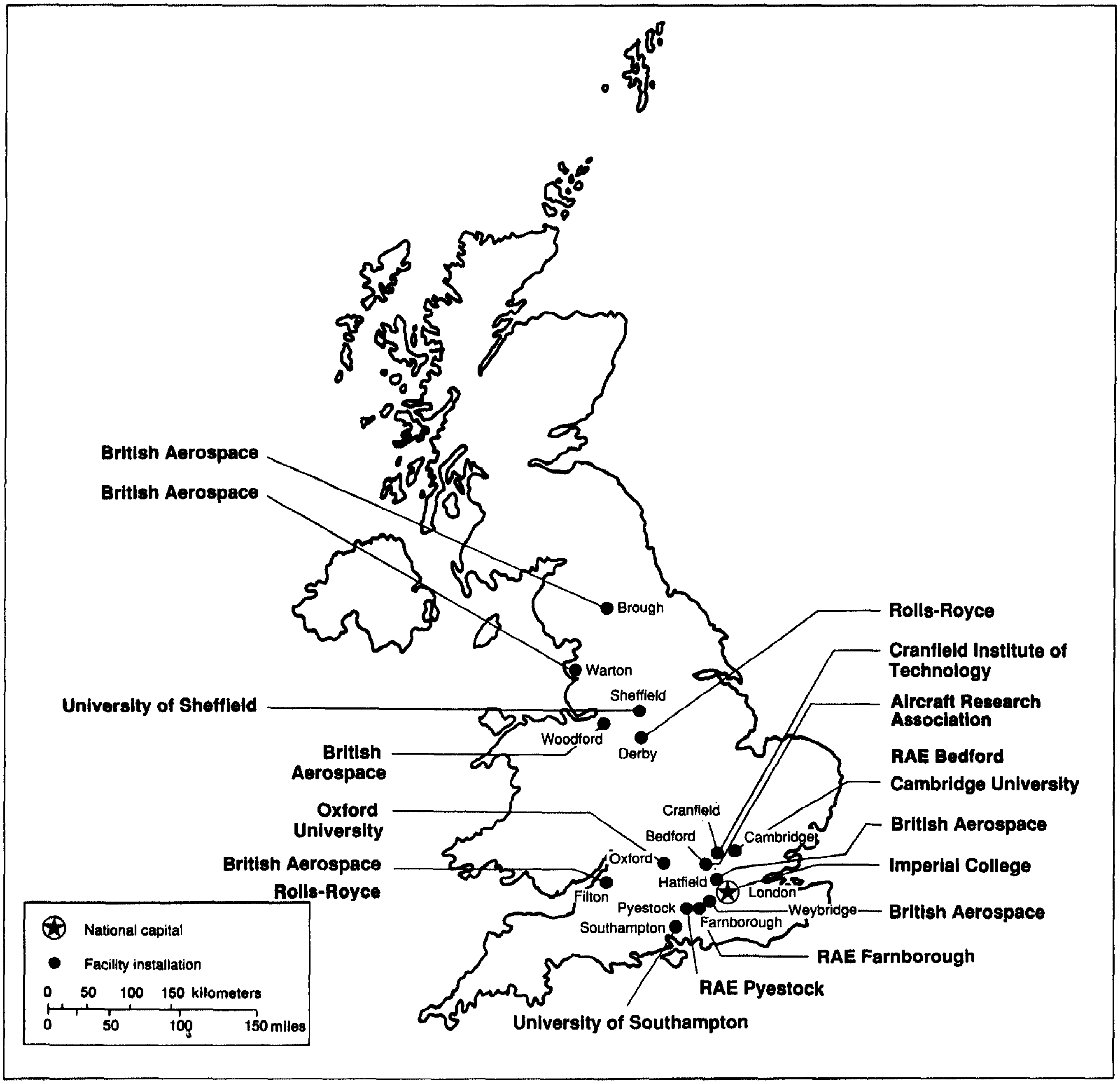
Figure VIII.16: Schematic Diagram of the NLR Supersonic Wind Tunnel



Source: NLR

Aerospace Test Facilities in the United Kingdom

Figure IX.1: Map of Test Facilities in the United Kingdom



Source: GAO

Unique Characteristics: Fences are fitted to airfoil models to minimize tunnel sidewall boundary layer interference with the upper surface supercritical flow development.

Applications/Current Programs: Current programs include industry projects and research.

General Comments: The ARA Bedford Two-Dimensional Wind Tunnel is a highly productive facility with a utilization rate of over 2,000 runs per year. A new brochure is expected to be available in December 1989.

Photograph/Schematic Available: No

References: None available.

Date of Information: October 1989

Applications/Current Programs: Wind tunnel activities included two-dimensional boundary layer research, aircraft development, and occasional non-aerospace testing.

General Comments: The BAe Brough 7 × 5 ft Low-Speed Wind Tunnel was decommissioned and is no longer owned and operated by British Aerospace, Military Aircraft, Ltd. The tunnel was sold to a non-aeronautical company in 1989 and removed from the British Aerospace site at Brough. The tunnel, however, has been reactivated by its new owner for non-aeronautical applications.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 94.

Date of Information: January 1990

BAe Filton 12 × 10 ft Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Filton, United Kingdom

Owner(s):
British Aerospace
Commercial Aircraft, Ltd.
Airbus Division
P.O. Box 77
Filton House
Filton, Bristol, Avon BS99 7AR
United Kingdom

Operator(s): British Aerospace, Commercial Aircraft, Ltd.

International Cooperation: Group for Aeronautical Research and Technology in Europe (GARTEUR) (France)

Point of Contact: Mike Marsden, British Aerospace, Commercial Aircraft, Ltd., Tel.: [44]-(272)-69-38-31, ext. 2809

Test Section Size: 10 x 12 x 25 ft

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0 to 0.25 or 5 to 280 ft/s
Reynolds Number: 0 to 1.8 x 10^6/ft
Total Pressure: Atmospheric
Dynamic Pressure: 0 to 43 lb/ft^2
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1954
Date Placed in Operation: Not available
Date(s) Upgraded: 1955
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Filton 12 × 10 ft Wind Tunnel is a continuous-flow, closed-circuit subsonic wind tunnel.

Testing Capabilities: The model is supported by one- or two-shielded struts from a six-component, electromechanical, overhead, virtual-center mechanical balance. The facility is powered by a single, 7-bladed, 22-ft diameter fan driven by 2,000-hp electric motors. An alternative 30 ft wide × 25 ft high working section is available in the return circuit for speeds up to 30 mph. The tunnel is suitable for large floor-mounted models with a span up to 10 ft. Auxiliary equipment consists of a 280-psi compressed-air system capable of continuous running at 1 lb/s or, for example, 2 lb/s for 25 min at 200 psi.

Data Acquisition: The tunnel has a computerized on-line data acquisition system for the six-component balance. In addition, up to 30 channels of steady-state or dynamic data can be acquired. The pressure measurement system incorporates 10 scanivalves and can record and analyze data up to 400 pressure tappings. For dynamic analysis, a complete Fast Fourier Transform computer system is available.

Planned Improvements (Modifications/Upgrades): Not available

BAe Hatfield 9 × 7 ft Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Hatfield, United Kingdom

Owner(s):
British Aerospace
Commercial Aircraft, Ltd.
Airlines Division
Wind Tunnel Department
Manor Road
Hatfield, Hertfordshire AL10 9TL
United Kingdom

Operator(s): British Aerospace, Commercial Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Robin G.B. Webb, British Aerospace, Commercial Aircraft, Ltd., Tel.: [44]-(7072)-62345, ext. 52185

Test Section Size: 6.7 x 8.7 x 18.5 ft

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0 to 0.22 or 0 to 250 ft/s
Reynolds Number: 0 to 1.6 x 10^6/ft
Total Pressure: Atmospheric plus dynamic pressure
Dynamic Pressure: 0 to 74 lb/ft^2
Total Temperature: Ambient plus (water spray-cooled)
Run Time: Continuous
Comments: Normal operating speed is Mach 0.18 or 200 ft/s.

Cost Information
Date Built: 1954
Date Placed in Operation: 1954
Date(s) Upgraded: None
Construction Cost: Not available
Replacement Cost: $6.4 million (1990)
Annual Operating Cost: $480,000 (1990)
Unit Cost to User: About $1,600 per day (1990)
Source(s) of Funding: None

Number and Type of Staff
Engineers: 4
Scientists: 0
Technicians: 2
Others: The support team is shared with the BAe Hatfield 15 ft Wind Tunnel.
Administrative/Management: 1
Total: At least 7

Description: The BAe Hatfield 9 × 7 ft Wind Tunnel is a continuous-flow, closed-circuit, closed-throat subsonic wind tunnel.

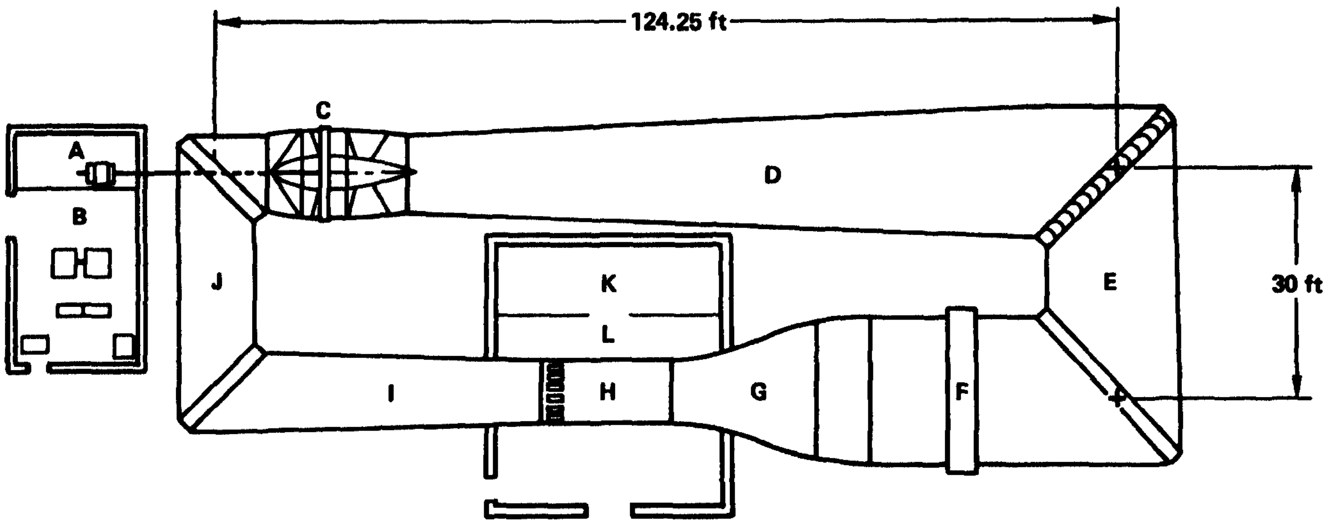
Testing Capabilities: The tunnel is powered by a 500-hp electric motor driving a 12-ft diameter fan. Models are mounted by a three-strut system onto an underfloor mechanical balance. The tunnel uses a six-component mechanical balance. Compressed air supplies up to 10 lb/s at 100 psig, and suction of 2,500 ft^3/min at 25 in. mercury are available. A variable height ground board and a reflection plane for half-models are also available.

Data Acquisition: Digital signals from the mechanical balance and analog signals from various devices (such as pressure transducers and strain gauges) are processed and fed to the Wind Tunnel Department's own computer for on-line computation and presentation.

Planned Improvements (Modifications/Upgrades): These include replacing the weighbeams of the balance with displacement transducers and installing on-line computer graphics.

Unique Characteristics: None

Figure IX.4: Schematic Diagram of the BAe Hatfield 9 × 7 ft Wind Tunnel



A – FAN MOTOR
B – MOTOR ROOM
C – FAN SECTION
D – THIRD DIFFUSER
E – FOURTH DIFFUSER
F – SCREEN SECTION
G – 5:1 CONTRACTION
H – WORKING SECTION
I – FIRST DIFFUSER
J – SECOND DIFFUSER
K – HEATING PLANT
L – CONTROL BLOCK

Source: BAe Hatfield

Planned Improvements (Modifications/Upgrades): These include replacing the front inlet screen to improve the flow, increasing the speed to Mach 0.18 or 200 ft/s, replacing the weighbeams on the balance with displacement transducers, and installing an on-line computer graphic display. A compressed air system to 700 psi is currently being installed.

Unique Characteristics: The open-circuit configuration of the tunnel is ideal for wake producing powered models. The large square test section is also configured for V/STOL work.

Applications/Current Programs: These include support for current and future British Aerospace, Commercial Aircraft, Ltd. projects. Current programs include engine simulation (rotors) using air motors.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 59.

Date of Information: January 1990

BAe Warton 2.7 X 2.1 m Low-Speed Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Preston, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
Warton Aerodrome
Preston, Lancashire PR4 1AX
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Alan N. Dewar, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52856

Test Section Size: 2.1 x 2.7 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.003 to 0.197 or 1 to 67 m/s
Reynolds Number: 0.1 to 5 x 10^6/m
Total Pressure: Atmospheric plus dynamic pressure
Dynamic Pressure: 3.2 kN/m^2
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1948
Date Placed in Operation: Not available
Date(s) Upgraded: 1960, 1975, and 1981
Construction Cost: Not available
Replacement Cost: $4.8 *million* (1990)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

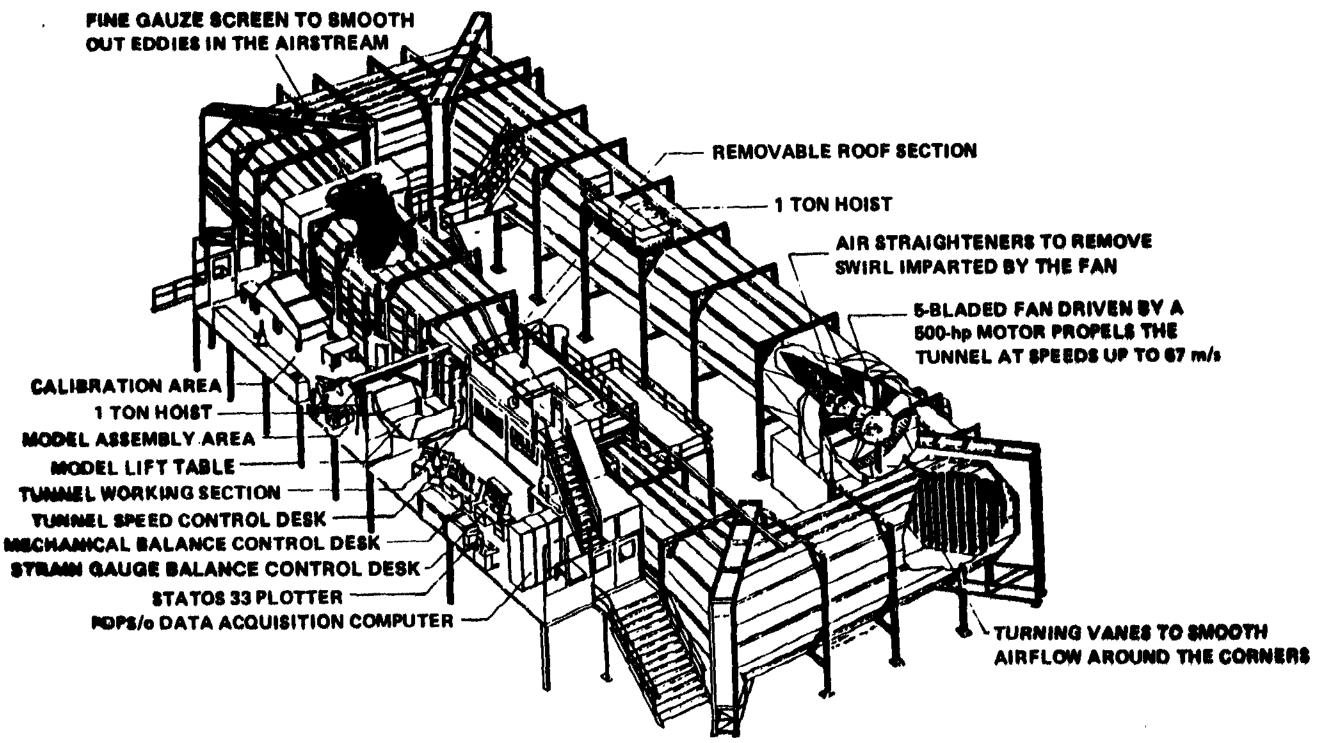
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Warton 2.7 X 2.1 m Low-Speed Wind Tunnel is a continuous-flow, closed-circuit, single-return subsonic wind tunnel.

Testing Capabilities: The tunnel is powered by a 380-kW DC motor from an AC/DC generator using a 5-bladed fan. It has a 5-degree diffuser, a contraction ratio of 5, and 1 screen. The speed is uniform to about 13 percent; the upwash and sidewash is within 0.43 degrees. Turbulence level is 0.25 percent. The tunnel has a platform-type mechanical balance, 5.1-kN normal force, 3 struts, and 6 weighbeams with load cells. The tunnel has two sting mounting systems: one for large models with an incidence of −3 degrees to 30 degrees and sideslip of −6 degrees to 17 degrees, and one for small models with an incidence of −5 degrees to 95 degrees and sideslip of −15 degrees to 40 degrees. The tunnel also has several internal strain-gauge balances, 6 components, and a maximum normal force of 3.3 kN. Air is supplied at 1 kg/s at 7 bars and stored at 23 m^3 at 30 bars.

Data Acquisition: The tunnel has a dedicated minicomputer (DEC PDP 11/24) with on-line reduction and plotting as well as computer storage of 15-year output with a fully indexed retrieval system.

Figure IX.6: Schematic Drawing of the BAe Warton 2.7 × 2.1 m Low-Speed Wind Tunnel



Source: NASA

Data Acquisition: A dedicated minicomputer (DEC PDP 8) is linked to the site's central processing unit for reduction and storage. Computer storage of 15-year output and fully indexed retrieval are available.

Planned Improvements (Modifications/Upgrades): The dedicated minicomputer is to be replaced in 1990 with a DEC PDP 11 for on-line reduction and plotting. Other improvements include an additional intake screen and maintenance and replacement of lifted items for long-term active operation.

Unique Characteristics: Not available

Applications/Current Programs: The tunnel is used for aircraft design and development, flight test support, new project assessment, and aerodynamic research by a major manufacturer of combat aircraft. It is fully active on a flexible program, allowing quick reaction to new demands. It is also fully staffed for design and manufacture of models, rigs, and strain-gauge balances, as well as for calibration, testing, and analysis. Low-speed aerodynamic tests of HOTOL are also being conducted in the tunnel.

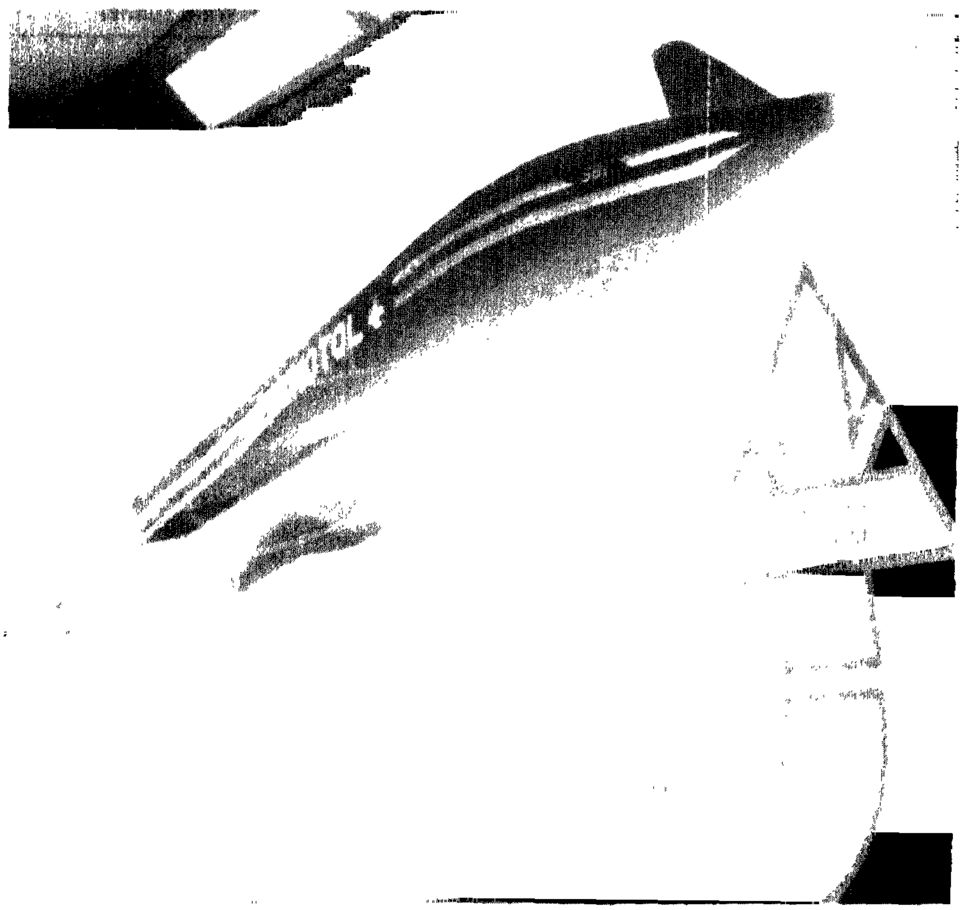
General Comments: The tunnel has a shielded intake and exit and solid walls. The working second floor and roof are constructed of concrete and the walls are brick. The contraction and split vane diffuser are supported by steel frames. The tunnel is clad in plywood.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 57.

Date of Information: January 1990

Figure IX.8: Low-Speed Aerodynamic *Characteristics of a 1/20 Scale Model of* HOTOL in the BAe Warton 18 ft V/STOL Wind Tunnel



Source: BAe Warton

Applications/Current Programs: Not applicable

General Comments: The BAe Weybridge 3 × 2 ft High-Speed Wind Tunnel was decommissioned in 1989 and has been dismantled. Moreover, the British Aerospace site at Weybridge has been closed and torn down.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 98.

Date of Information: January 1990

BAe Warton 13 × 9 ft Low-Speed Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Preston, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
Warton Aerodrome
Preston, Lancashire PR4 1AX
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Alan N. Dewar, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52856

Test Section Size: 9 x 13 ft

Operational Status: Decommissioned but being relocated and reactivated (see General Comments)

Utilization Rate: Full double day shift (when operational)

Performance
Mach Number: 0.18 to 0.27 or 200 to 300 ft/s
Reynolds Number: 0 to 2.2 x 10^6/ft
Total Pressure: Atmospheric
Dynamic Pressure: 0 to 145 lb/ft^2
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1950
Date Placed in Operation: Not available
Date(s) Upgraded: 1970, 1980, and 1990
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

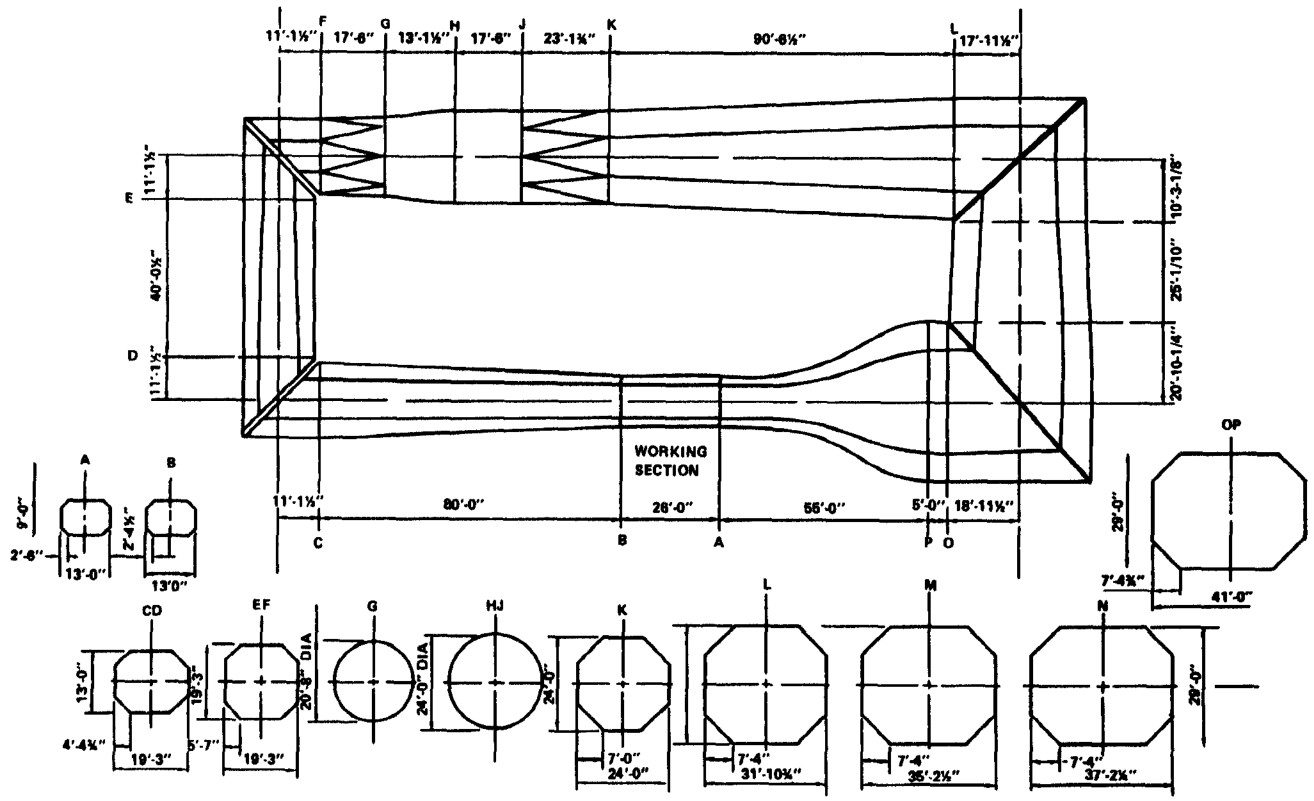
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Warton 13 × 9 ft Low-Speed Wind Tunnel is a continuous-flow, closed-circuit, single-return subsonic wind tunnel. The tunnel has a closed test section and can accommodate a model with a 9-ft wing span. The tunnel also has an underfloor electromechanical balance and an underfloor strain-gauge balance.

Testing Capabilities: The tunnel has a single-stage, 7-bladed, 24-ft (7.3 m) diameter fan driven through a bevel reduction gear-box by electric motors developing 2,200 hp. The test section is a 13 × 9 ft (4 × 2.7 m) rectangular with large corner fillets. Turntables of 7 ft (2.13 m) in diameter are installed in both the roof and floor, their rotational axes being on the centerline of the balance. The main balances are an underfloor six-component virtual-center balance and an underfloor five-component half-model balance.

Data Acquisition: The tunnel has a dedicated PDP 11/60 on-line data acquisition system, multitasking with graph plotting, and background computation roles. Data recording is achieved by 16 digital and/or 16 analog inputs.

Figure IX.10: Schematic Diagram of the BAe Warton 13 × 9 ft Low-Speed Wind Tunnel



Source: NASA

been removed to Manchester University where it has been reactivated. The new point of contact is Dr. D.J. Smith, Manchester University, Tel.: [44]-(61)-275-2000.

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 72.

Date of Information: January 1990

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to study the low-speed aerodynamics of generalized research models and flight vehicle configurations, including dynamic stability measurements.

General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 66.

Date of Information: November 1989

RAE Farnborough 5 m Low-Speed Wind Tunnel

Country: United Kingdom

Location: Royal Aerospace Establishment Farnborough, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Farnborough
AE2 Division
Aerodynamics Department
Farnborough, Hampshire GU14 6TD
United Kingdom

Operator(s): Royal Aerospace Establishment Farnborough

International Cooperation: Not available

Point of Contact: Superintendent, AE2 Division, Royal Aerospace Establishment Farnborough, Tel.: [44]-(252)-24461, ext. 5377

Test Section Size: 4.2 x 5 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0 to 0.33 or 0 to 133 m/s
Reynolds Number: Up to 18 x 10^6/m
Total Pressure: 1 to 3 bars
Dynamic Pressure: Up to 16 kN/m^2
Total Temperature: Ambient to 313 degrees Kelvin
Run Time: 15 min
Comments: None

Cost Information
Date Built: 1978
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

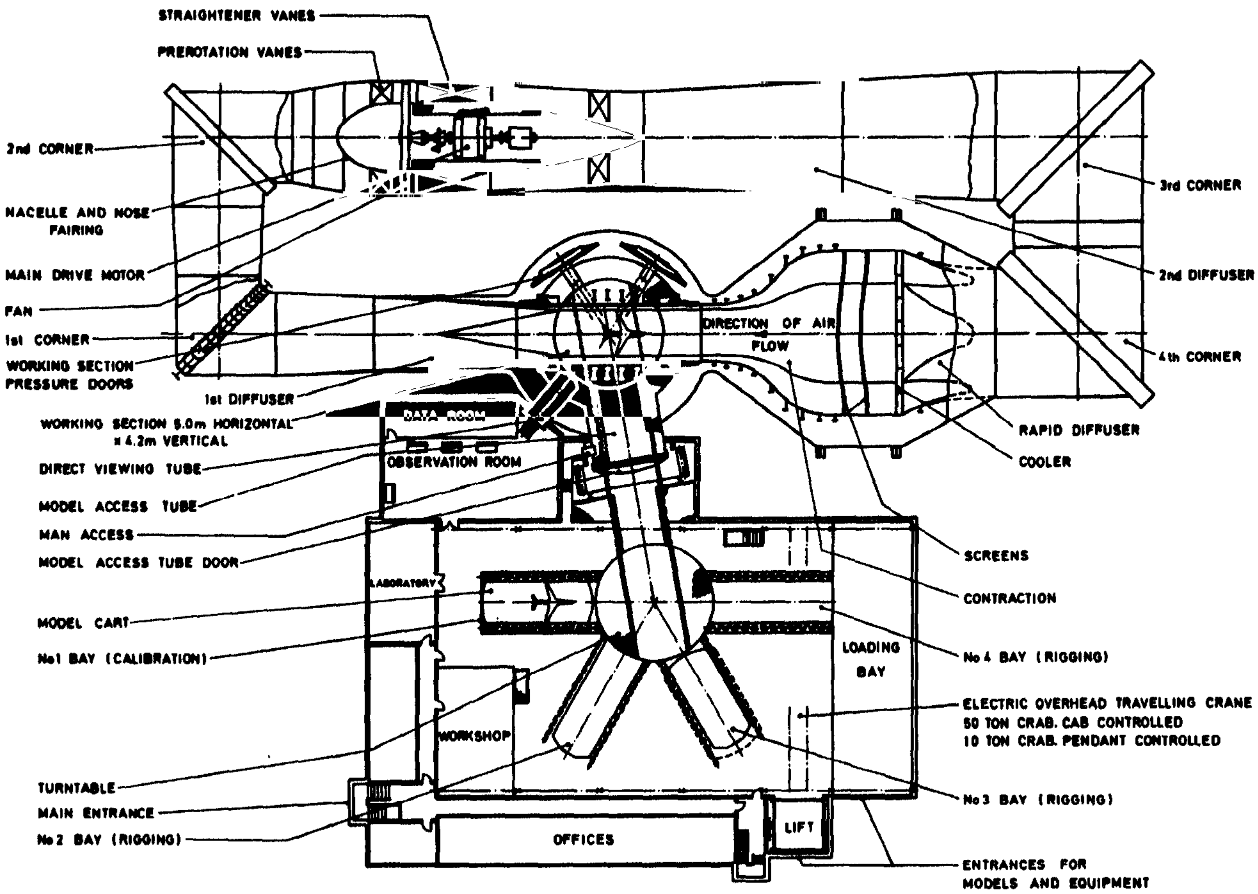
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Farnborough 5 m Low-Speed Wind Tunnel is a continuous-flow, return-circuit subsonic wind tunnel.

Testing Capabilities: Models are supported on interchangeable mobile carts that become the test-section floor. The carts include (1) the sting support cart with a range of 38 degrees obtained using a circular arc quadrant and with an unturned strain-gauge balance, (2) a mechanical balance cart that has a six-component virtual-center mechanical balance under the floor, and (3) a general-purpose cart for miscellaneous tests including tunnel calibration. Model carts are interchangeable in about 60 min. The test section can be isolated from the pressurized circuit or repressurized in about 60 min. Special rigs can be used for high-incidence tests, measurement of full-scale store drag, and a low-drag support for accurate drag measurements. Auxiliary air can be supplied to models at 22 atm and 7.9 kg/s. Suction at 4.2 m^3/s is also available.

Data Acquisition: A modular system based on multiple minicomputers arranged in a two-tier network is used. Independent front-end packages are dedicated to particular wind tunnel tasks.

Figure IX.12: Schematic Diagram of the RAE Farnborough 5 m Low-Speed Wind Tunnel

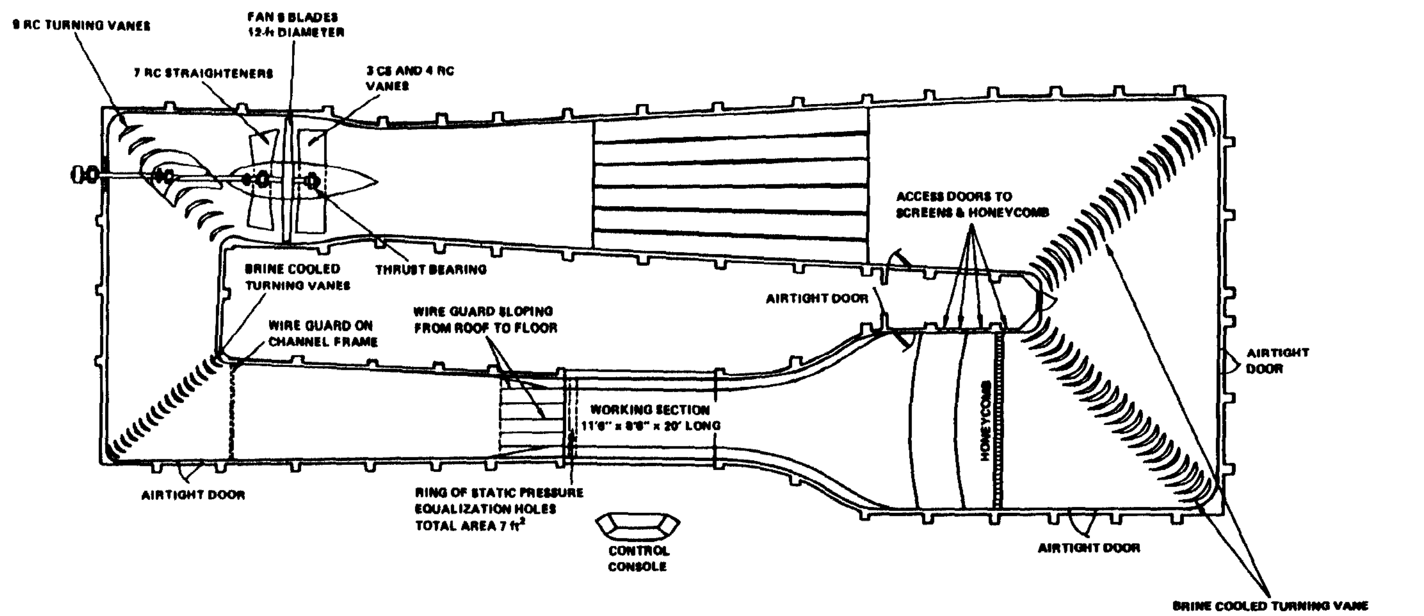


Source: RAE Farnborough

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 64.

Date of Information: November 1989

Figure IX.13: Schematic Diagram of the RAE Farnborough 11.5 × 8.5 ft Wind Tunnel



Source: NASA

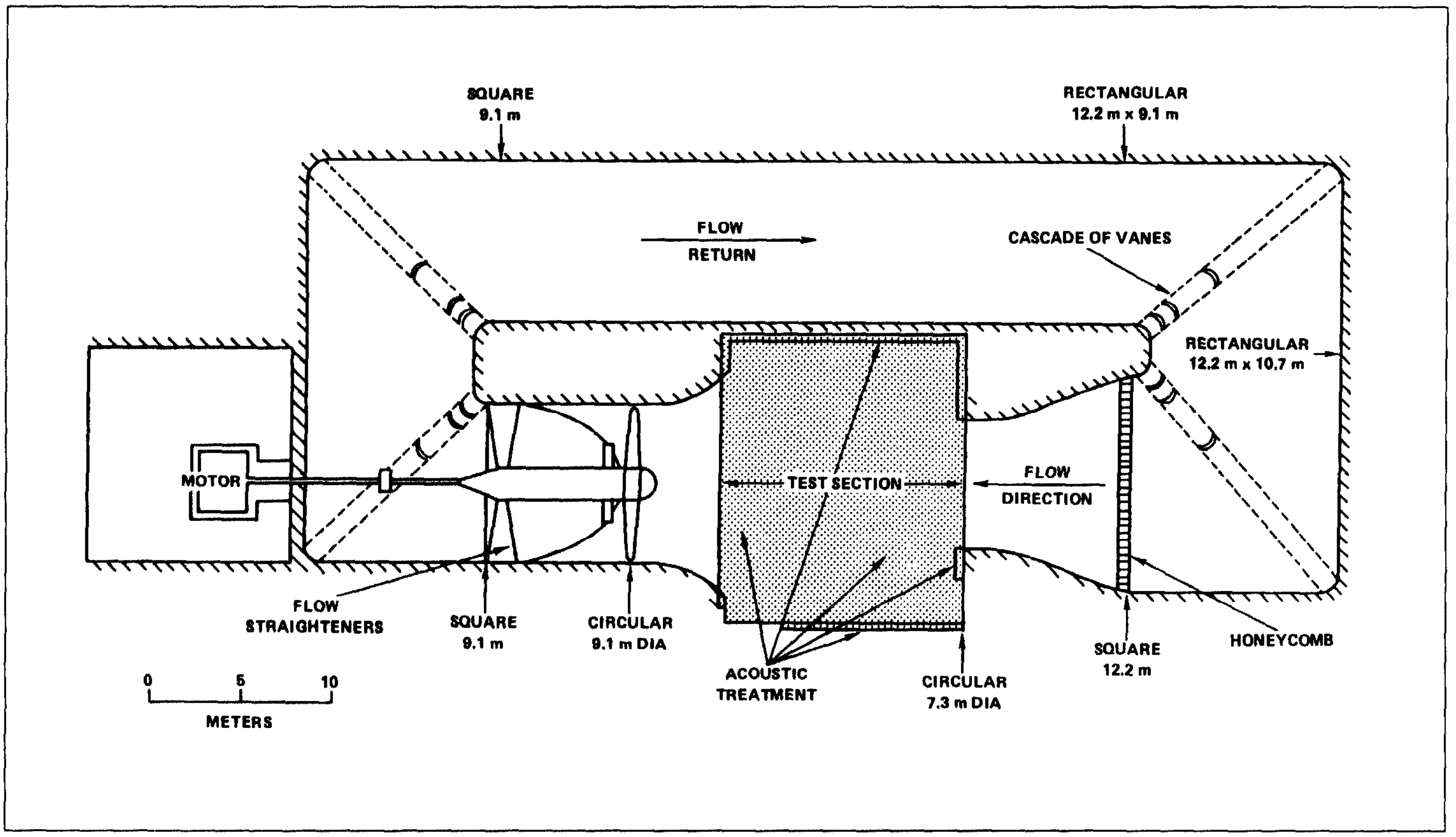
General Comments: None

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 115.

Date of Information: November 1989

Figure IX.14: Schematic Diagram of the RAE Farnborough 24 ft Anechoic Low-Speed Wind Tunnel



Source: NASA

BAe Woodford 30 × 27 in. Supersonic Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Woodford, United Kingdom

Owner (s):
British Aerospace
Commercial Aircraft, Ltd.
Airlines Division
Chester Road
Woodford, Bramhall
Stockport, Cheshire SK7 1QR
United Kingdom

Operator(s): British Aerospace, Commercial Aircraft, Ltd.

International Cooperation: Not applicable

Point of Contact: Robin G.B. Webb, British Aerospace, Commercial Aircraft, Ltd., Tel.: [44]-(7072)-62345, ext. 52185

Test Section Size: 0.76 x 0.69 m

Operational Status: Decommissioned (see General Comments)

Utilization Rate: Not operational

Performance
Mach Number: 1.6 to 3.5
Reynolds Number: 56 x 10^6/m at Mach 1.6 and 30 x 10^6/m at Mach 3.5
Total Pressure: 1.5 bars at Mach 1.6 and 5 bars at Mach 3.5
Dynamic Pressure: Not available
Total Temperature: Ambient
Run Time: Not available
Comments: None

Cost Information
Date Built: 1955
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The BAe Woodford 30 × 27 in. Supersonic Wind Tunnel was an intermittent supersonic wind tunnel. The tunnel was decommissioned and has been scrapped. It had a closed working section and was also used as an open-jet tunnel.

Testing Capabilities: The tunnel was capable of conducting conventional testing of sting-mounted models. The diffuser of the tunnel provided a 3-ft diameter open-jet at speeds up to Mach 1, which was used for ad hoc testing, primarily of full-scale components.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not applicable

Unique Characteristics: Not available

Applications/Current Programs: Not available

General Comments: The BAe Woodford 30 × 27 in. Supersonic Wind Tunnel has been decommissioned and scrapped.

Cambridge University Supersonic Wind Tunnels

Country: United Kingdom

Location: Cambridge University, Cambridge, United Kingdom

Owner(s):
Cambridge University
Department of Engineering
Trumpington Street
Cambridge, Cambridgeshire CB2 1PZ
United Kingdom

Operator(s): Cambridge University

International Cooperation: None

Point of Contact: Dr. L.C. Squire, Cambridge University, Tel.: [44]-(223)-332634

Test Section Size: 18 x 11.4 cm (nozzle exit diameter)

Operational Status: Active

Utilization Rate: 20 tests per day

Performance
Mach Number: 3.5 (maximum)
Reynolds Number: 8 x 10^6/ft
Total Pressure: 1 bar
Dynamic Pressure: Not available
Total Temperature: 300 degrees Kelvin
Run Time: 60 s
Comments: None

Cost Information
Date Built: 1960
Date Placed in Operation: 1962
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 0
Scientists: 0
Technicians: 0
Others: 5 research assistants, 2 research students, and 1 staff member
Administrative/Management: 0
Total: 8 (2 persons are required to run the facility)

Description: The Cambridge University Supersonic Wind Tunnels consist of two identical supersonic tunnels.

Testing Capabilities: The tunnels are capable of conducting pressure measurements, various types of visualization, and laser holography tests.

Data Acquisition: The tunnels have on-line channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The two tunnels are used for research, training, and some contract research.

General Comments: None

Photograph/Schematic Available: No

RAE Bedford 3 × 4 ft Supersonic Wind Tunnel

Country: United Kingdom

Location: Royal Aerospace Establishment Bedford, Bedford, United Kingdom

Owner(s):
Royal Aerospace Establishment Bedford
Bedford, Bedfordshire MK41 6AE
United Kingdom

Operator(s): Royal Aerospace Establishment Bedford

International Cooperation: Not available

Point of Contact: Dr. D.E. Mowbray, Royal Aerospace Establishment Bedford, Tel.: [44]-(234)-225840

Test Section Size: 4 x 3 ft

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 2.5 to 5 (contoured)
Reynolds Number: 13 x 10^6/ft (at Mach 4.5)
Total Pressure: 0.4 to 12 bars
Dynamic Pressure: 200 to 2,000 lb/ft^2
Total Temperature: 423 degrees Kelvin
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1960
Date Placed in Operation: 1960 (reopened in 1983)
Date(s) Upgraded: 1965 and 1977
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Bedford 3 × 4 ft Supersonic Wind Tunnel is a continuous-flow, return-circuit supersonic wind tunnel. The tunnel has a flexible nozzle enabling operation at any Mach number between Mach 2.5 and 5. The tunnel has two 18-stage axial flow and two 8-stage centrifugal compressors that can be run in parallel or in a series. The total drive power is 66 MW.

Testing Capabilities: The tunnel has a rear-sting support for models, giving −5 degrees to 27 degrees of pitch with full 360 degrees of roll. Interchangeable support carts are used. Sidewall mounting of models is possible using the schlieren window cutout. High-pressure air supply is available. Air storage capacity is 90 m^3 at 262 bars supplying a line at 69 bars (1,000 psig).

Data Acquisition: A dedicated system based on a Hewlett Packard 1000 computer records all tunnel and model parameters for force and pressure plotting tests, monitors the steady and dynamic loads on the force balance, and provides on-line reduction and presentation of data. The tunnel has the capacity for 24 low-level analog signals and 24 pressure scanning switches.

RAE Bedford 8 × 8 ft Subsonic/Supersonic Wind Tunnel

Country: United Kingdom

Location: Royal Aerospace Establishment Bedford, Bedford, United Kingdom

Owner(s):
Royal Aerospace Establishment Bedford
Bedford, Bedfordshire MK41 6AE
United Kingdom

Operator(s): Royal Aerospace Establishment Bedford

International Cooperation: Not available

Point of Contact: Dr. D.E. Mowbray, Royal Aerospace Establishment Bedford, Tel.: [44]-(234)-225840

Test Section Size: 8 x 8 ft

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.1 to 0.9 (subsonic) and 1.35 to 2.5 (supersonic)
Reynolds Number: 10 x 10^6/ft at Mach 0.9 and 4 x 10^6/ft at Mach 2.5
Total Pressure: 0.1 to 4 bars (subsonic) and 0.1 to 1.3 bars (supersonic)
Dynamic Pressure: Up to 1,600 lb/ft^2 (subsonic) and up to 1,300 lb/ft^2 (supersonic)
Total Temperature: 315 degrees Kelvin
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1957
Date Placed in Operation: 1957
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Bedford 8 × 8 ft Subsonic/Supersonic Wind Tunnel is a continuous-flow, closed-circuit tunnel with subsonic and supersonic operating ranges. Subsonic control is achieved with a variable sonic throat downstream of the working section. It has a flexible nozzle ahead of the working section to provide a supersonic Mach number range continuously variable between Mach 1.35 and 2.5. The tunnel has an axial flow compressor with two stages for subsonic and eight stages for supersonic operation. Total drive power is 68 MW.

Testing Capabilities: Rear-sting support for models provides +/−22.5 degrees of pitch with full 360 degree of roll. The sidewall-mounted half-model balance support system provides −15 to 35 degrees of pitch. The tunnel has a support system for two-dimensional wings spanning the tunnel. It has a high-pressure air supply with storage capacity of 90 m^3 at 262 bars supplying a line at 69 bars (1,000 psig).

Data Acquisition: A dedicated system based on a Hewlett Packard 1000 computer records all tunnel and model parameters for force and pressure plotting tests, monitors the steady and dynamic loads on the force

ARA Bedford M4T Blowdown Wind Tunnel

Country: United Kingdom

Location: Aircraft Research Association, Bedford, United Kingdom

Owner(s):
Aircraft Research Association
Manton Lane
Bedford, Bedfordshire MK41 7PF
United Kingdom

Operator(s): Aircraft Research Association

International Cooperation: Not available

Point of Contact: Chief Executive, Aircraft Research Association, Tel.: [44]-(234)-50681

Test Section Size: 1 x 1.33 ft

Operational Status: Active (low-level usage)

Utilization Rate: 6 tests per day (maximum)

Performance
Mach Number: 4 to 5
Reynolds Number: 14 to 23 x 10^6/ft
Total Pressure: 147 to 294 psia
Dynamic Pressure: 1,500 to 3,000 lb/ft^2
Total Temperature: 684 degrees Kelvin
Run Time: 30 s (maximum)
Comments: Nozzle exit diameter is 1 x 1.33 ft.

Cost Information
Date Built: 1965
Date Placed in Operation: 1965
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ARA Bedford M4T Blowdown Wind Tunnel is a hypersonic wind tunnel with atmospheric exhaust.

Testing Capabilities: The tunnel is capable of testing sting-mounted force and pressure models and pitch damping models. It also has schlieren and shadowgraph capability.

Data Acquisition: Up to 22 channels of data can be recorded including a 6-component strain-gauge balance, individual pressure transducers, and a scanivalve.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current programs include industry projects and research.

General Comments: A new brochure is expected to be available in December 1989.

ARA Bedford M7T Blowdown Wind Tunnel

Country: United Kingdom

Location: Aircraft Research Association, Bedford, United Kingdom

Owner(s):
Aircraft Research Association
Manton Lane
Bedford, Bedfordshire MK41 7PF
United Kingdom

Operator(s): Aircraft Research Association

International Cooperation: Not available

Point of Contact: Chief Executive, Aircraft Research Association, Tel.: [44]-(234)-50681

Test Section Size: 1 ft diameter

Operational Status: Active (low-level usage)

Utilization Rate: 6 tests per day (maximum)

Performance
Mach Number: 6, 7, and 8 (contoured)
Reynolds Number: 10 to 15 x 10^6/ft
Total Pressure: 1,470 to 2,940 psia
Dynamic Pressure: 1,700 to 2,600 lb/ft^2
Total Temperature: 1,530 degrees Rankine
Run Time: 48 s (maximum)
Comments: Nozzle exit diameter is 1.02 ft.

Cost Information
Date Built: 1965
Date Placed in Operation: 1965
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The ARA Bedford M7T Blowdown Wind Tunnel is a hypersonic wind tunnel with atmospheric exhaust.

Testing Capabilities: The tunnel is capable of testing sting-mounted force and pressure models and pitch damping models. It also has schlieren and shadowgraph capability.

Data Acquisition: Up to 22 channels of data can be recorded including a 6-component strain-gauge balance, individual pressure transducers, and a scanivalve.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current programs include industry projects and research.

General Comments: A new brochure is expected to be available in December 1989.

BAe Warton Guided Weapons Wind Tunnel

Country: United Kingdom

Location: British Aerospace, Preston, United Kingdom

Owner(s):
British Aerospace
Military Aircraft, Ltd.
The GW Wind Tunnel, W258
Warton Aerodrome
Preston, Lancashire PR4 1AX
United Kingdom

Operator(s): British Aerospace, Military Aircraft, Ltd.

International Cooperation: Not available

Point of Contact: Joe A. Smith, British Aerospace, Military Aircraft, Ltd., Tel.: [44]-(772)-633333, ext. 52874

Test Section Size: 0.457 x 0.457 x 0.6 m

Operational Status: Active

Utilization Rate: 4 to 5 tests per day

Performance
Mach Number: 1.7 to 6 (contoured)
Reynolds Number: 90 x 10^6/m at Mach 1.7, typically 140 x 10^6/m at Mach 3 (30 s run), and 45 x 10^6/m at Mach 6
Total Pressure: 2 to 34 bars (maximum at Mach 6)
Dynamic Pressure: 50 to 450 kN/m^2
Total Temperature: 288 to 473 degrees Kelvin (maximum at Mach 6)
Run Time: 10 to 200 s
Comments: Nozzle exit diameter is 52 cm. Also see General Comments.

Cost Information
Date Built: 1961
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $20 million (1990)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

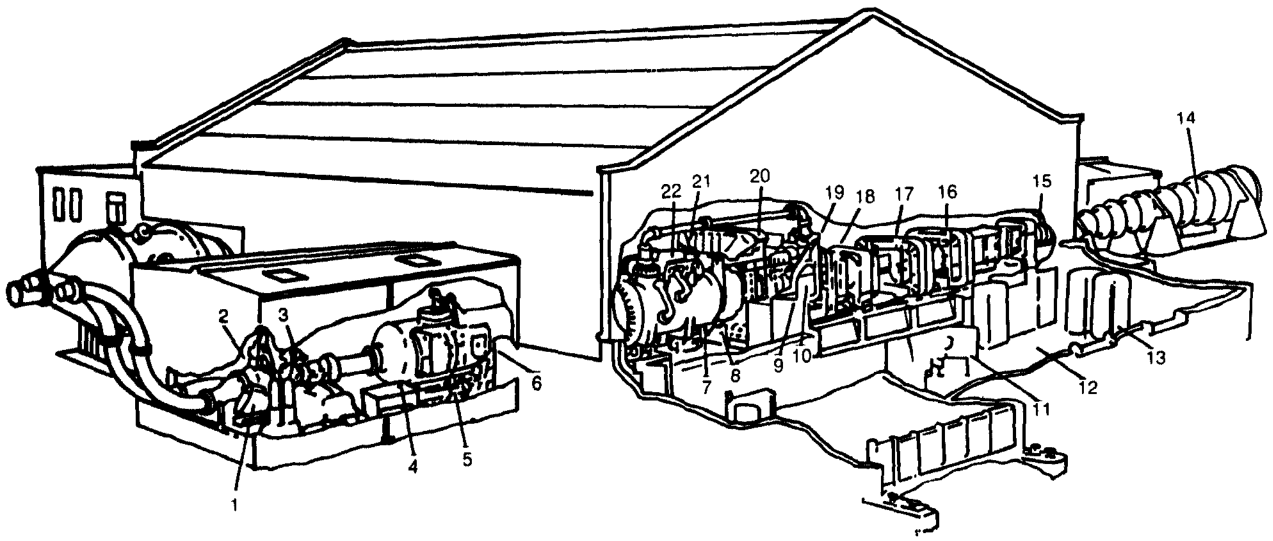
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 6

Description: The BAe Warton Guided Weapons Wind Tunnel is an intermittent blowdown hypersonic wind tunnel. Air is stored at 360 m^3 at 40 bars. Air storage is shared with the BAe Warton 1.2 m High-Speed Wind Tunnel. Typical recharge time after a test 15 to 30 min.

Testing Capabilities: The tunnel is capable of conducting force balance, pressure, and heat transfer tests. It has a continuously rolling sting (0.16 to 1 revolutions per second) with integral slip rings that carry models via strain-gauge internal or rear-sting balances. Pressure plotting is performed using external scanivalves or discrete transducers. Heat transfer measurements have been obtained using thermocouples or calorimeter plates. A 0.3-m diameter schlieren system traverses a 0.6 × 0.3 m window.

Data Acquisition: The tunnel uses a purpose-built minicomputer-based system with provision for 15 analog inputs, 2 synchro inputs, 64 thermocouple inputs (multiplexed into 4 channels), digital input and output channels, and a scanivalve drive unit. Up to 250 data points per

Figure IX.17: Schematic Drawing of the BAe Warton Guided Weapons Wind Tunnel



1. Valve tie down
2. Butterfly stop valve
3. Cone control valve
4. Pressure vessel with inlet diffuser cone
5. Dummy heater
6. Heater matrix
7. Settling chamber
8. Main jacks
9. Working section
10. Model
11. Main control console
12. Control room
13. Data handling console
14. Fixed subsonic diffuser
15. Transition piece
16. Diffuser hydraulic jacks
17. Moving diffuser
18. Model cart
19. Yoke and quadrant
20. Flexible nozzle
21. Secondary main jacks
22. Pressure balance system

Source: NASA

hypersonic configurations over a range of angles of attack up to 70 degrees. The aerodynamic characteristics of slender axisymmetric vehicles at low angles of attack are also being investigated. The free-flight technique is being used to study the dynamic stability of hypersonic vehicles.

General Comments: None

Photograph/Schematic Available: Yes

References: Department of Aeronautics and Astronautics, The University of Southampton. Departmental Research Report 1986. Southampton: The University of Southampton, October 1986, pp. 69-70. Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 104 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 21-25 (EOARD Technical Report).

Date of Information: September 1989

The University of Southampton Light Piston Isentropic Compression Facility

Country: United Kingdom

Location: The University of Southampton, Southampton, United Kingdom

Owner(s):
The University of Southampton
Department of Aeronautics and Astronautics
The University, Highfield
Southampton, Hampshire S09 5NH
United Kingdom

Operator(s): The University of Southampton

International Cooperation: France and ESA

Point of Contact: Professor Robin A. East, The University of Southampton, Tel.: [44]-(703)-592324

Test Section Size: 0.21 m diameter (open-jet)

Operational Status: Active

Utilization Rate: Up to 10 to 15 tests per day

Performance
- **Mach Number:** Mach 6.85 (contoured) and 9.4 (contoured)
- **Reynolds Number:** 12 x 10^6/ft
- **Total Pressure:** 90 bars
- **Dynamic Pressure:** 0.8 bar at Mach 6.85 and 0.2 bar at Mach 9.4
- **Total Temperature:** 600 degrees Kelvin at Mach 6.85 and 850 degrees Kelvin at Mach 9.4
- **Run Time:** Up to 1 s
- **Comments:** The facility may be configured as a hypersonic wind tunnel or high-pressure combustion facility.

Cost Information
- **Date Built:** 1975
- **Date Placed in Operation:** 1976
- **Date(s) Upgraded:** Continuous process
- **Construction Cost:** $66,600 (1975)
- **Replacement Cost:** $326,000 (1989)
- **Annual Operating Cost:** $97,800 per year (1989)
- **Unit Cost to User:** Minimum $163 per run (1989); cost determined by type of test
- **Source(s) of Funding:** British government, British industry, and The University of Southampton

Number and Type of Staff
- **Engineers:** 2
- **Scientists:** 0
- **Technicians:** 1
- **Others:** 0
- **Administrative/Management:** 1 (part-time)
- **Total:** 4 (at least 2 persons required)

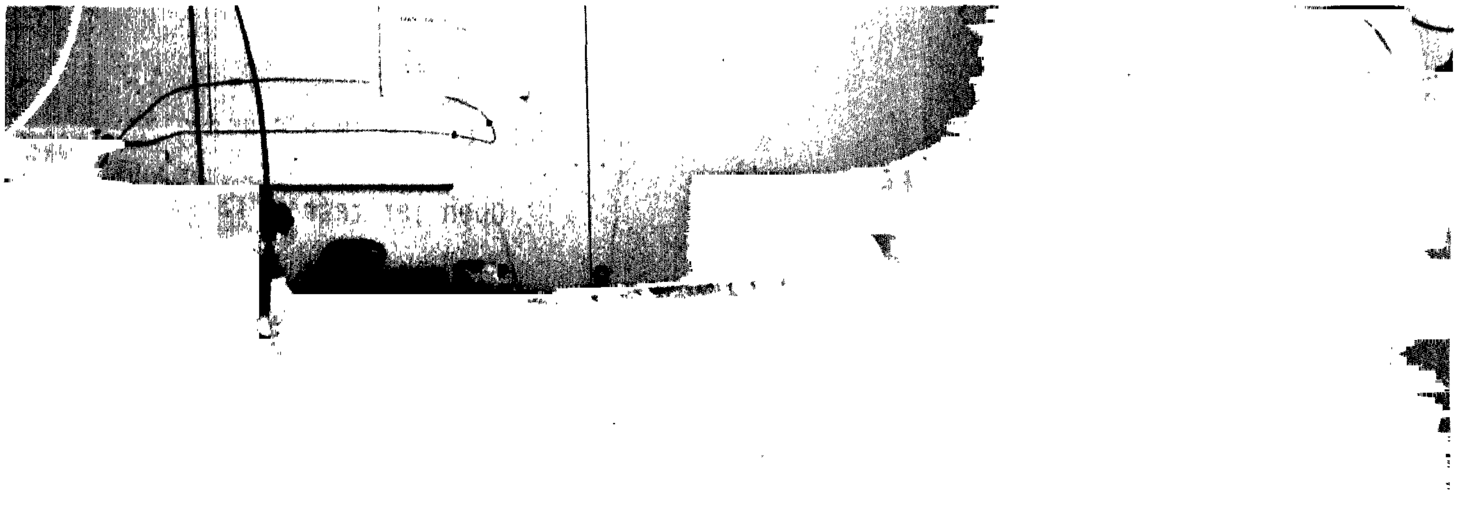
Description: The University of Southampton Light Piston Isentropic Compression Facility is a hypersonic wind tunnel and combustion facility. The facility generates heated air or nitrogen by piston compression. It may be configured as an intermittent hypersonic wind tunnel with steady flow conditions of approximately 1 s duration or as a high-pressure intermittent 1 s combustion research facility.

Testing Capabilities: The facility is capable of conducting aerodynamic heating, hypersonic aircraft stability and control, aerodynamic force measurements, high-pressure mixing, and combustion studies. The facility is also capable of conducting dynamic stability and heat transfer tests. It has schlieren flow visualization and liquid crystal thermography capability.

Data Acquisition: The facility has 12 on-line channels of data.

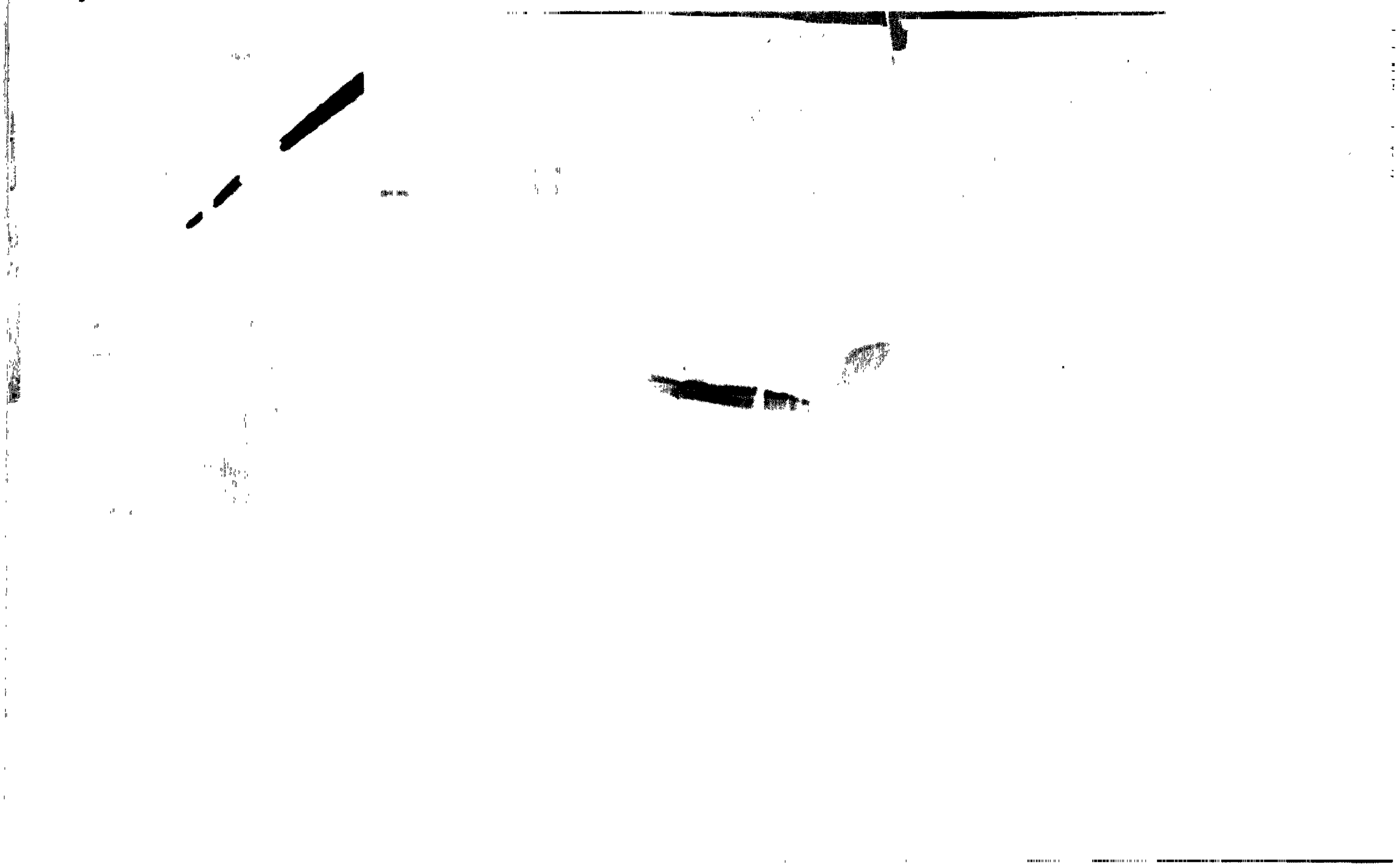
Planned Improvements (Modifications/Upgrades): These include installing a force balance and updating the data acquisition system.

Figure IX.19: Hypersonic Nozzle and Open-jet Test Section of The University of Southampton Light Piston Isentropic Compression Facility



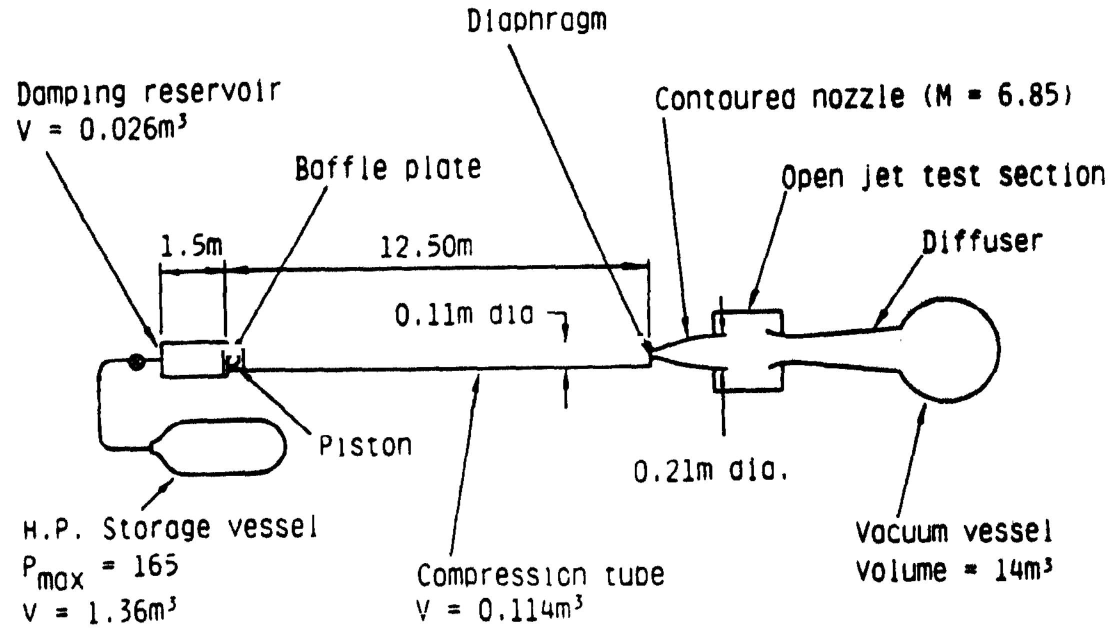
Source: The University of Southampton

Figure IX.21: Compression Tube and Hypersonic Nozzle of The University of Southampton Light Piston Isentropic Compression Facility



Source: The University of Southampton

Figure IX.20: Schematic Drawing of The University of Southampton Light Piston Isentropic Compression Facility



Source: U.S. Air Force EOARD

Cranfield Gun Tunnel

Country: United Kingdom

Location: Cranfield Institute of Technology, Cranfield, United Kingdom

Owner(s):
Cranfield Institute of Technology
College of Aeronautics
Cranfield, Bedfordshire MK43 OAL
United Kingdom

Operator(s): Cranfield Institute of Technology

International Cooperation: ESA

Point of Contact: Professor J.L. Stollery, Cranfield Institute of Technology, Tel.: [44]-(234)-752743

Test Section Size: 8 in. diameter

Operational Status: Active

Utilization Rate: 6 tests per day

Performance
Mach Number: 8.2 and 12.2
Reynolds Number: 2.8×10^6/ft and 0.9×10^6/ft
Total Pressure: 110 bars
Dynamic Pressure: Not available
Total Temperature: 1,290 degrees Kelvin
Run Time: 20 ms
Comments: Nozzle exit diameter is 8 in.

Cost Information
Date Built: 1957 to 1958
Date Placed in Operation: 1958
Date(s) Upgraded: 1961 and 1989
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 0
Scientists: 0
Technicians: 0
Others: 1 or 2 persons from any of these categories are required
Administrative/Management: 0
Total: 1 to 2

Description: The Cranfield Gun Tunnel is a hypervelocity wind tunnel. It was originally built at the Imperial College in London and was known as the Imperial College Hypersonic Gun Tunnel. It was extensively used between 1958 and 1975. In 1989 the tunnel was moved to the Cranfield Institute of Technology in Cranfield and recommissioned.

Testing Capabilities: The tunnel is capable of conducting heat transfer, pressure, and optical flow visualization tests. A three-component strain-gauge balance is used for force measurements.

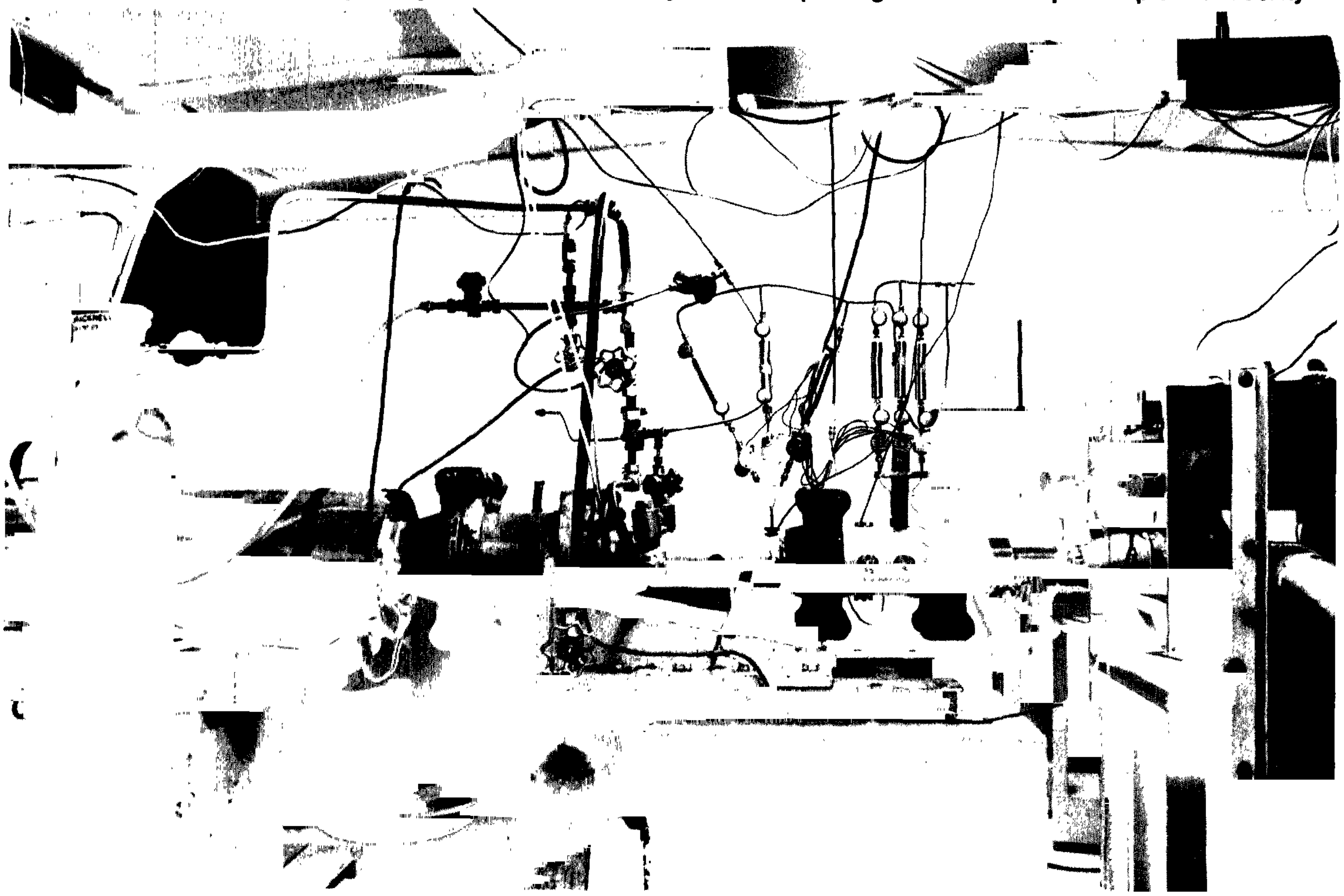
Data Acquisition: The tunnel has six digital channels of data.

Planned Improvements (Modifications/Upgrades): These include further data acquisition channels and laser holography capability.

Unique Characteristics: None

Applications/Current Programs: Current programs include control effectiveness at hypersonic speeds, flow separation due to rocket plumes, and glancing interaction caused by sharp and blunt fins.

Figure IX.22: Combustion Testing Configuration of The University of Southampton Light Piston Isentropic Compression Facility



Source: The University of Southampton

Imperial College Heated N_2 Wind Tunnel

Country: United Kingdom

Location: Imperial College, London, United Kingdom

Owner(s):
Imperial College
Department of Aeronautics
Prince Consort Road
London SW7 2BY
United Kingdom

Operator(s): Imperial College

International Cooperation: Not available

Point of Contact: Dr. J.K. Harvey, Imperial College, Tel.: [44]-(1)-589-5111, ext. 4011

Test Section Size: 20 cm (nozzle exit diameter)

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 20 to 25 (contoured)
Reynolds Number: 0.006 to 0.1 x 10^6/m
Total Pressure: 25 to 500 bars
Dynamic Pressure: Not available
Total Temperature: 2,000 degrees Kelvin (maximum)
Run Time: Continuous
Comments: Nozzle exit diameter is 20 cm with a useful core of 7.5 cm.

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 0
Scientists: 0
Technicians: 1 to 2
Others: 0
Administrative/Management: 0
Total: 2

Description: The Imperial College Heated N_2 Wind Tunnel is a hypervelocity wind tunnel.

Testing Capabilities: The tunnel is capable of conducting pressure, heat transfer, and drag tests. It has electron beam testing capability for density and rotational temperature measurement. The tunnel also has a lift balance.

Data Acquisition: The tunnel has 16 on-line channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Current programs include research into rarefield flow centered around the Direct Simulation Monte-Carlo method. A three-dimensional code was developed to calculate the flow around a blunt-ended cylinder and a spherically blunted cone both at angle of attack at a Knudsen number greater than 0.03. Experimental verification has shown that the predictions for the former shape at zero

General Comments: The Cranfield Gun Tunnel replaced the Cranfield Helium Wind Tunnel, which has been scrapped. The Cranfield Helium Wind Tunnel had not been used since 1975. The Cranfield Gun Tunnel is a simple, inexpensive hypersonic wind tunnel that is excellent for conducting heat transfer rate measurements.

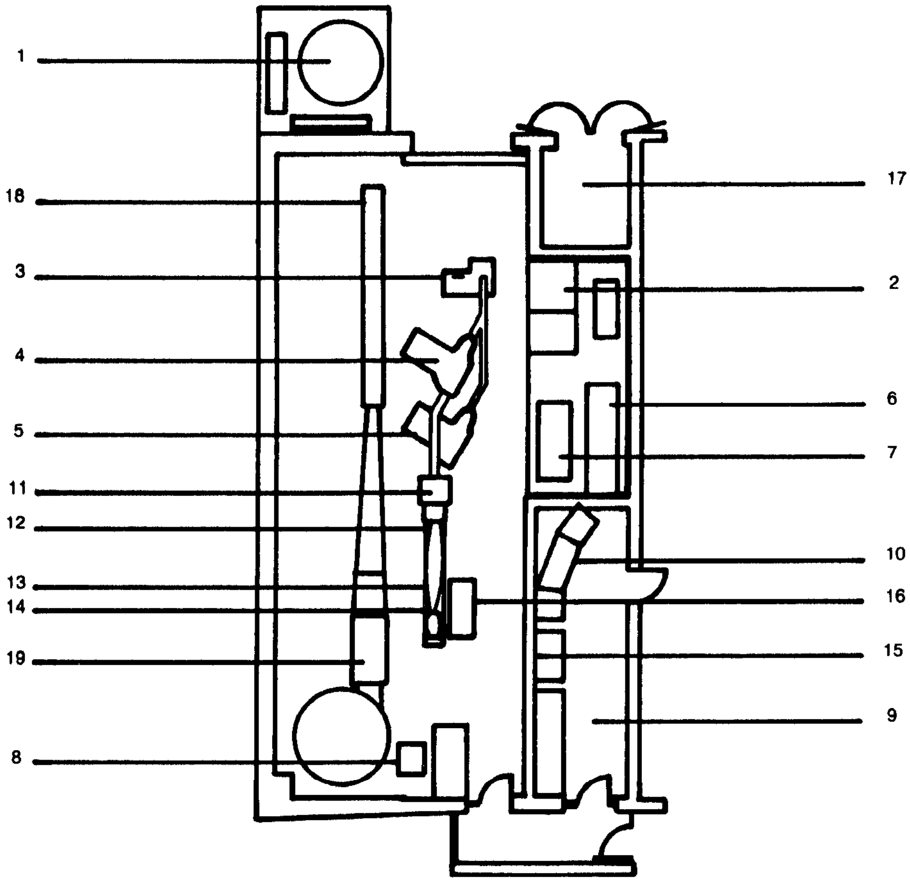
Photograph/Schematic Available: No

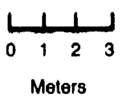
References: Stollery, J.L., D.J. Maull, and B.J. Belcher. "The Imperial College Hypersonic Gun Tunnel, August 1958—July 1959." Journal of the Royal Aerospace Society, vol. 64, p. 589, 1960. Needham, D.A. Progress Report on the Imperial College Hypersonic Gun Tunnel. London: Imperial College, 1963 (Imperial College Rept. No. 118).

Date of Information: October 1989

Figure IX.23: Schematic Diagram of the Imperial College Heated N_2 Wind Tunnel

1. Liquid nitrogen store
2. 3 900 vacuum pumps
3. RUVAC 46 vacuum pumps
4. RUVAC 89 vacuum pumps
5. RUVAC 89 vacuum pumps
6. Stage 1&2 compressor
7. Stage 3 compressor
8. Heater power supply
9. Control room
10. Control panel
11. Heat exchanger
12. Diffuser
13. Test section
14. Nozzle
15. Data acquistion
16. Spectrometer
17. Electron beam lab
18. Gun tunnel driver
19. Gun tunnel test section





Source: U.S. Air Force EOARD

incidence are precise. Experiments are in progress to measure the lift and drag acting on, and a density distribution about, a cone incidence at Mach 25.

General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 94 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 11 and 14-16 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: October 1989

surveys of pitot and total temperature within the flow. Earlier investigations have included electron beam fluorescence measurements of mean and fluctuating density on a similar layer. Studies of hypersonic cavity flows have also recently been completed.

General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 94 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 11-14 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: October 1989

Imperial College Hypersonic Gun Tunnel No. 2

Country: United Kingdom

Location: Imperial College, London, United Kingdom

Owner(s):
Imperial College
Department of Aeronautics
Prince Consort Road
London SW7 2BY
United Kingdom

Operator(s): Imperial College

International Cooperation: None

Point of Contact: Dr. J.K. Harvey, Imperial College, Tel.: [44]-(1)-589-5111, ext. 4011

Test Section Size: 45 cm (nozzle exit diameter)

Operational Status: Active

Utilization Rate: 4 tests per day

Performance
Mach Number: 9 (contoured)
Reynolds Number: 14 x 10^6/ft
Total Pressure: 550 bars (maximum)
Dynamic Pressure: Not available
Total Temperature: 1,070 degrees Kelvin
Run Time: 5 ms
Comments: Nozzle exit diameter is 45 cm with a useful core of 25 cm.

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 0
Scientists: 1
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 2

Description: The Imperial College Hypersonic Gun Tunnel No. 2 is a hypersonic wind tunnel.

Testing Capabilities: The tunnel is capable of conducting pressure, heat transfer, and schlieren flow visualization tests. It also has electron beam testing capability.

Data Acquisition: The tunnel has 24 on-line channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel is currently being used for studies on hypersonic turbulent boundary layers, transition, and base flows. An investigation is being conducted as part of ESA's Hermes spaceplane program on a 5 degree sharp cone to provide precise data on the boundary layer and base flow regions for code validation. The study is centered on surface pressure and heat transfer measurements and on

Oxford University Gun Tunnel

Country: United Kingdom

Location: Oxford University, Oxford, United Kingdom

Owner(s):
Oxford University
Department of Engineering Science
Parks Road
Oxford, Oxfordshire OX1 3PJ
United Kingdom

Operator(s): Oxford University

International Cooperation: Australia

Point of Contact: Professor Terry V. Jones, Oxford University, Tel.: [44]-(865)-722274

Test Section Size: Not available

Operational Status: Active

Utilization Rate: 8 tests per day (maximum)

Performance
Mach Number: 6, 8, and 9 (contoured)
Reynolds Number: 12 x 10^6/ft at Mach 6, 6.4 x 10^6/ft at Mach 8, and 2.5 x 10^6/ft at Mach 9
Total Pressure: 130 bars (maximum)
Dynamic Pressure: Not available
Total Temperature: 1,300 degrees Kelvin (720 degrees Kelvin in the LICH mode)
Run Time: 50 to 80 ms
Comments: Reynolds Number is based on exit diameter.

Cost Information
Date Built: 1965
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: British Ministry of Defence Procurement Executive, Rolls-Royce, and the Science and Engineering Research Council.

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

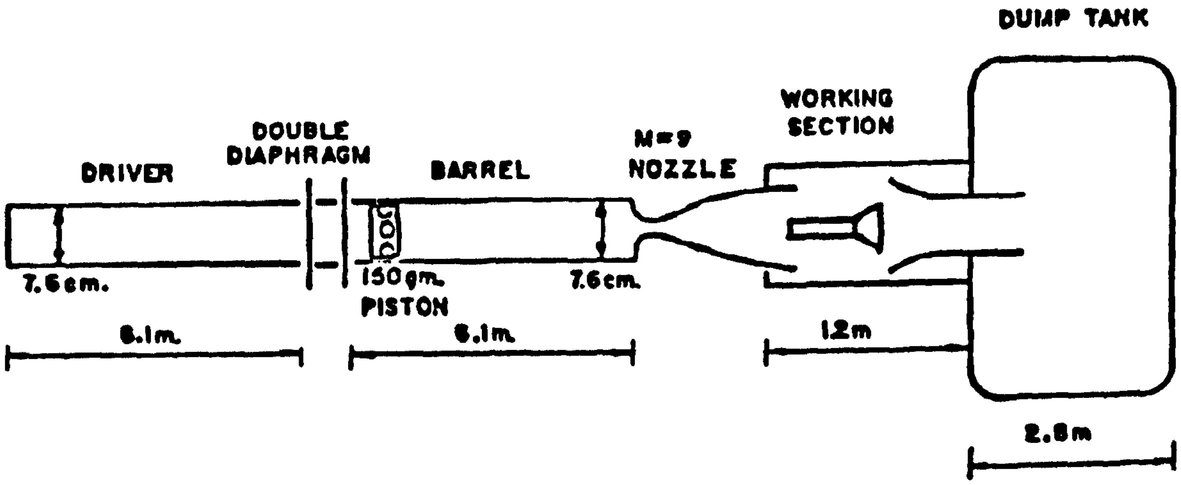
Description: The Oxford University Gun Tunnel employs multiple shock heating to raise temperature sufficient to avoid condensation when expanding to hypersonic conditions.

Testing Capabilities: High Mach number flows are produced which are non-dissociating but which are of sufficient duration for transition studies and the establishment of flows around complex models. The tunnel is capable of conducting normal force (with free flight), heat transfer, and schlieren flow visualization tests.

Data Acquisition: The tunnel has 64 on-line channels of data. Flow traversing during the running time is undertaken.

Planned Improvements (Modifications/Upgrades): The tunnel can also be run as a LICH tunnel (a Ludwieg tube with isentropic compression heating) to avoid transients for free flight studies. The LICH mode of operation was devised at Oxford University on an early gun tunnel, which was replaced by the present facility.

Figure IX.24: Schematic Diagram of the Imperial College Hypersonic Gun Tunnel No. 2



Source: U.S. Air Force EOARD

RAE Farnborough Shock Tunnel—LICH Tube

Country: United Kingdom

Location: Royal Aerospace Establishment Farnborough, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Farnborough
Farnborough, Hampshire GU14 6TD
United Kingdom

Operator(s): Royal Aerospace Establishment Farnborough

International Cooperation: Not available

Point of Contact: D.N. Foster, Royal Aerospace Establishment Farnborough, Tel.: [44]-(252)-24461, ext. 5428

Test Section Size: 0.76 m diameter x 1 m long

Operational Status: Active

Utilization Rate: 2 tests per day

Performance
- **Mach Number:** 7 (conical)
- **Reynolds Number:** 3.7×10^7/m at Mach 7
- **Total Pressure:** 80 bars
- **Dynamic Pressure:** 70 kN/m^2
- **Total Temperature:** 625 degrees Kelvin
- **Run Time:** 100 ms
- **Comments:** Nozzle exit diameter is 36 cm with a useful core of 28 cm at Mach 7.

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** 1986
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** 4

Description: The RAE Farnborough Shock Tunnel is currently operating in the LICH mode (a Ludwieg tube with isentropic compression heating) at Mach 7. The shock tube mode has not been used since 1983, and the Ludwieg tube has not yet been commissioned. External tube heating to about 400 degrees Celsius is available for LICH and Ludwieg tube operation.

Testing Capabilities: The tunnel is capable of conducting heat transfer, pressure, and force measurement tests. The tunnel also has schlieren flow visualization capability. The tunnel's incidence gear is capable of setting incidence in the range of 0 to 90 degrees in 1 degree steps.

Data Acquisition: The tunnel has 30 on-line channels of data.

Planned Improvements (Modifications/Upgrades): These include operation at Mach 9 and 11.

Unique Characteristics: The tunnel has a large working section and relatively long running time for a LICH tube.

Unique Characteristics: None

Applications/Current Programs: Current programs include plume and jet studies. The tunnel is also used to conduct heat transfer and surface pressure measurements.

General Comments: The tunnel may be converted to the LICH mode, yielding Mach 8.25 and very uniform pressures for 45 ms. Conversion to the gun tunnel mode can be made in 1 week.

Photograph/Schematic Available: No

References: Hoyt, Capt. Anthony R. European Hypersonic Technology London: European Office of Aerospace Research and Development, 1986, p. 101 (EOARD Technical Report). Holden, Michael S. "A Review of the Current Capabilities in Europe to Perform Experimental Research in Hypersonic Flow." In: European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, pp. 17-20 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels" In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428). Wendt, John F. "European Research Program on Hypersonic Aerodynamics." In: Eurohyp Review, 1989. Oldfield, M.L.G., and D.L. Schultz. "A Ludwieg Tube with Light Piston Isentropic Compression Heating." Aeronautical Research Council 34255 HYP 935, 1984.

Date of Information: September 1989

RAE Farnborough Shock Tunnel—Ludwieg Tube Mode

Country: United Kingdom

Location: Royal Aerospace Establishment Farnborough, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Farnborough
Farnborough, Hampshire GU14 6TD
United Kingdom

Operator(s): Royal Aerospace Establishment

International Cooperation: Not available

Point of Contact: D.N. Foster, Royal Aerospace Establishment Farnborough, Tel.: [44]-(252)-24461, ext. 5428

Test Section Size: 0.76 m diameter x 1 m long

Operational Status: Under construction

Utilization Rate: 4 tests per day

Performance
Mach Number: 5 (contoured)
Reynolds Number: 1.7 to 4.3 x 10^8/m
Total Pressure: 400 bars
Dynamic Pressure: 1,370 kN/m^2
Total Temperature: 520 degrees Kelvin
Run Time: 100 ms
Comments: Nozzle exit diameter is 23 cm with a useful core of 20 cm.

Cost Information
Date Built: Under construction
Date Placed in Operation: Planned for mid-1991
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

Description: The RAE Farnborough Shock Tunnel is currently operating in the LICH mode (a Ludwieg tube with isentropic compression heating) at Mach 7. The tunnel's shock tube mode has not been used since 1983 and the Ludwieg tube mode has not yet been commissioned. External tube heating to about 400 degrees Celsius is available for LICH and Ludwieg tube operation.

Testing Capabilities: The tunnel is capable of conducting heat transfer and pressure measurement tests. The tunnel also has schlieren flow visualization capability.

Data Acquisition: The tunnel has 30 on-line channels of data.

Planned Improvements (Modifications/Upgrades): These include a new channel section and fast-acting plug valve.

Unique Characteristics: The tunnel achieves full-scale Reynolds Number for typical weapon configurations at low altitude.

Applications/Current Programs: The tunnel is used for detailed measurements of heat transfer rates and pressures on model surfaces.

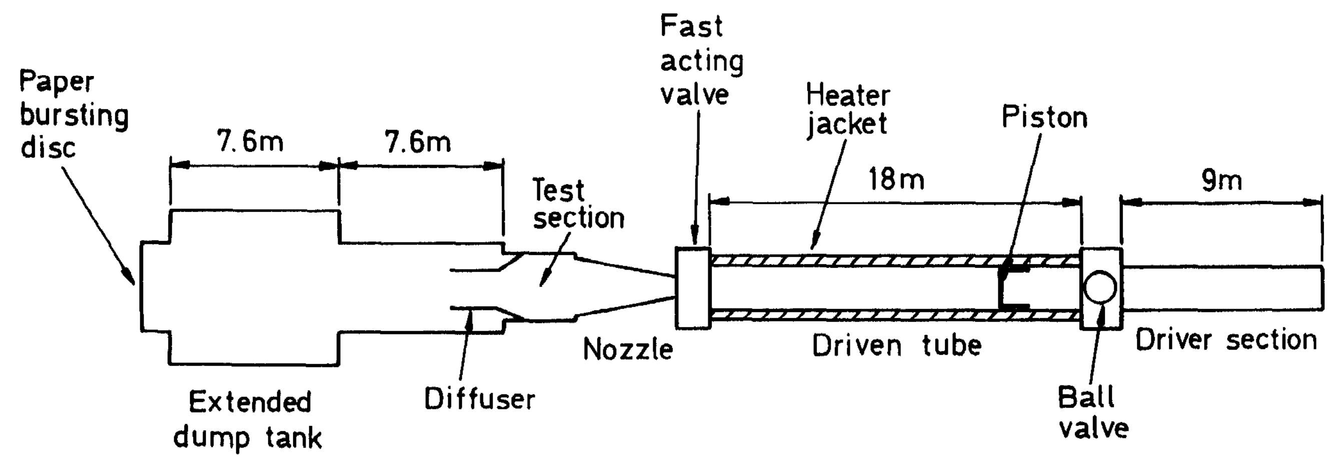
General Comments: None

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 103 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: November 1989

Figure IX.25: Schematic Diagram of the RAE Farnborough Shock Tunnel—LICH Tube



Source: RAE Farnborough

RAE Farnborough Shock Tunnel—Shock Tube Mode

Country: United Kingdom

Location: Royal Aerospace Establishment Farnborough, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Farnborough
Farnborough, Hampshire GU14 6TD
United Kingdom

Operator(s): Royal Aerospace Establishment Farnborough

International Cooperation: Not available

Point of Contact: D.N. Foster, Royal Aerospace Establishment Farnborough, Tel.: [44]-(252)-24461, ext. 5428

Test Section Size: 0.38 x 0.38 x 0.3 m

Operational Status: Decommissioned

Utilization Rate: 1 test per day (when tunnel was operational)

Performance
Mach Number: 7, 9, 10, and 13 (conical) and 9 and 13 (contoured)
Reynolds Number: 1.4 x 10^7/m at Mach 7 and 2 x 10^5/m at Mach 10
Total Pressure: 400 bars
Dynamic Pressure: 4 to 340 kN/m^2
Total Temperature: 800 to 4,000 degrees Kelvin
Run Time: 3 to 10 ms (tailored reflected shock)
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: 1960
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: 2

Description: The RAE Farnborough Shock Tunnel was operating in the LICH mode (a Ludwieg tube with isentropic compression heating) at Mach 7. The tunnel has been decommissioned. Its shock tube mode has not been used since 1983, and the Ludwieg tube mode has not yet been commissioned.

Testing Capabilities: The tunnel was capable of conducting heat transfer measurement tests and had schlieren flow visualization capability.

Data Acquisition: The tunnel had 30 on-line channels of data.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: The tunnel had very high stagnation pressures, which resulted from using hydrogen as the driver gas.

Applications/Current Programs: None

General Comments: The tunnel has been decommissioned.

Applications/Current Programs: The tunnel is used for measurement of heat transfer rates at full-scale Reynolds Numbers.

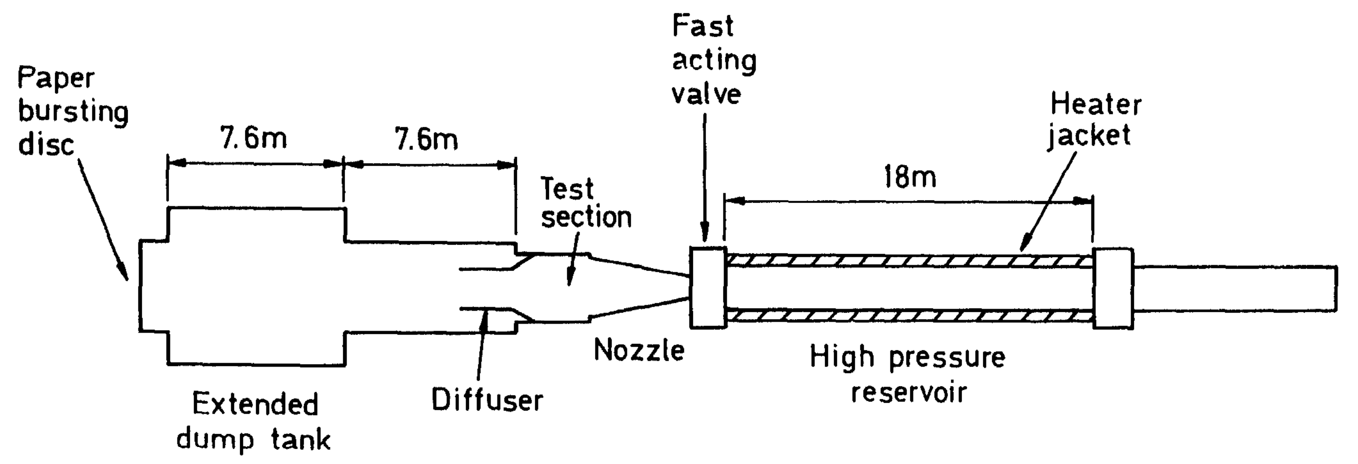
General Comments: Safety aspects of the overall design concept have been approved for the Ludwieg Tube Mode and detailed design and manufacturing are underway.

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 103 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

Date of Information: November 1989

Figure IX.26: Schematic Diagram of the RAE Farnborough Shock Tunnel—Ludwieg Tube Mode



Source: RAE Farnborough

The University of Sheffield Shock Tunnel

Country: United Kingdom

Location: The University of Sheffield, Sheffield, United Kingdom

Owner(s):
The University of Sheffield
Department of Mechanical and Process Engineering
Chemical Engineering and Fuel Technology
Mappin Street
Sheffield, South Yorkshire S1 3JD
United Kingdom

Operator(s): The University of Sheffield, Department of Mechanical and Process Engineering, Chemical Engineering and Fuel Technology

International Cooperation: NASP Joint Program Office (the United States)

Point of Contact: Professor J. Swithenbank, The University of Sheffield, Department of Mechanical and Process Engineering, Chemical Engineering and Fuel Technology, Tel.: [44]-(742)-768555

Test Section Size: About 8 cm useful equivalent diameter; less than 1 m long

Operational Status: Active

Utilization Rate: Daily

Performance
Mach Number: 6 to 15 (flight) and 1 to 5 (combustor)
Reynolds Number: About 1 x 10^5/ft
Total Pressure: 70 bars
Dynamic Pressure: About 50 kN/m^2 (flight)
Total Temperature: 4,500 degrees Kelvin
Run Time: About 2 ms
Comments: The shock tunnel's driver pressure is operated up to 2,500 psi.

Cost Information
Date Built: 1962
Date Placed in Operation: 1962
Date(s) Upgraded: 1989
Construction Cost: $1 million (including instrumentation) (1962)
Replacement Cost: $1 million (1989)
Annual Operating Cost: About $300,000 (minimum) (1989)
Unit Cost to User: $1,000 per day (1989)
Source(s) of Funding: NASP Joint Program Office

Number and Type of Staff
Engineers: 4 (students)
Scientists: 2 (research fellows)
Technicians: 1
Others: 0
Administrative/Management: 0
Total: 7

Description: The University of Sheffield Shock Tunnel is a tailored/interface hypervelocity shock tunnel. Since the combustor chamber operates at about one-third of the flight Mach number, direct-connect testing can be carried out in a test section very similar to a conventional supersonic wind tunnel. Reasonable simulation can be carried out with stagnation pressures of about 200 bars and stagnation temperatures of about 5,000 degrees Kelvin.

Testing Capabilities: The facility is capable of conducting studies of supersonic combustion for scramjet operation between Mach 7 and 20. The shock tunnel has a double beam sodium line reversal apparatus for conducting temperature tests, piezoelectric transducers for pressure tests, ionization gauges for shock speed tests, a two-dimensional laser Doppler velocimeter for velocity tests, and laser interferometry for density tests.

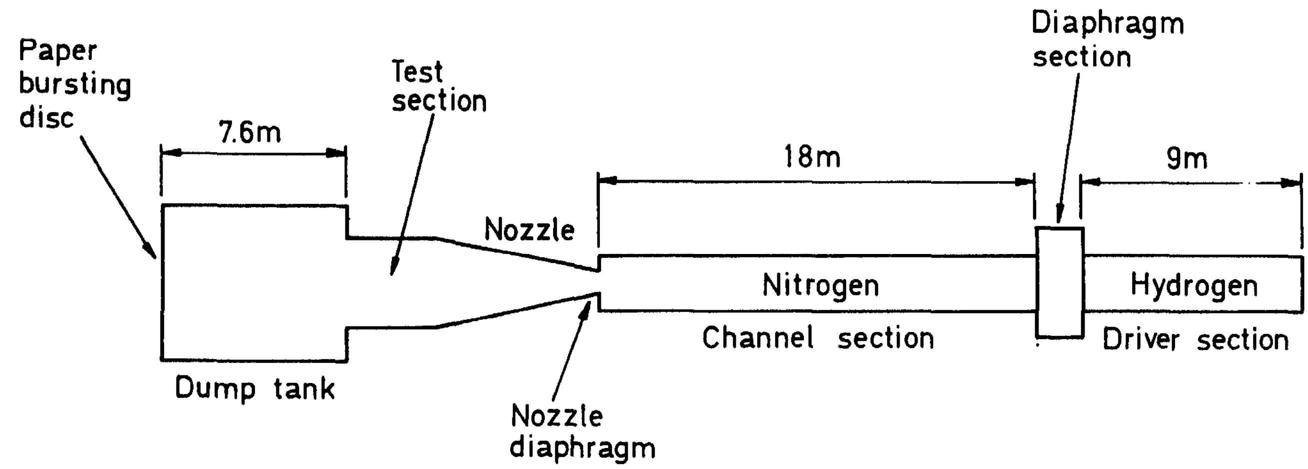
Data Acquisition: The tunnel has a Hewlett Packard 400-MHz multiplexed multichannel computer, which is interfaced with the data

Photograph/Schematic Available: Yes

References: Hoyt, Capt. Anthony R. European Hypersonic Technology. London: European Office of Aerospace Research and Development, 1986, p. 103 (EOARD Technical Report). Wendt, John F. "European Hypersonic Wind Tunnels." In: Aerodynamics of Hypersonic Lifting Vehicles. Bristol, United Kingdom: NATO AGARD, 1987 (AGARD Conference Proceedings No. 428).

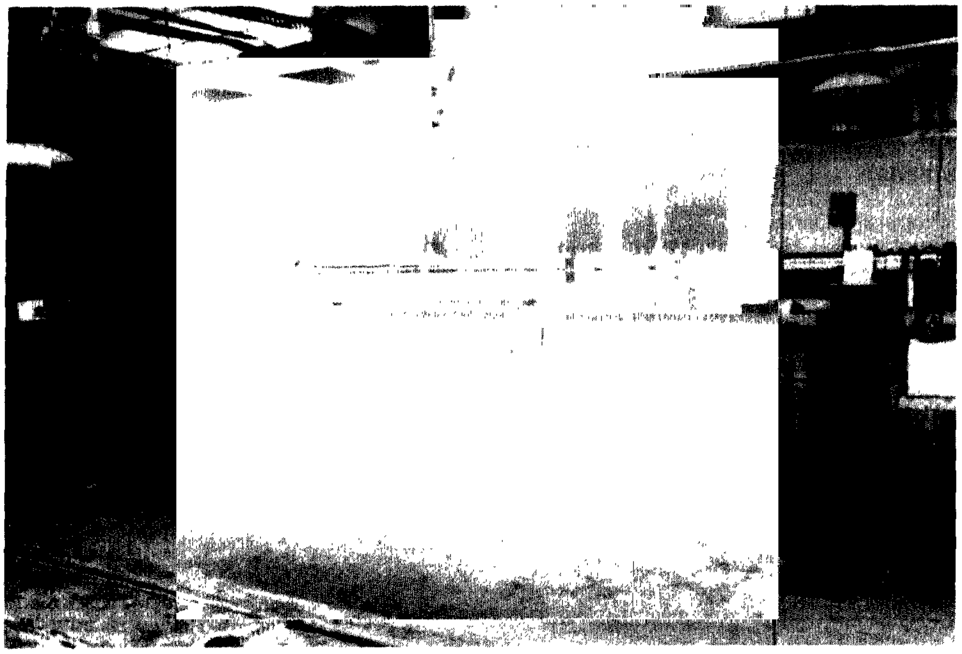
Date of Information: November 1989

Figure IX.27: Schematic Diagram of the RAE Farnborough Shock Tunnel—Shock Tube Mode



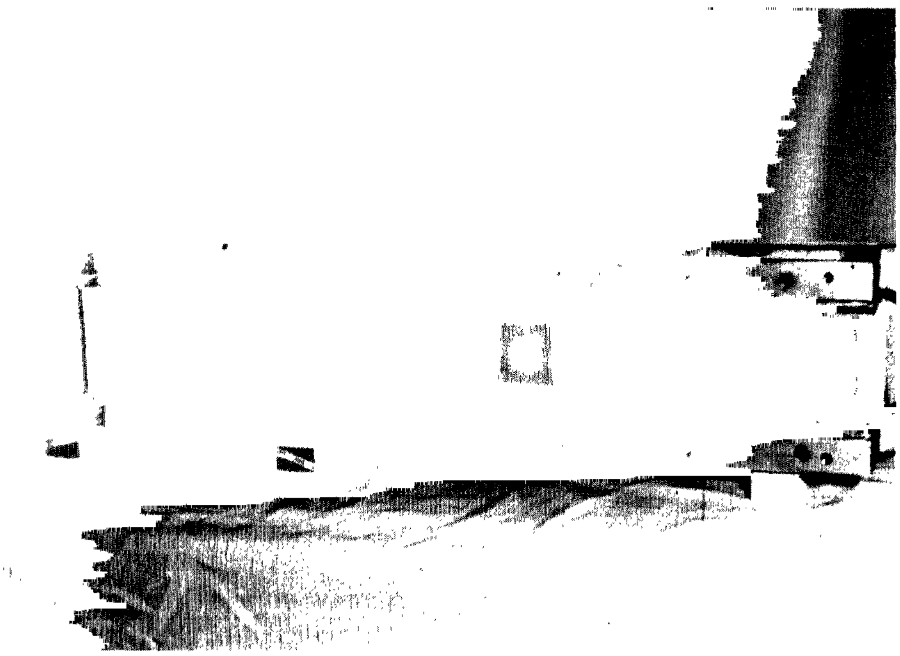
Source: RAE Farnborough

Figure IX.28: The University of Sheffield Shock Tunnel



Source: The University of Sheffield

Figure IX.29: Rectangular Test Section With Wedge Fuel Injectors of The University of Sheffield Shock Tunnel



Source: The University of Sheffield

acquisition and analysis system. The tunnel has 12 channels of data, a 40-ms FM drum custom system, and a two channel Tektronix 200-MHz computerized system.

Planned Improvements (Modifications/Upgrades): Performance goals include increasing the shock tunnel's Mach number to 20, total pressure to 1,000 bars, and total temperature to 5,000 degrees Kelvin.

Unique Characteristics: None

Applications/Current Programs: The shock tunnel is currently used by the NASP Technology Maturation Program to conduct a research program designed to establish high Mach number design criteria that minimize overall combustor loss mechanisms and maximize scramjet performance.

General Comments: The supersonic combustion test facilities, previously developed at The University of Sheffield during the 1960s, have been reactivated.

Photograph/Schematic Available: Yes

References: Swithenbank, J., et al. "Turbulent Mixing in Supersonic Combustion Systems." American Institute of Aeronautics and Astronautics 89-0260. Swithenbank, J., et al. "Mixing Power Concepts in Scramjet Combustor Design." NASA Langley Combustion Workshop, 1989.

Date of Information: December 1989

Applications/Current Programs: These include support of the British military engine development program.

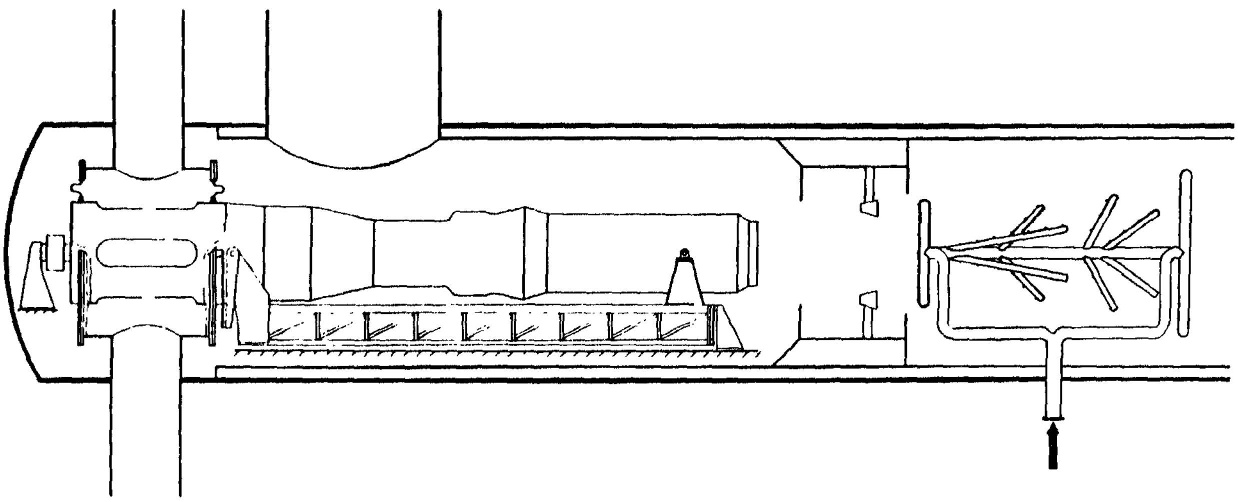
General Comments: Replacement cost includes a percentage for common services (such as air supplies, fuel systems, and the central computer).

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 93.

Date of Information: November 1989

Figure IX.31: Schematic Drawing of the RAE Pyestock ATF Cell 2 Altitude Engine Test Facility



Source: NASA

RAE Pyestock ATF Cell 1 Altitude Engine Test Facility

Country: United Kingdom

Location: Royal Aerospace Establishment Pyestock, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Pyestock
Propulsion Department
Farnborough, Hampshire GU14 0LS
United Kingdom

Operator(s): Royal Aerospace Establishment Pyestock

International Cooperation: Not available

Point of Contact: Head of Propulsion Department, Royal Aerospace Establishment Pyestock, Tel.: [44]-(252)-544411

Test Chamber Size: 12 ft diameter x 122 ft long

Operational Status: Standby

Utilization Rate: Double day shift (when operational)

Performance
Mass Flow: 450 lb/s (maximum)
Altitude Range: 50,000 ft
Temperature Range: Ambient to 450 degrees Fahrenheit
Pressure Range: 2 to 100 psia
Speed Range: Mach 0 to 3.5
Comments: None

Cost Information
Date Built: 1954
Date Placed in Operation: Not available
Date(s) Upgraded: 1984
Construction Cost: Not available
Replacement Cost: $38,889,000 (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Pyestock ATF Cell 1 is primarily a supersonic free-jet altitude engine test facility. It is being adapted for connected testing of turbojet engines with an airflow capacity of up to 250 lb/s.

Testing Capabilities: This facility was originally designed for the free-jet testing of ramjet engines, but it has been modified to provide for free-jet testing of model intakes for supersonic aircraft, tests on small turbojet engines, and reheat combustion systems. The upgrading to test military turbofans of low bypass ratio is almost complete. Cell altitude conditions are achieved using air-driven ejectors.

Data Acquisition: Data acquisition and processing is controlled by a Gould computer system, which is being upgraded to provide for on-line assessment of plant and test rig or engine behavior. The instrumentation system includes 350 pressures by scanivalve, 100 individual pressures, and 200 temperatures.

Planned Improvements (Modifications/Upgrades): These include enhancement of the data acquisition system.

Unique Characteristics: None

Applications/Current Programs: Since the cell is in standby status, it currently has no programs.

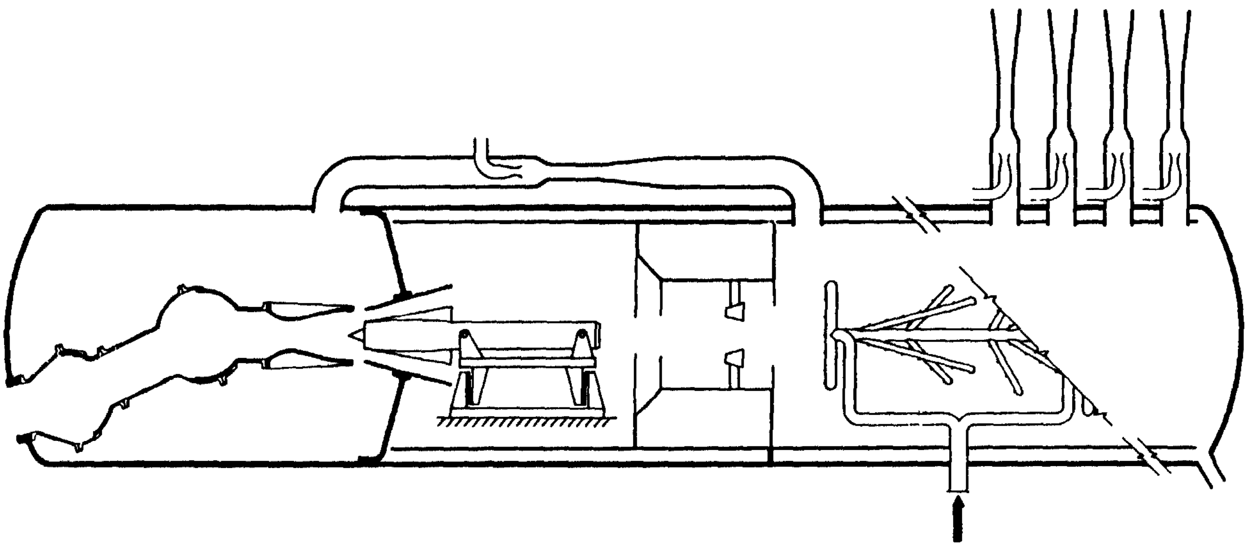
General Comments: Replacement cost includes a percentage for common services (such as air supplies, fuel systems, and the central computer). The facility currently is in standby status.

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 97.

Date of Information: November 1989

Figure IX.30: Schematic Drawing of the RAE Pyestock ATF Cell 1 Altitude Engine Test Facility



Source: NASA

RAE Pyestock ATF Cell 3 Altitude Engine Test Facility

Country: United Kingdom

Location: Royal Aerospace Establishment Pyestock, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Pyestock
Propulsion Department
Farnborough, Hampshire GU14 0LS
United Kingdom

Operator(s): Royal Aerospace Establishment Pyestock

International Cooperation: Not available

Point of Contact: Head of Propulsion Department, Royal Aerospace Establishment Pyestock, Tel.: [44]-(252)-544411

Test Cell Size: 20 ft diameter x 80 ft long

Operational Status: Active

Utilization Rate: Double day shift

Performance
Mass Flow: 600 lb/s (maximum)
Altitude Range: 65,000 ft
Temperature Range: −100 to 400 degrees Fahrenheit
Pressure Range: 2 to 39 psia
Speed Range: Mach 0 to 2.5
Comments: Thrust level is up to 30,000 lb.

Cost Information
Date Built: 1960
Date Placed in Operation: Not available
Date(s) Upgraded: 1988
Construction Cost: Not available
Replacement Cost: $116,640,000 (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Pyestock ATF Cell 3 is a direct-connect and free-jet altitude engine test facility. It has a high-accuracy thrust measurement capability. It also has a special capability to conduct icing tests.

Testing Capabilities: The facility is primarily used for connected tests on advanced military turbofans and turbojets. Performance evaluation, engine handling, altitude relight, and icing trials are possible over a wide operational envelope. Free-jet testing, including icing of smaller engines and components, is an added capability. Cell altitude conditions and exhaust gas extraction are achieved by use of exhauster compressors.

Data Acquisition: Data acquisition and processing are controlled by a Gould computer system, which provides on-line measurement of plant and test rig behavior. The instrumentation system includes 500 individual pressures and 200 temperatures, fuel flows, shaft speeds, and thrust.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include support of the British military engine development program.

General Comments: Replacement cost includes a percentage for common services (such as air supplies, fuel systems, and the central computer).

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 94.

Date of Information: November 1989

RAE Pyestock ATF Cell 2 Altitude Engine Test Facility

Country: United Kingdom

Location: Royal Aerospace Establishment Pyestock, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Pyestock
Propulsion Department
Farnborough, Hampshire GU14 0LS
United Kingdom

Operator(s): Royal Aerospace Establishment Pyestock

International Cooperation: Not available

Point of Contact: Head of Propulsion Department, Royal Aerospace Establishment Pyestock, Tel.: [44]-(252)-544411

Test Cell Size: 2 ft diameter x 122 ft long

Operational Status: Active

Utilization Rate: Double day shift

Performance
Mass Flow: 450 lb/s (maximum)
Altitude Range: 50,000 ft
Temperature Range: Ambient to 450 degrees Fahrenheit
Pressure Range: 2 to 100 psia
Speed Range: Mach 0 to 2.5
Comments: None

Cost Information
Date Built: 1954
Date Placed in Operation: Not available
Date(s) Upgraded: 1988
Construction Cost: Not available
Replacement Cost: $38,880,000 (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Pyestock ATF Cell 2 is primarily a connected altitude engine test facility for turbojet and low bypass ratio engines with airflows up to 450 lb/s.

Testing Capabilities: The facility is used for connected testing of reheat systems, which are supplied with high-pressure, high-temperature air through a preheater. It may also be adapted to test jet engines at conditions representing low altitude and high subsonic speed. Exhaust gases are extracted by four air-driven ejectors.

Data Acquisition: Data acquisition and processing are controlled by a Gould computer system, which provides on-line assessment of plant and test rig behavior. The instrumentation system includes 200 temperature and 100 individual pressure measurements.

Planned Improvements (Modifications/Upgrades): These include uprating the preheater delivery temperature by installation of a hydrogen-fueled secondary preheater.

Unique Characteristics: None

RAE Pyestock ATF Cell 4 Altitude Engine Test Facility

Country: United Kingdom

Location: Royal Aerospace Establishment Pyestock, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Pyestock
Propulsion Department
Farnborough, Hampshire GU14 0LS
United Kingdom

Operator(s): Royal Aerospace Establishment Pyestock

International Cooperation: Not available

Point of Contact: Head of Propulsion Department, Royal Aerospace Establishment Pyestock, Tel.: [44]-(252)-544411

Test Cell Size: 30 ft diameter x 60 ft long

Operational Status: Mothballed

Utilization Rate: Not operational

Performance
Mass Flow: 500 lb/s
Altitude Range: 100,000 ft
Temperature Range: Ambient to 880 degrees Fahrenheit
Pressure Range: 3 to 60 psia
Speed Range: Mach 1.5 to 3.5
Comments: None

Cost Information
Date Built: 1966
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $116,640,000 (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Pyestock ATF Cell 4 is a large free-jet supersonic altitude engine test cell. The facility has a free-jet test section, but no thrust measurement capability.

Testing Capabilities: The facility has a variable Mach number blowing nozzle, providing variation of incidences and/or yaw while running. It was originally designed to test engines of about 150 lb/s sea level static flow over a range of Mach numbers from 1.5 to 3.5. The size of the blowing nozzle has since been doubled to 25 ft^2 to enable tests of a Concorde intake and Olympus 593 engine to be carried out over a Mach number range from approximately 1.7 to 2.3. It also has been used for free-jet testing of military aircraft intakes plus engine at subsonic speeds.

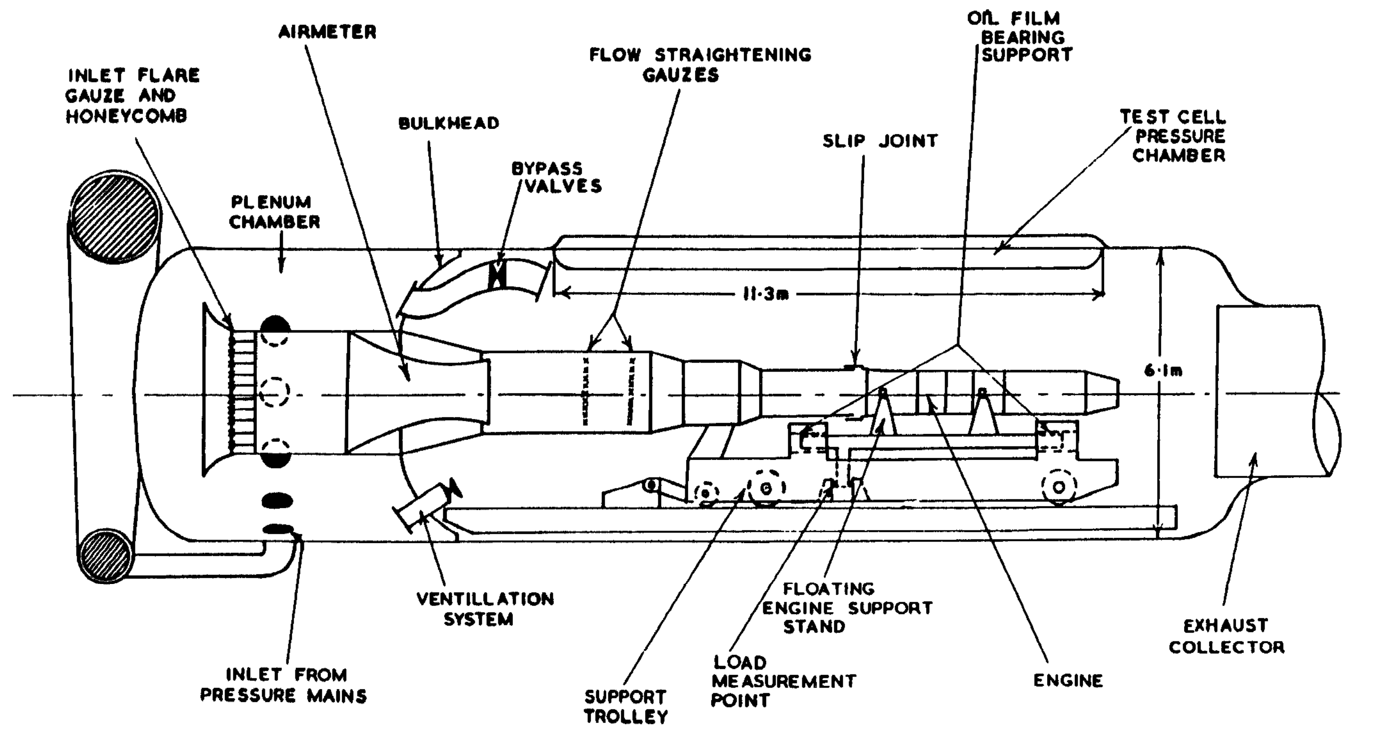
Data Acquisition: A comprehensive data acquisition and processing system controlled by a Gould computer can be provided.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: Since the cell has been mothballed, it currently has no programs.

Figure IX.32: Schematic Drawing of the RAE Pyestock ATF Cell 3 Altitude Engine Test Facility



Source: NASA

RAE Pyestock ATF Cell 3W Altitude Engine Test Facility

Country: United Kingdom

Location: Royal Aerospace Establishment Pyestock, Farnborough, United Kingdom

Owner(s):
Royal Aerospace Establishment Pyestock
Propulsion Department
Farnborough, Hampshire GU14 0LS
United Kingdom

Operator(s): Royal Aerospace Establishment Pyestock

International Cooperation: Not available

Point of Contact: Head of Propulsion Department, Royal Aerospace Establishment Pyestock, Tel.: [44]-(252)-544411

Test Cell Size: 25 ft diameter x 56 ft long

Operational Status: Active

Utilization Rate: Double day shift

Performance
Mass Flow: 1,400 lb/s
Altitude Range: 50,000 ft
Temperature Range: −50 degrees Fahrenheit to ambient
Pressure Range: 2 psia to atmospheric
Speed Range: Subsonic
Comments: None

Cost Information
Date Built: 1969
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: $77,760,000 (1985)
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The RAE Pyestock ATF Cell 3W is a direct-connect and free-jet altitude engine test facility. It has a high-accuracy thrust capability. It also has a special capability to conduct free icing tests.

Testing Capabilities: The facility is primarily used for connected testing of high bypass ratio turbofans up to 60,000 lb thrust, but it can also be used on icing trials on full-scale helicopter fuselages. Intake air is drawn from the atmosphere through an inlet cooler, which is refrigerated using aqueous ammonia. Cell altitude conditions and exhaust gas extraction are achieved by use of exhauster compressors.

Data Acquisition: Data acquisition and processing is controlled by a Gould computer system, which provides for on-line measurement of plant and test rig behavior. The instrumentation system includes 200 individual pressures, 500 pressures on scanivalve, 800 temperatures, fuel flows, shaft speed, and thrust.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: Not available

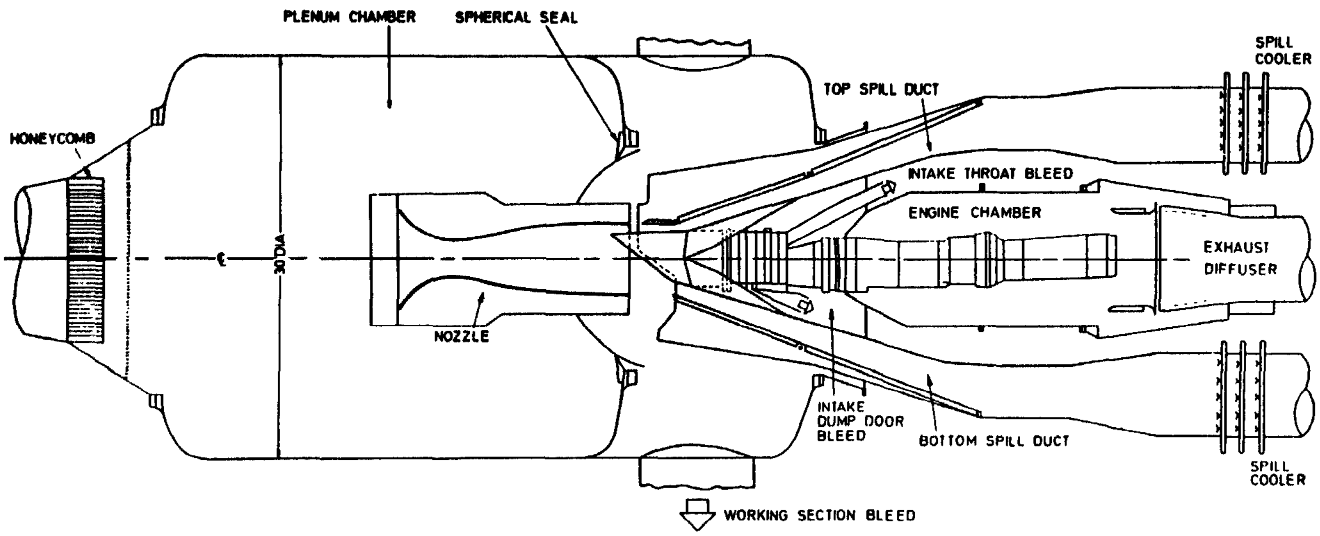
General Comments: Replacement cost includes a percentage for common services (such as air supplies, fuel systems, and the central computer).

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 95.

Date of Information: November 1989

Figure IX.33: Schematic Drawing of the RAE Pyestock ATF Cell 4 Altitude Engine Test Facility



Source: NASA

Rolls-Royce ATF C-1 Altitude Engine Test Facility

Country: United Kingdom

Location: Rolls-Royce, Derby, United Kingdom

Owner(s):
Rolls-Royce plc
P.O. Box 31
Derby, Derbyshire DE2 8BJ
United Kingdom

Operator(s): Rolls-Royce

International Cooperation: Not available

Point of Contact: A.C. Moorcroft, Rolls-Royce, Tel.: [44]-(332)-246701

Test Cell Size: 9 ft diameter x 38 ft long

Operational Status: Active

Utilization Rate: Not available

Performance
Mass Flow: 400 lb/s
Altitude Range: 70,000 ft
Temperature Range: −113 to 355 degrees Fahrenheit
Pressure Range: 73 psia
Speed Range: Mach 0 to 2.5
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The Rolls-Royce ATF C-1 is a direct-connect and free-jet altitude engine test facility. It has a thrust capability of 20,000 lb/ft. The turboshaft engine has up to 6,000 hp.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: Not available

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

Applications/Current Programs: These include support of the British civil engine development program and helicopter icing.

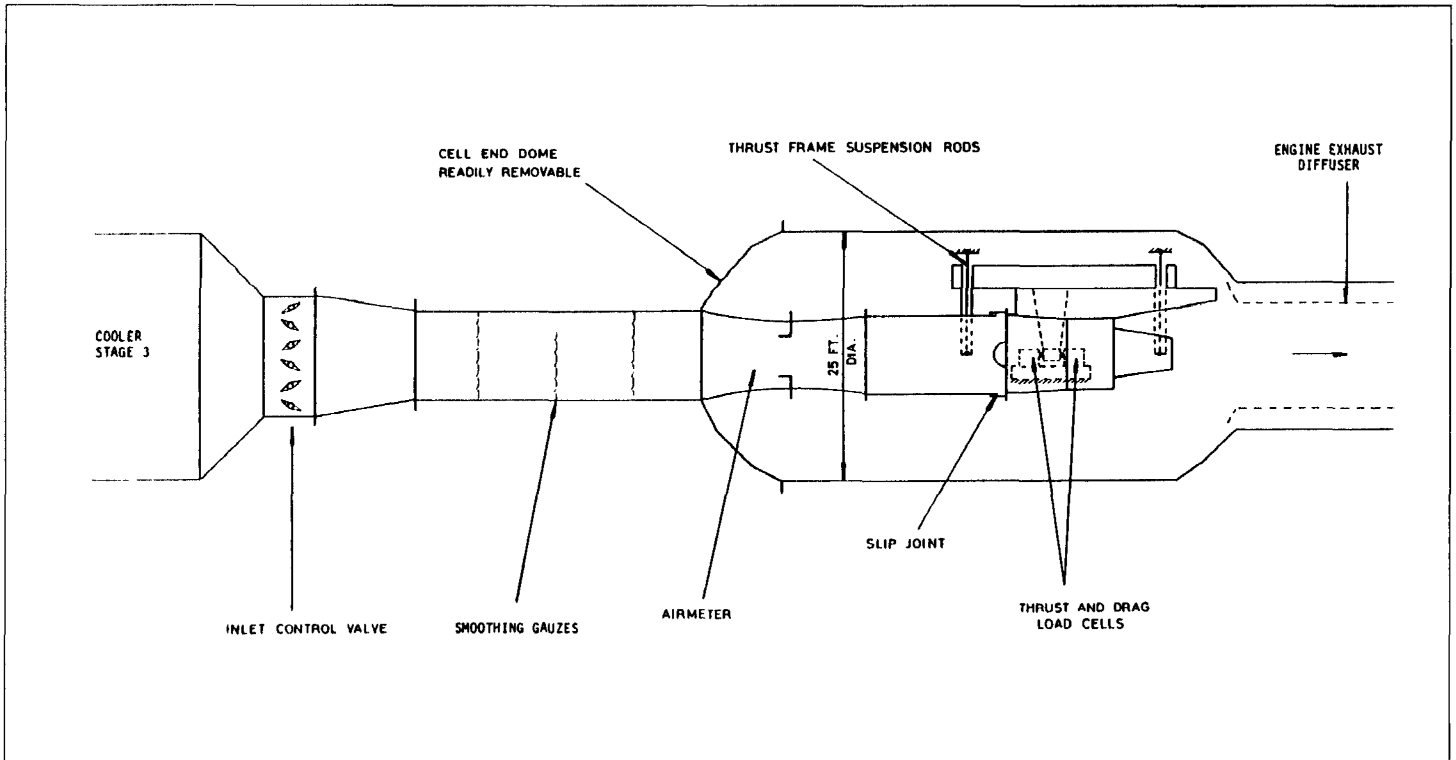
General Comments: Replacement cost includes a percentage for common services (such as air supplies, fuel systems, and the central computer).

Photograph/Schematic Available: Yes

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 96.

Date of Information: November 1989

Figure IX.34: Schematic Diagram of the RAE Pyestock ATF Cell 3W Altitude Engine Test Facility



Source: NASA

Rolls-Royce ATF C-2 Altitude Engine Test Facility

Country: United Kingdom

Location: Rolls-Royce, Derby, United Kingdom

Owner(s):
Rolls-Royce plc
P.O. Box 31
Derby, Derbyshire DE2 8BJ
United Kingdom

Operator(s): Rolls-Royce

International Cooperation: Not available

Point of Contact: A.C. Moorcroft, Rolls-Royce, Tel.: [44]-(332)-246701

Test Cell Size: 9 ft diameter x 38 ft long

Operational Status: Active

Utilization Rate: Not available

Performance
Mass Flow: 400 lb/s
Altitude Range: 70,000 ft
Temperature Range: −113 to 355 degrees Fahrenheit
Pressure Range: 73 psia
Speed Range: Mach 0 to 2.5
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The Rolls-Royce ATF C-2 is a direct-connect and free-jet altitude engine test facility. The installed thrust stand has a capacity of about 20,000 lb/ft.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: Not available

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 98.

Date of Information: January 1990

Rolls-Royce TP 131A Altitude Engine Test Facility

Country: United Kingdom

Location: Rolls-Royce, Filton, United Kingdom

Owner(s):
Rolls-Royce plc
P.O. Box 3
Filton, Bristol, Avon BS12 7QE
United Kingdom

Operator(s): Rolls-Royce

International Cooperation: Not available

Point of Contact: I.C. Stephens, Rolls-Royce, Tel.: [44]-(272)-795064

Test Cell Size: 10 ft diameter x 80 ft long

Operational Status: Active

Utilization Rate: Not available

Performance
- **Mass Flow:** 400 lb/s
- **Altitude Range:** 90,000 ft
- **Temperature Range:** 841 degrees Fahrenheit
- **Pressure Range:** 165 psia
- **Speed Range:** Mach 0 to 4.2
- **Comments:** None

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** Not available
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The Rolls-Royce TP 131A is a direct-connect and free-jet altitude engine test facility. It has high-pressure storage of 72,000 lb of air at 3,600 psia.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not available

Unique Characteristics: Not available

Applications/Current Programs: Not available

General Comments: None

Photograph/Schematic Available: No

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 99.

Date of Information: January 1990

Aerospace Test Facilities in West Germany

Figure X.1: Map of Test Facilities in West Germany

Source: GAO

References: Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Airbreathing Propulsion and Flight Simulators. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 2, p. 98.

Date of Information: January 1990

between a sound field and turbulent flow or the instability of free boundary layers; and the influence of the Reynolds Number on the flow stream in blowers and in the output of blowers. The plant could also be operated with a Roots blower to test rarefied gas flows up to pressures of 10^{-3} torr. Other testing capabilities included hot-wire anemometry, measuring fluctuations in the flow with microphone probes, and correlational test techniques.

Data Acquisition: On-line test data collection and evaluation was performed by the Hewlett Packard 2116 C process computer. Standard vacuum measuring techniques used a McLeod vacuum meter, Thermistor vacuum meter, and Statham pressure gauge.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel was used to measure the turbulence structure of free-jets and their sensitivity to sound fields and environmental conditions. It was also used to test how devices function under the influence of low air density (simulation of conditions up to heights of 50 km was possible).

General Comments: The tunnel was decommissioned and has been dismantled.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-8 (in German).

Date of Information: October 1989

DLR Berlin Evacuable Free-jet Experimental Plant 1

Country: West Germany

Location: Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin and Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Berlin, West Germany

Owner(s):
Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik
Abteilung Turbulenzforschung
Mueller-Breslau-Strasse 8
D-1000 Berlin 12
West Germany

Operator(s): Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin and Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: Not available

Point of Contact: Hermann-Foettinger Institut der Technischen Universitat Berlin, Tel.: [49]-(30)-313-30-83

Test Section Size: 1.2 x 2.8 m (cylindrical) and 0.8 x 1.2 m (smoothing chamber)

Operational Status: Dismantled (see General Comments)

Utilization Rate: Not operational

Performance
Mach Number: Less than 0.4
Reynolds Number: 5×10^5/m
Total Pressure: 100 bars
Dynamic Pressure: Not available
Total Temperature: Not available
Run Time: Not available
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Berlin Evacuable Free-jet Experimental Plant 1 was a subsonic wind tunnel. The tunnel was decommissioned and has been dismantled. The tunnel was used to produce free-jets in the subsonic range. Operation was continuous in a closed circuit. The flow state could be influenced by loudspeakers upstream from the nozzle as well as by evacuating the test chamber at low density. As a result, independent variation of the Mach number and the Reynolds Number was possible. The cylindrical test chamber measured 1.2 × 2.8 m long, and the smoothing chamber measured 0.8 × 1.2 m long. The smoothing chamber was separated in the middle by a flange. Nozzles had diameters of 1, 3, 5, 7.5, 10, and 14 cm. Mach number and Reynolds Number were variable (independently of one another) by lowering air density. Loudspeakers built into the smoothing chamber had a sound field of 30-w power output.

Testing Capabilities: When the tunnel was operational, tests were conducted to investigate phenomena of laminar-turbulent transition and the structure of free-jet turbulence in independently variable ranges of the Reynolds Number, Mach number, and Strouhal number; the interaction

DLR Berlin Low-Velocity Wind Tunnel

Country: West Germany

Location: Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin and Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Berlin, West Germany

Owner(s):
Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik
Abteilung Turbulenzforschung
Mueller-Breslau-Strasse 8
D-1000 Berlin 12
West Germany

Operator(s): Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin and Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: Not available

Point of Contact: Hermann-Foettinger Institut der Technischen Universitat Berlin, Tel.: [49]-(30)-313-30-83

Test Section Size: Not available

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.14 or 50 m/s
Reynolds Number: 4.5×10^6/m
Total Pressure: 100 bars
Dynamic Pressure: Not available
Total Temperature: Not available
Run Time: Not available
Comments: None

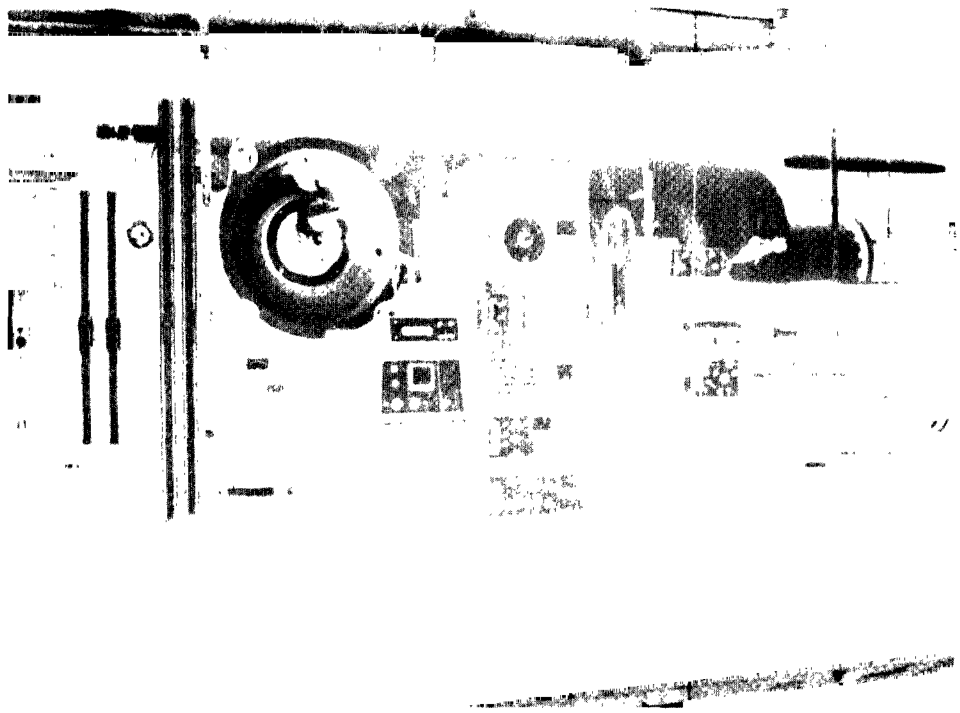
Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Berlin Low-Velocity Wind Tunnel is a subsonic wind tunnel built with a closed test chamber (recycling in concrete, smoothing chamber in steel construction) and four exchangeable test cells. The tunnel contains a six-component balance, a rotating table, and a mechanical device enabling the gas to be exchanged for experiments by making flows visible with smoke. The blower is provided with mufflers at the intake as well as at the exhaust side. The cross section of the smoothing chamber is 4.2 × 4.2 m. The length of the test chamber is 10 m, subdivided into equally long, exchangeable cells. Flow velocity in the test chamber is continuously variable up to 50 m/s (Mach 0.14).

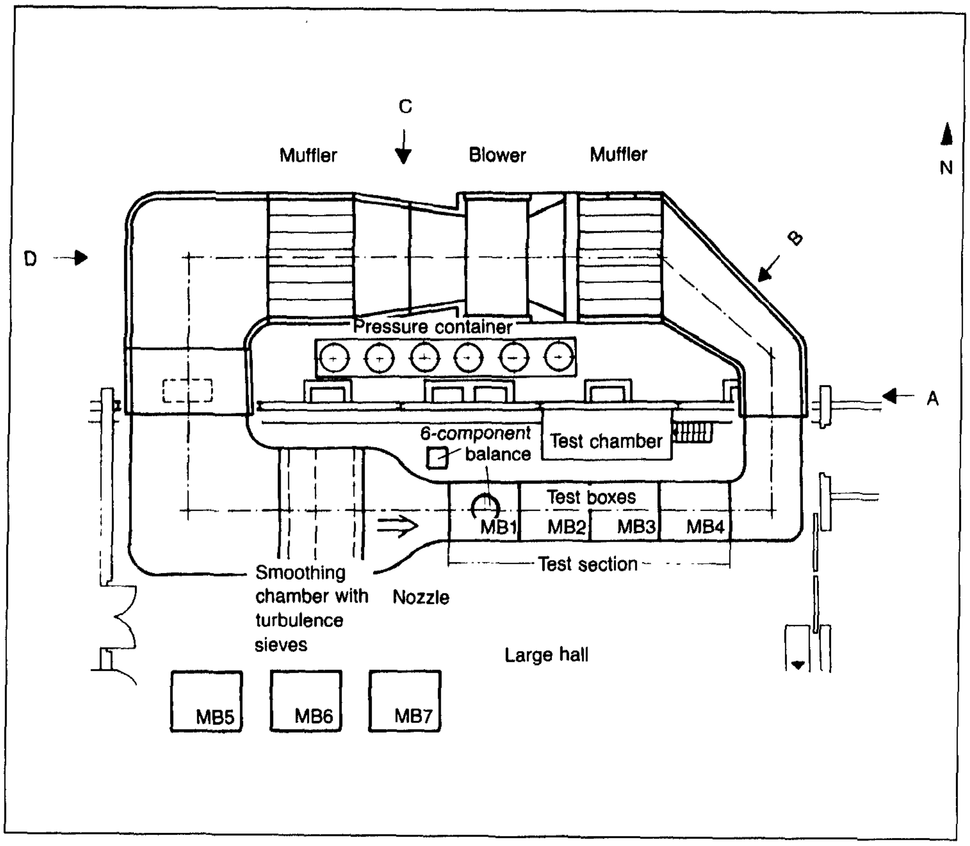
Testing Capabilities: The tunnel is used to investigate basic problems of flow around bodies and their wakes as well as aerodynamic problems of industry (airplanes, buildings, and ships). It is possible to simulate some properties of the ground boundary layer. Interference phenomena and problems of flow-around noise can also be investigated. Drive power of the blower is 500 kW. The air circuit can be opened, allowing an

Figure X.2: DLR Berlin Evacuable Free-jet Experimental Plant 1



Source: DLR

Figure X.3: Schematic Diagram of the DLR Berlin Low-Velocity Wind Tunnel



Source: DLR

exchange of gas for smoke for flow visualization. The tunnel has a muffler before and after the blower with a cooler. The exchangeability of the four test cells optimizes test preparations. The tunnel also has a rotating table for models. It has hot-wire anemometry, laser Doppler anemometry, flow visualization, microphone probes to measure pressure fluctuations, Statham pick-off, scanivalves, and a multitubed manometer.

Data Acquisition: The tunnel's on-line data collection and evaluation is performed by a Hewlett Packard 2116 C process computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include flow around objects (models and components), wake flows behind objects, problems of interference in the case of flow around objects, simulation of the atmospheric ground boundary layer, building aerodynamics, and flow-around noise.

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-10 (in German).

Date of Information: October 1989

an electronic pressure gauge. It uses methods to test pressure fluctuations. It also uses correlational measuring techniques.

Data Acquisition: The tunnel has on-line data collection and evaluation that is performed by a Hewlett Packard 2116 C process computer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to conduct tests of wall boundary layers and flow around bodies of arbitrary configurations. It is also used to test measuring techniques in unsteady flows.

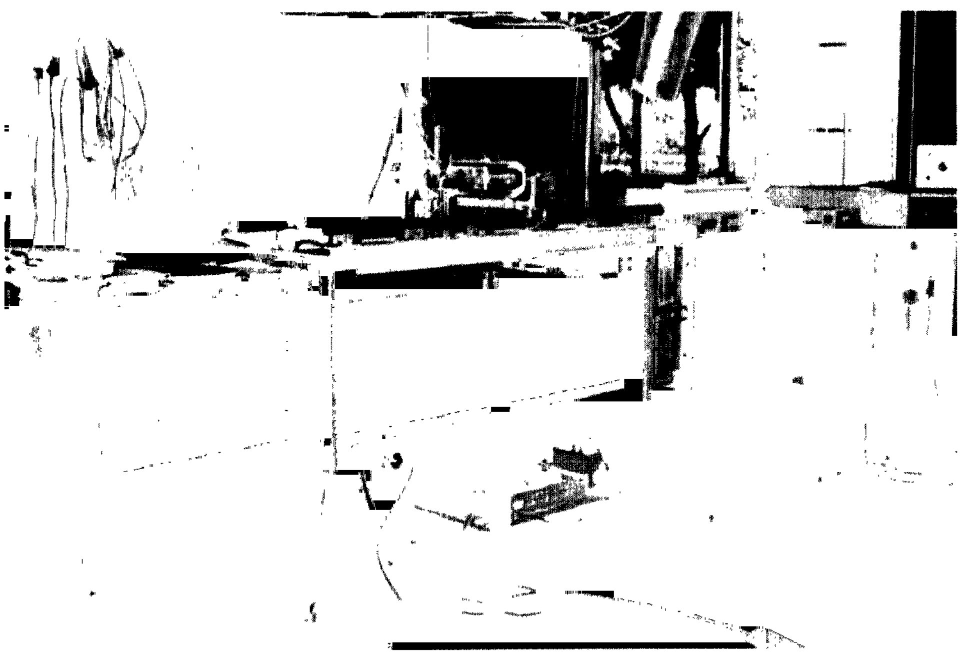
General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-9 (in German).

Date of Information: October 1989

Figure X.4: DLR Berlin Unsteady Wind Tunnel



Source: DLR

DLR Berlin Unsteady Wind Tunnel

Country: West Germany

Location: Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin and Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Berlin, West Germany

Owner(s):
Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik
Abteilung Turbulenzforschung
Mueller-Breslau-Strasse 8
D-1000 Berlin 12
West Germany

Operator(s): Hermann-Foettinger Institut fuer Thermo- und Fluiddynamik der Technischen Universitat Berlin and Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: Not available

Point of Contact: Hermann-Foettinger Institut der Technischen Universitat Berlin, Tel.: [49]-(30)-313-30-83

Test Section Size: 0.5 x 0.5 x 6 m

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.08 or 30 m/s
Reynolds Number: Not available
Total Pressure: 100 bars
Dynamic Pressure: Not available
Total Temperature: Not available
Run Time: Not available
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Berlin Unsteady Wind Tunnel is a subsonic wind tunnel. It has a square cross section (0.5 × 0.5 m) about 6 m long. It also has a rotating valve system at one end. A radial blower draws air through the tunnel and rotating valve system. The flow in the tunnel can be varied in frequency and amplitude, creating unsteady conditions. The operating level can be kept stable through a bypass in which an equal valve system, shifted by 90 percent, is synchronized. The tunnel is used for basic research in unsteady wall boundary layers and bodies in unsteady flow and their wakes. The test chamber in the middle of the tunnel is about 1.5 m long and contains a plate glass observation window. The probe shift path is in the direction of the main flow. The valve system at the end of the tunnel consists of four rotating valves, whose frequency can be varied continuously from about 1 to 50 Hz. The main flow is continuously adjustable up to 30 m/s (Mach 0.08).

Testing Capabilities: The tunnel is capable of conducting tests using hot-wire anemometry, laser Doppler anemometry, microphone probes, and

Data Acquisition: The tunnel is capable of test cycle control with the process computer, real-time representation of test results, data collection on magnetic tapes and disks, and test evaluation independent of the local computer center. The tunnel's data collecting unit has a connection to the local computer center.

Planned Improvements (Modifications/Upgrades): Installation of a strain-gauge balance for half-models is planned.

Unique Characteristics: None

Applications/Current Programs: These include low-speed aerodynamics and flow characteristics of airplane models with a wingspan of up to 2.3 m, missiles, vehicles, and buildings as well as partial models. The tunnel is also used to test static and dynamic stability of aircraft configurations.

General Comments: Tests are commissioned by DLR institutes, the aircraft industry, other firms, and West German government ministries.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-2 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 69. Kausche, G., H. Otto, D. Christ, and R. Siebert. Der Niedergeschwindigkeits-Windkanal der DFVLR in Braunschweig (The Low-Velocity Wind Tunnel of DFVLR in Braunschweig). Koln, West Germany: DFVLR, 1988 (DFVLR-Mitteilung 88-25) (in German).

Date of Information: October 1988

DLR Braunschweig 3.25 m × 2.8 m² Wind Tunnel (NWB)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Braunschweig, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Braunschweig
Flughafen
D-3300 Braunschweig
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Dr. Gerhard Kausche, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(531)-395-2450

Test Section Size: 3.25 m x 2.8 m² x 6.2 m and 9.1 m² (test chamber cross section)

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.22 (open) and 0.26 (closed)
Reynolds Number: 5 x 10^6/m (open) and 6 x 10^6/m (closed)
Total Pressure: Atmospheric
Dynamic Pressure: 3.4 kN/m² (open) and 5 kN/m² (closed)
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1960
Date Placed in Operation: 1961
Date(s) Upgraded: 1983
Construction Cost: Not available
Replacement Cost: $150.9 million (1989)
Annual Operating Cost: Not available
Unit Cost to User: Depends on test requirements
Source(s) of Funding: See General Comments

Number and Type of Staff
Engineers: 2
Scientists: 2
Technicians: 2
Others: 1 (data acquisition)
Administrative/Management: 1
Total: 8

Description: The DLR Braunschweig 3.25 m × 2.8 m² Wind Tunnel is a continuous-flow, closed-circuit, subsonic wind tunnel. It has an open and closed test section measuring 3.25 m × 2.8 m² at the nozzle cross section and is 6.2 m long. Flow velocity can be varied between 0 and 75 m/s (Mach 0.22) in the open test section and between 0 and 90 m/s (Mach 0.26) in the closed test section. The single-step blower with (at rest) adjustable blades is driven by a 1,400-kW DC motor with thyristor control. Models can be adjusted 360 degrees around the vertical axis and 75 degrees around the horizontal axis.

Testing Capabilities: The tunnel is equipped with standard test equipment for measuring forces, moments, velocities, pressures, and temperature. Special equipment includes internal multicomponent strain-gauge balances with support system and pressure testing equipment for up to 960 measuring positions (scanivalves and PSI-system). The tunnel also has a mobile oscillatory derivative balance, a rolling and spinning derivative balance, equipment for profile and half-model tests, jettison test technology, and a compressed air supply system. The walls of the closed test section contain a slot system that allows changes in the open area ratio between 0 and 12 percent.

DLR Braunschweig Jet-simulation Wind Tunnel (SSB)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Braunschweig, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Braunschweig
Flughafen
D-3300 Braunschweig
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(531)-395-2450

Test Section Size: 440 mm diameter

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.35 to 0.8
Reynolds Number: 7 to 14 x 10^6/m
Total Pressure: Not available
Dynamic Pressure: Not available
Total Temperature: Ambient
Run Time: Not available
Comments: Not available

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

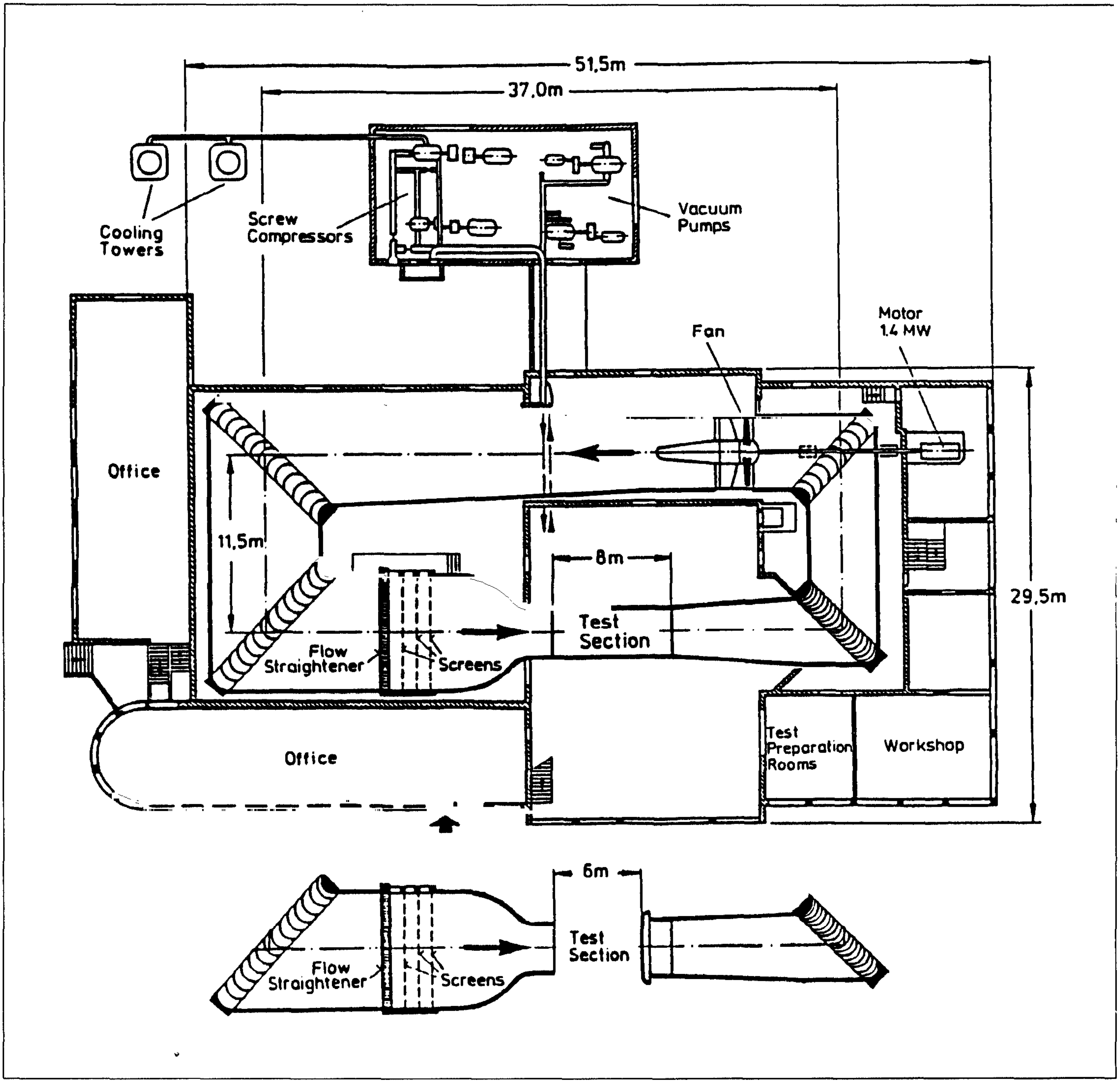
Description: The DLR Braunschweig Jet-simulation Wind Tunnel is a subsonic wind tunnel with a closed test chamber and an open circuit that operates by suction. Atmospheric air is drawn through a bell-shaped inlet and through the test chamber by a J-79 jet engine. The test chamber has a circular cross section with windows to enable flow observation. The model is inserted into the middle of the test chamber by a nose strut suspension.

Testing Capabilities: The tunnel is capable of conducting pressure and and temperature measurements in the flow field. It can also conduct jet-simulation with cold air and hot combustion gases for jet temperatures between 280 and 1,000 degrees Kelvin, pressure ratios between 1 and 3, and a mass flow between 0 and 3.5 kg/s.

Data Acquisition: The tunnel has a pressure measurement position switch (scanivalve) and test data collection unit with a process computer.

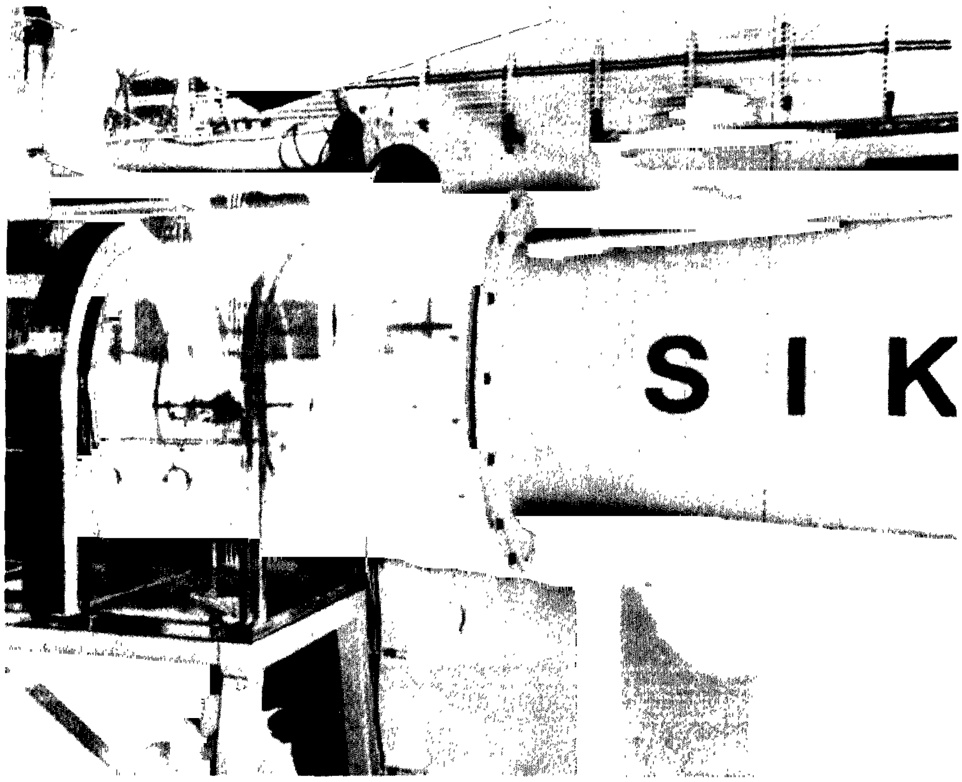
Planned Improvements (Modifications/Upgrades): None

Figure X.5: Schematic Diagram of the DLR Braunschweig 3.25 m × 2.8 m² Wind Tunnel (NWB)



Source: DLR

Figure X.6: DLR Braunschweig Jet-simulation Wind Tunnel (SSB)



Source: DLR

Unique Characteristics: The tunnel has an air compressor installation in the Main Division Wind Tunnel and a hot gas-producing installation.

Applications/Current Programs: The tunnel is used for flow investigations of aircraft afterbodies including jet engine nacelles. Test objects include a jet simulator, interference cell jet, engine simulation, and shear vector control. The maximum diameter of a test model is 100 mm.

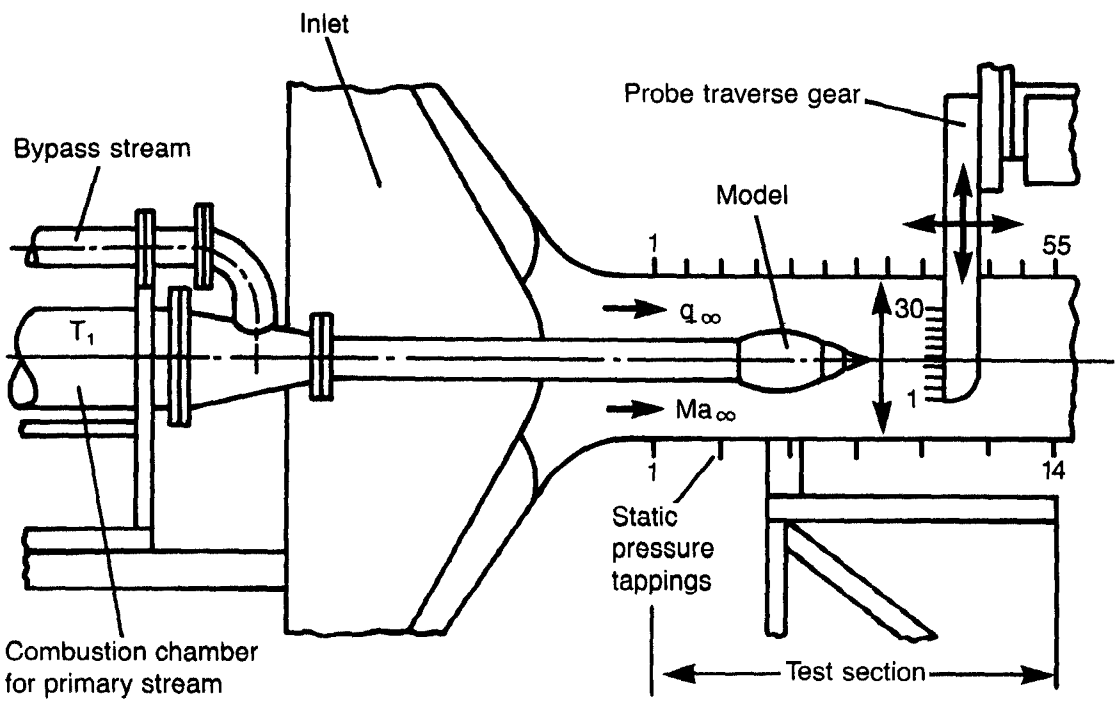
General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-5 (in German). Zacharias, A. Der Strahlinduktionskanal der Institut fuer Entwurfs Aerodynamik der DFVLR Braunschweig (SIB) (The Jet-induction Tunnel of the Institute for Aerodynamic Design at DFVLR Braunschweig (SIB)). Koln, West Germany: DFVLR, 1981 (DFVLR-IB-129-81/13) (in German).

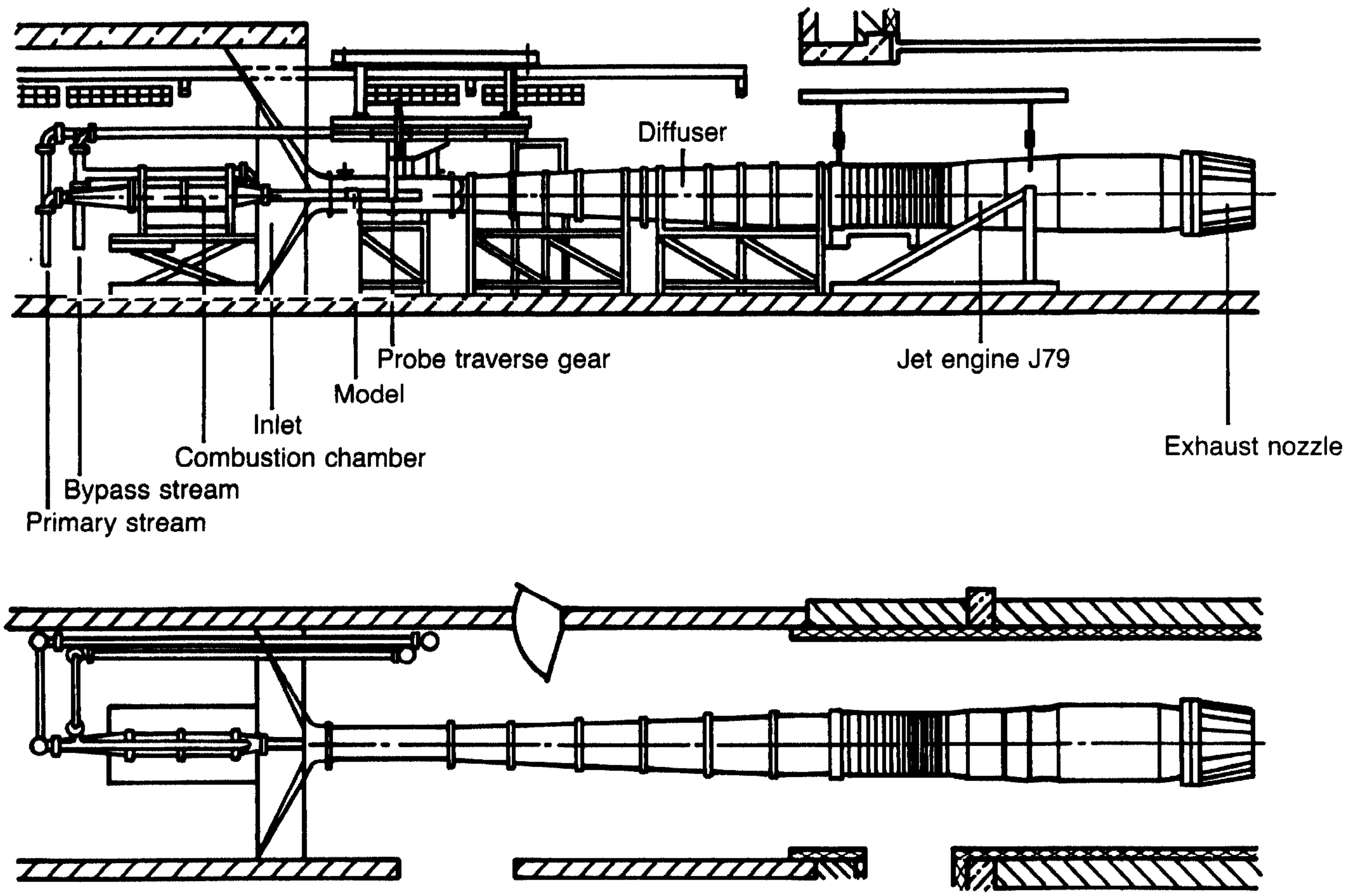
Date of Information: October 1989

Figure X.8: Schematic Diagram of the Combustion Chamber, Inlet, Test Section, and Probe Traverse Gear of the DLR Braunschweig Jet-simulation Wind Tunnel (SSB)



Source: DLR

Figure X.7: Schematic Diagram of the DLR Braunschweig Jet-simulation Wind Tunnel (SSB)



Source: DLR

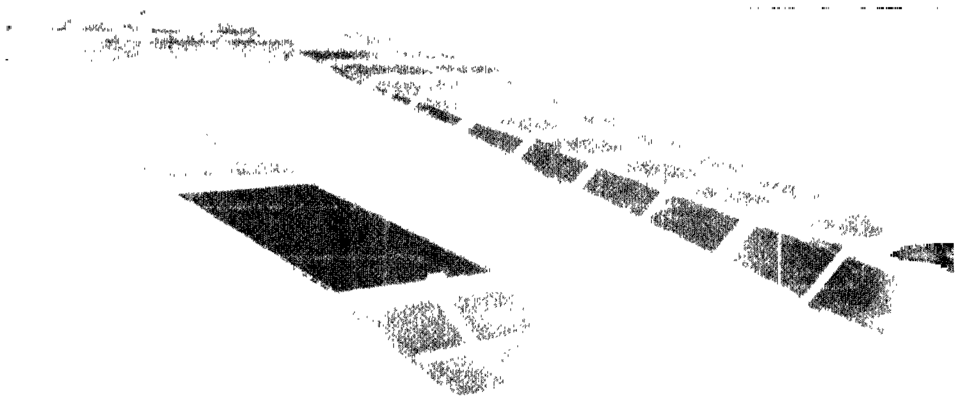
General Comments: The tunnel conducts tests for DLR and West German industry.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-11 (in German).

Date of Information: October 1989

Figure X.9: DLR Braunschweig Model Subsonic Wind Tunnel (MUB)



Source: DLR

DLR Braunschweig Model Subsonic Wind Tunnel (MUB)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Braunschweig, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanal
Abteilung Braunschweig
Flughafen
D-3300 Braunschweig
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(531)-395-2450

Test Section Size: 1.3 m x 1.3 m^2 x 2.46 m long and 0.82 m x 0.82 m^2 x 1.64 m long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.14 to 0.38 or 55 to 130 m/s
Reynolds Number: Not available
Total Pressure: Not available
Dynamic Pressure: Not available
Total Temperature: Not available
Run Time: Not available
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: See General Comments

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Braunschweig Model Subsonic Wind Tunnel has two closed test chambers (one arranged behind the other) measuring 1.3 m × 1.3 m^2 cross section and 2.46 m long and 0.82 m × 0.82 m^2 cross section and 1.64 m long, respectively. It operates with recycled air. Wind velocity can be varied between 0 and 55 m/s (Mach 0.14) in the large test chamber and between 0 and 130 m/s (Mach 0.38) in the small test chamber. The single-step 1.6 m-diameter blower with adjustable blades (at rest) is driven by a DC motor with thyristor control.

Testing Capabilities: The tunnel is capable of conducting force and pressure measurements. It has slotted test chamber walls.

Data Acquisition: The tunnel has on-line data processing capability.

Planned Improvements (Modifications/Upgrades): Remodeling of one test chamber is planned.

Unique Characteristics: None

Applications/Current Programs: These include models of airplanes and automobiles, and probes.

DLR Goettingen 1 m Wind Tunnel (1MG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: None

Point of Contact: Dr. Grosche, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2179

Test Section Size: 1 x 0.7 m (rectangular cross section) x 1.3 m long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.002 to 0.19 or 0.7 to 65 m/s
Reynolds Number: 1.3 x 10^6/m
Total Pressure: 1 bar
Dynamic Pressure: 0 to 2,600 Pa
Total Temperature: 293 degrees Kelvin
Run Time: Continuously
Comments: None

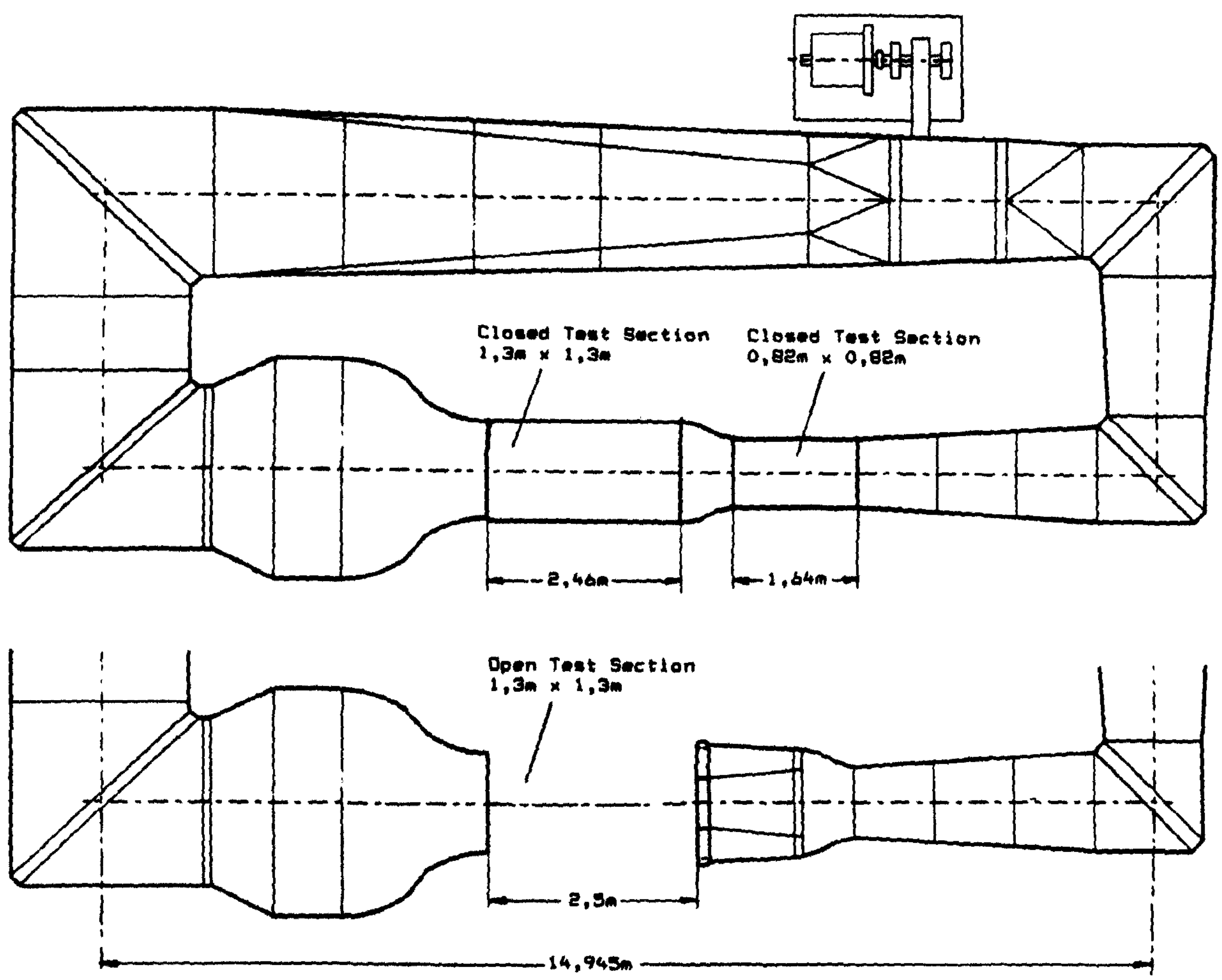
Cost Information
Date Built: Not available
Date Placed in Operation: 1962
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Goettingen 1 m Wind Tunnel is a subsonic wind tunnel. The tunnel is a continually operated low-velocity wind tunnel with an open-jet test section and closed return-circuit (Goettingen type). The elliptical nozzle (1 × 0.7 m) provides a test cross section of 0.6 m^2. The installed power is 88 kW. The contraction ratio is 4.8. The tunnel is mainly used for research work and, on request, for contract work in the field of industrial aerodynamics.

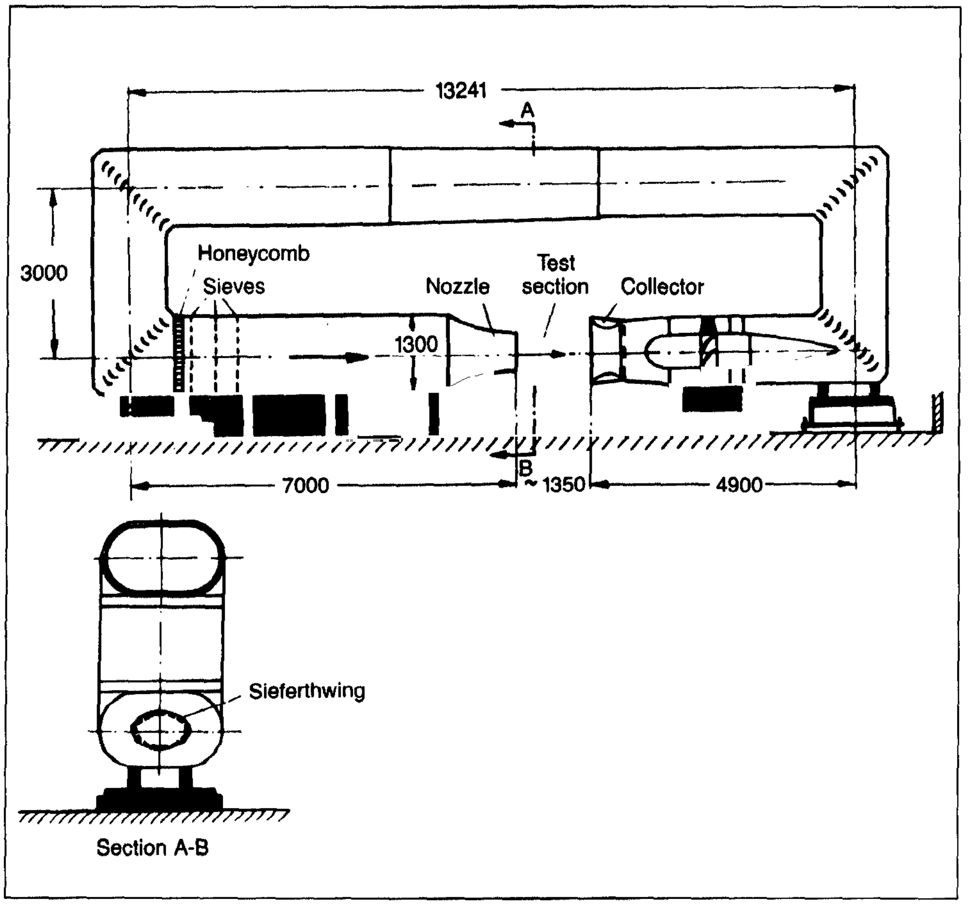
Testing Capabilities: To conduct pressure measurements, the tunnel is equipped with pressure transducers and scanivalves. For velocity measurements, the tunnel has multi-hole directional probes and hot-wire anemometry. Flow visualization tests are conducted using the oil flow technique, liquid crystals, infrared imaging, and laser light sheet techniques. A microcomputer-controlled probe traversing mechanism (for three axes) is available as well as special equipment for testing smoke and heat extraction systems. The tunnel has a compressed air supply of 1.6 kg/s at 21 bars.

Figure X.10: Schematic Diagram of the DLR Braunschweig Model Subsonic Wind Tunnel (MUB)



Source: DLR

Figure X.11: Schematic Diagram of the DLR Goettingen 1 m Wind Tunnel (1MG)



Source: DLR

Data Acquisition: The tunnel has multi-channel integrating digital voltmeters, A/D converters, and a microcomputer.

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include research in the field of boundary layers and separated flows. The tunnel is also used for the calibration of directional probes and anemometers for wind speed measurement. Industrial aerodynamic tests are conducted in the tunnel. It can test models of aircraft with a wingspan up to 0.5 m and fuselage length up to 0.6 m.

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-6 (in German).

Date of Information: October 1989

line data connection to the DLR computer center. The tunnel uses a DEC computer, which is capable of providing numerical and graphic real-time results representation. Results are presented on a printer and graphic display in the tunnel's control room. The duration of a typical force measuring cycle is 100 measuring positions in 3 to 5 min.

Planned Improvements (Modifications/Upgrades): These include a computer-controlled adjustable probe for measuring the flow field, a new model support with improved control capabilities by computer, and a new test rig for half-models. Improvements of flow quality by installing new stagnation chamber components and a nozzle are also planned.

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to test models of airplanes, flying objects, vehicles, buildings, original-size luges, bobsleds, skiers, building annexes, superstructures, and engine simulators. It is also used to conduct research programs, including aeroelastic problems, of different DLR institutes.

General Comments: Tests are commissioned by DLR institutes, the aircraft industry, other firms, and West German government ministries.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-3 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 71. Baumert, S., et al. Der 3 × 3 m Niedergeschwindigkeitswindkanal (NWG) der DFVLR in Goettingen (Stand 1988) (The 3 × 3 m Low-Velocity Wind Tunnel (NWG) at DFVLR in Goettingen (Status 1988)). Koln, West Germany: DFVLR, 1988 (DFVLR-Mitteilung 89-05) (in German).

Date of Information: October 1989

DLR Goettingen 3 X 3 m Subsonic Wind Tunnel (NWG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Goettingen
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Dr. Fritz Lehthaus, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(551)-709-2148

Test Section Size: 3 m x 3 m^2 x 6 m and 9 m^2 (test chamber cross section)

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0 to 0.19 or 0 to 65 m/s
Reynolds Number: 4.4 x 10^6/m (maximum)
Total Pressure: Atmospheric
Dynamic Pressure: 2.4 kN/m^2 (maximum)
Total Temperature: Ambient
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1958
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: See General Comments

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Goettingen 3 X 3 m Subsonic Wind Tunnel is a continuous-flow, closed-circuit subsonic wind tunnel. It has a free-jet test section measuring 3 m X 3 m^2 at the nozzle cross section and operates with recycled air. Wind velocity can be varied between 0 and 65 m/s (Mach 0.19). Air is driven by a single-step blower with adjustable blades. The nozzle contraction is 5.44. It has a 1,200-kW DC motor with thyristor control and model adjustment of 360 degrees around the vertical axis and 45 degrees around the horizontal axis.

Testing Capabilities: The tunnel has internal six-component balances with support systems, pressure-testing equipment with about 1,000 measuring positions, a PSI-system, an ultrasonic testing method for measuring vortices, a probe-shifting device with programmable cycle for three components, remote-control shiftable floor plates with boundary layer suction, model engines, a compressed air plant, sound-absorbing lining of the test chamber for aeroacoustic measuring, and a laser light sheet technique.

Data Acquisition: The tunnel has 98 channels integrating digital voltmeters. It has an automatically controlled test cycle for force, pressure distribution, and flow measurings with the process computer; and on-

DLR Gottingen Cryogenic Tube Wind Tunnel (KRG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: None

Point of Contact: Dr. G. Hefer, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2323

Test Section Size: 0.4 x 0.35 m

Operational Status: Active

Utilization Rate: About 4 test per hour

Performance
- **Mach Number:** 0.3 to 0.9
- **Reynolds Number:** 4.5 x 10^8/m (maximum)
- **Total Pressure:** Less than 10 bars (maximum)
- **Dynamic Pressure:** Not available
- **Total Temperature:** Ambient to 100 degrees Kelvin
- **Run Time:** About 1 s
- **Comments:** None

Cost Information
- **Date Built:** Not available
- **Date Placed in Operation:** Not available
- **Date(s) Upgraded:** Not available
- **Construction Cost:** Not available
- **Replacement Cost:** Not available
- **Annual Operating Cost:** Not available
- **Unit Cost to User:** Not available
- **Source(s) of Funding:** Not available

Number and Type of Staff
- **Engineers:** Not available
- **Scientists:** Not available
- **Technicians:** Not available
- **Others:** Not available
- **Administrative/Management:** Not available
- **Total:** Not available

Description: The DLR Goettingen Cryogenic Tube Wind Tunnel is a subsonic wind tunnel.

Testing Capabilities: Not available

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): These include an adaptive wall test section.

Unique Characteristics: None

Applications/Current Programs: Not available

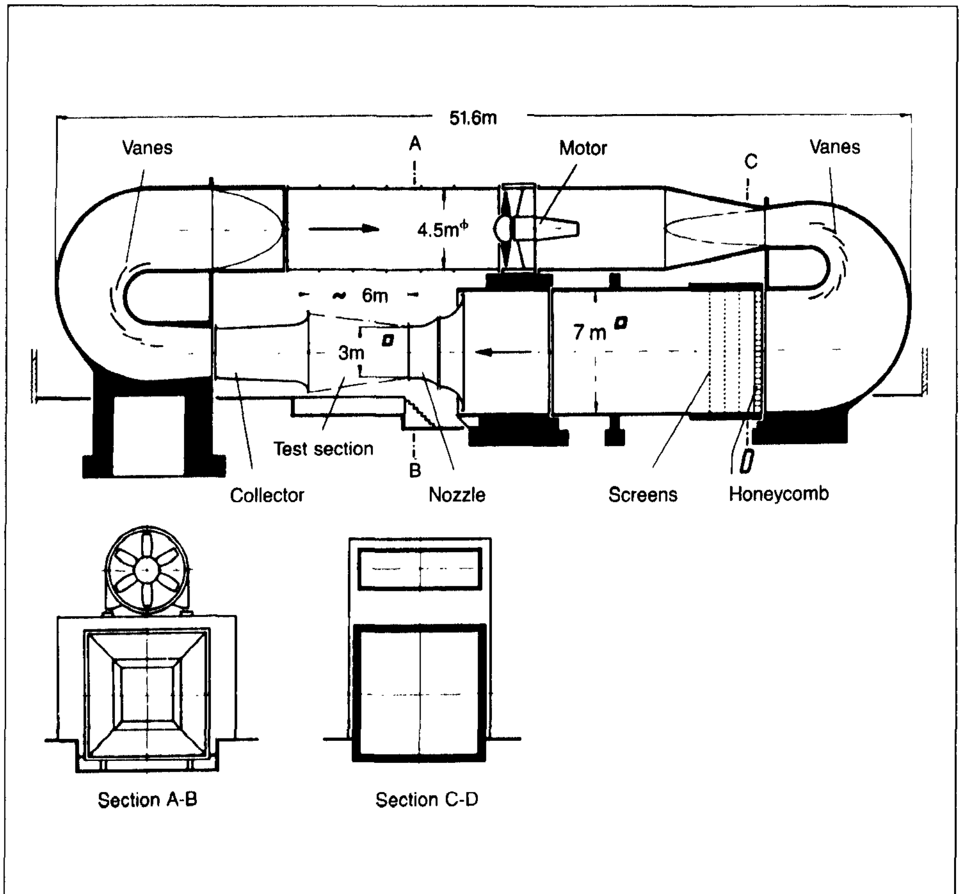
General Comments: None

Photograph/Schematic Available: No

References: None available

Date of Information: October 1989

Figure X.12: Schematic Diagram of the DLR Goettingen 3 × 3 m Subsonic Wind Tunnel (NWG)



Source: DLR

Unique Characteristics: The DLR Goettingen High Pressure Wind Tunnel is the only wind tunnel of its kind in the world.

Applications/Current Programs: The tunnel is used to test models of airplanes, flying objects, buildings, and vehicles at high Reynolds Numbers in steady and unsteady modes. Oil flow visualization techniques are used at different Reynolds Numbers on simple bodies of revolution.

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-5 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 108.

Date of Information: October 1989

DLR Goettingen High-Pressure Wind Tunnel (HDG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Goettingen
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Dr. Fritz Lehthaus, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(551)-709-2148

Test Section Size: 0.6 x 0.6 x 0.575 m (open) and 0.4 x 0.6 x 1 m (closed)

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.1 or 35 m/s
Reynolds Number: 2 x 10^8/m (maximum)
Total Pressure: 100 bars (maximum)
Dynamic Pressure: About 7.5 kN/m^2 (maximum)
Total Temperature: Ambient
Run Time: Continuous
Comments: Test gas used is air.

Cost Information
Date Built: Not available
Date Placed in Operation: 1981
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Goettingen High-Pressure Wind Tunnel is a subsonic wind tunnel used for high Reynolds Number investigations. It can be charged up to 100 bars, which permits the tunnel to attain very high Reynolds Numbers in incompressible fluid flow at 35 m/s (Mach 0.1). This makes the wind tunnel suited for tests that demand simulation of the full-scale Reynolds Number. The tunnel has interchangeable test sections. The circuit is cooled by dripping water over the exterior.

Testing Capabilities: The tunnel has six-component strain-gauge balances and piezobalances for steady and unsteady force measurements on two-dimensional profiles (especially on technical arrangements like cylinders) as well as a scanivalve system. The tunnel also has a locking system for test section exchange in the pressurized circuit.

Data Acquisition: The tunnel has 12 channels integrating digital voltmeters. The data acquisition system is connected to a local computer for real-time data reduction. The results are presented on a printer. The local computer is connected with DLR's computing center.

Planned Improvements (Modifications/Upgrades): These include flow visualization by liquid crystals.

)LR Goettingen Low-Turbulence Wind Tunnel (TUG)

:ountry: West Germany

.ocation: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

)wner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

)perator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

nternational Cooperation: None

'oint of Contact: Dr. Grosche, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2179

'est Section Size: 0.3 m x 1.5 m^2 x 6.25 m long

)perational Status: Active

Jtilization Rate: Not available

Performance
Mach Number: 0.13 or 0 to 45 m/s
Reynolds Number: 1 x 10^6/m
Total Pressure: 1 bar
Dynamic Pressure: 0 to 1,250 Pa
Total Temperature: 293 degrees Kelvin
Run Time: Continuously
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: 1954
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

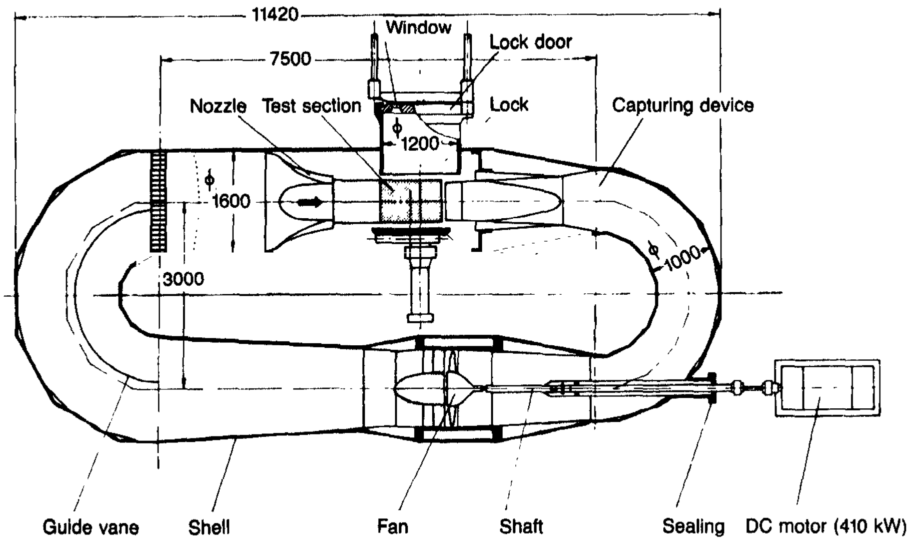
Description: The DLR Goettingen Low-Turbulence Wind Tunnel is a subsonic wind tunnel. The tunnel is a continuously operated, low-speed tunnel with closed test section and return through the test hall (Eiffel type). The turbulence level in the rectangular test section (0.3 m × 1.5 m^2 × 6.25 m long) is about 0.05 percent. The installed power is 80 kW. The contraction ratio is 15. When requested, the tunnel is used for calibrations (hot-wire anemometers, hot-film wall elements) and for testing lamina profiles and boundary layer control.

Testing Capabilities: The tunnel is equipped with pressure transducers and scanivalves for pressure measurements, a hot-wire anemometer for measuring velocity fluctuations, and a surface hot-film element and surface pitot tubes for skin friction measurements. Surface flow visualization is carried out using liquid crystals and the infrared imaging technique.

Data Acquisition: The tunnel is equipped with an integrating digital voltmeter and an analog magnetic tape recorder.

Planned Improvements (Modifications/Upgrades): None

Figure X.13: Schematic Diagram of the DLR Goettingen High-Pressure Wind Tunnel (HDG)



Source: DLR

DLR Koln-Porz 2.4 × 2.4 m Cryogenic Wind Tunnel (KKK)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Dr. Guenter Viehweger, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2295

Test Section Size: 2.4 m x 2.4 m^2 x 5.4 m long

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.01 to 0.36 or 5 to 100 m/s
Reynolds Number: 36 x 10^6/m
Total Pressure: 100 mbar
Dynamic Pressure: 9 kN/m^2
Total Temperature: 100 to 300 degrees Kelvin
Run Time: Continuous
Comments: None

Cost Information
Date Built: 1985
Date Placed in Operation: 1988
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 5
Scientists: 4
Technicians: 2
Others: 2
Administrative/Management: 2
Total: 15

Description: The DLR Koln-Porz 2.4 × 2.4 m Cryogenic Wind Tunnel is a subsonic wind tunnel. It has a closed test section measuring 2.4 m × 2.4 m^2 at the nozzle cross section and a length of 5.4 m. Flow velocity can be varied between 5 and 100 m/s (Mach 0.01 to 0.36), and gas temperature can be varied between 100 and 300 degrees Kelvin. To lower the temperature, liquid nitrogen is injected into the circuit. Gas is driven by a blower with 4.3-m fixed blades and a 1-MW DC motor of adjustable speed. The tunnel has warm-up rooms, which allow model changes while maintaining cryogenic temperatures in the tunnel circuit. The tunnel is intended to complement the European Transonic Windtunnel.

Testing Capabilities: The tunnel can be used for force, moment, and pressure investigations of full- or part-span models or components. It also has testing devices for velocity and temperatures. Special equipment includes a gate and model climate chamber with equipment for changing temperature at the model and at the model support, internal strain-gauge scales, and a nitrogen injection device for varying the gas temperature.

Data Acquisition: The tunnel controls the test angle with the process computer.

Unique Characteristics: None

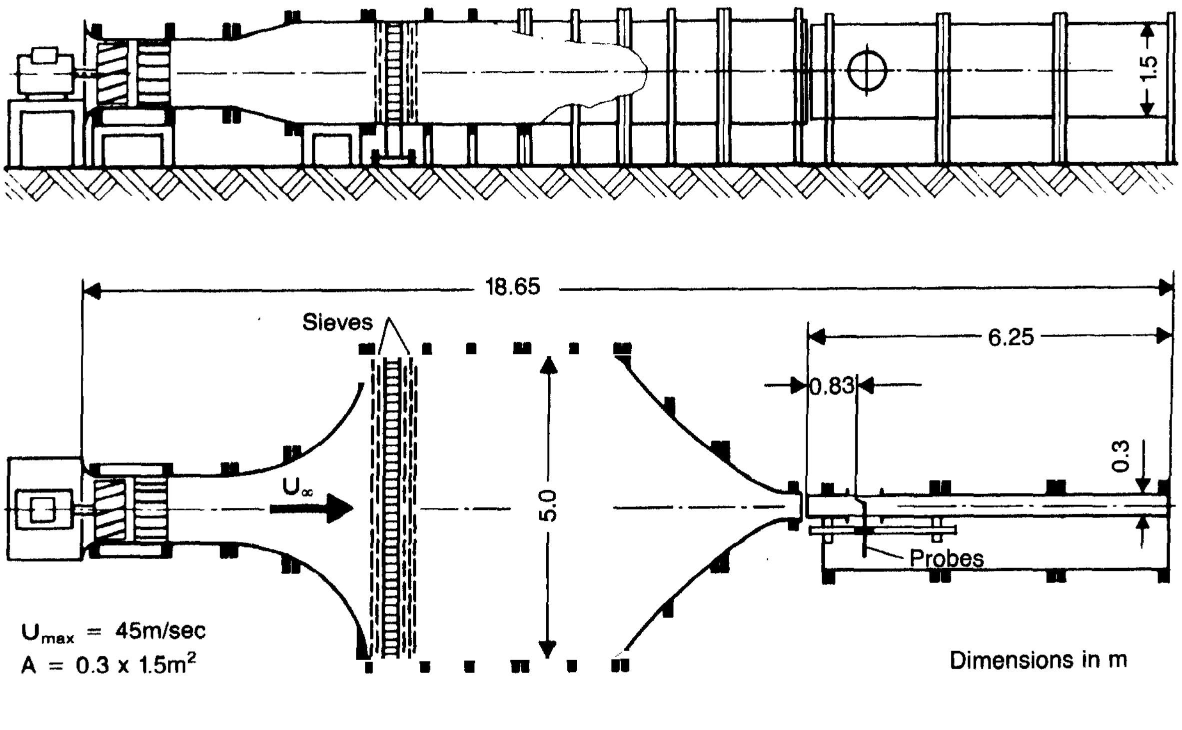
Applications/Current Programs: These include the development and calibration of hot-wire and hot-film sensors for measuring mean values and fluctuations of velocity as well as the amount and direction of wall sheer stress in three-dimensional boundary layers. The tunnel is also used to investigate boundary layer stability and laminar-turbulent transition.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-7 (in German).

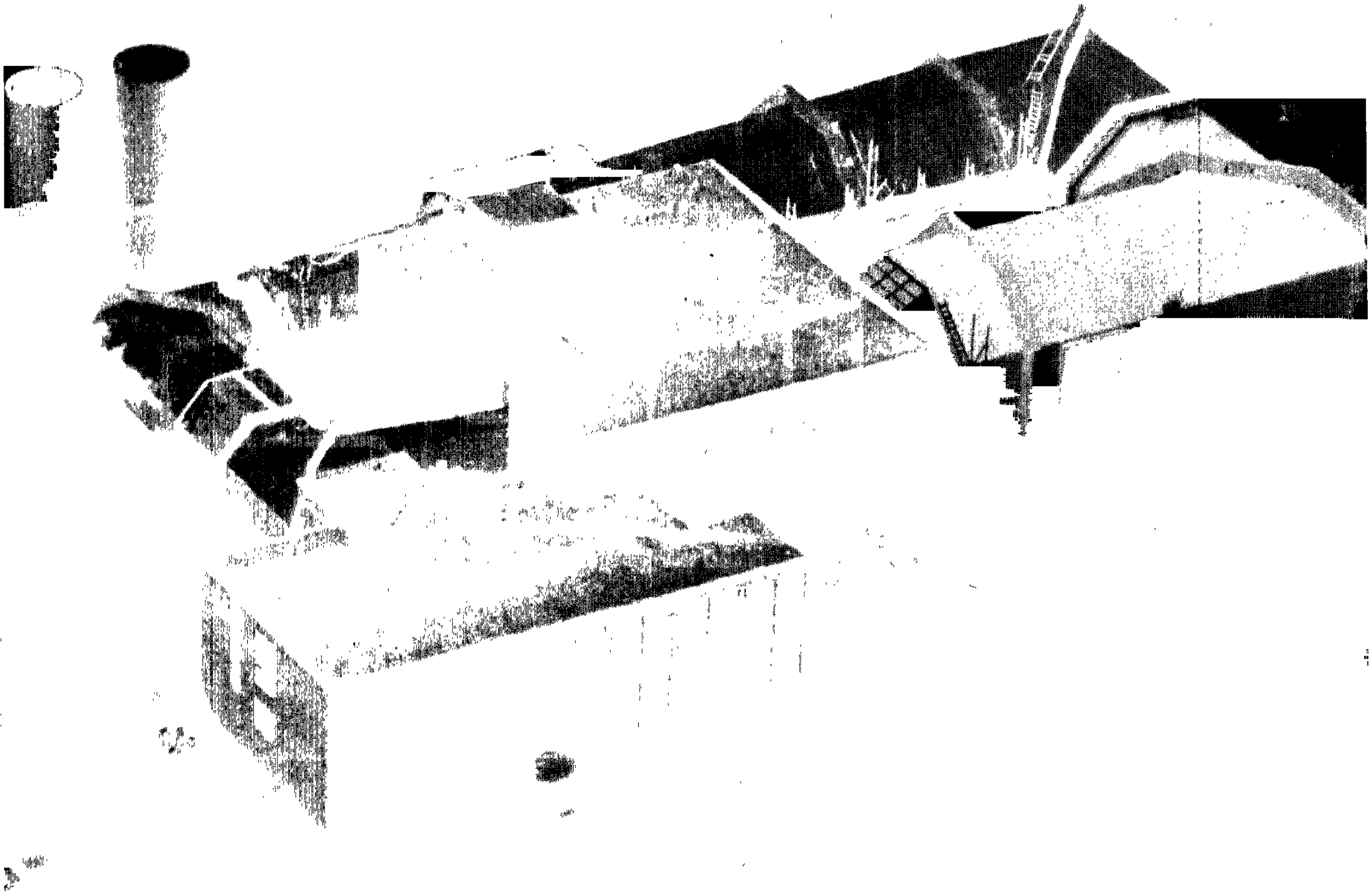
Date of Information: October 1989

Figure X.14: Schematic Diagram of the DLR Goettingen Low-Turbulence Wind Tunnel (TUG)



Source: DLR

Figure X.15: DLR Koln-Porz 2.4 × 2.4 m Cryogenic Subsonic Wind Tunnel (KKK)



Source: DLR

Planned Improvements (Modifications/Upgrades): The tunnel was remodeled for cryogenic operations from 1980 to 1985.

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to develop model and test methods at cryo-temperatures to conduct preliminary tests and subsequent measurings for the European Transonic Windtunnel. Tests of airplane models with a wingspan up to 1.5 m and fuselage length up to 2 m, flying objects, and vehicles are also being conducted.

General Comments: None

Photograph/Schematic Available: Yes

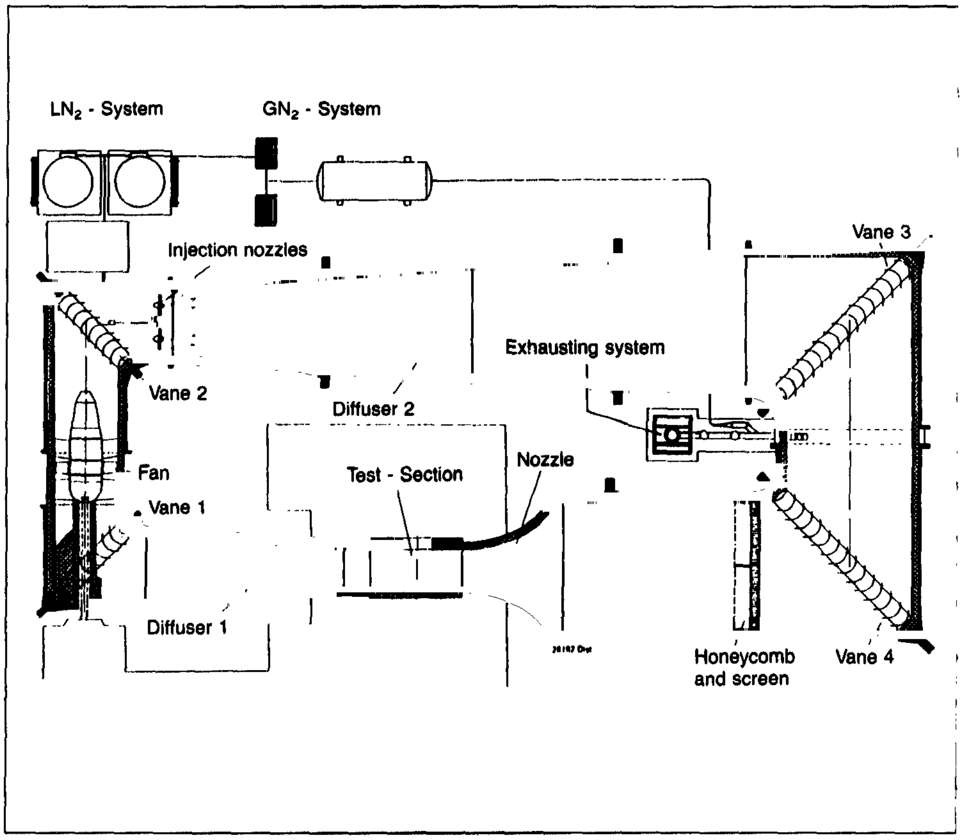
References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.1-4 (in German). Penaranda, Frank E., and M. Shannon Freda. eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 118.

Date of Information: October 1989

Figure X.17: Model in Test Section of the DLR Koln-Porz 2.4 × 2.4 m Cryogenic Subsonic Wind Tunnel (KKK)

Source: DLR

Figure X.16: Schematic Drawing of the DLR Koln-Porz 2.4 × 2.4 m Cryogenic Subsonic Wind Tunnel (KKK)



Source: NASA

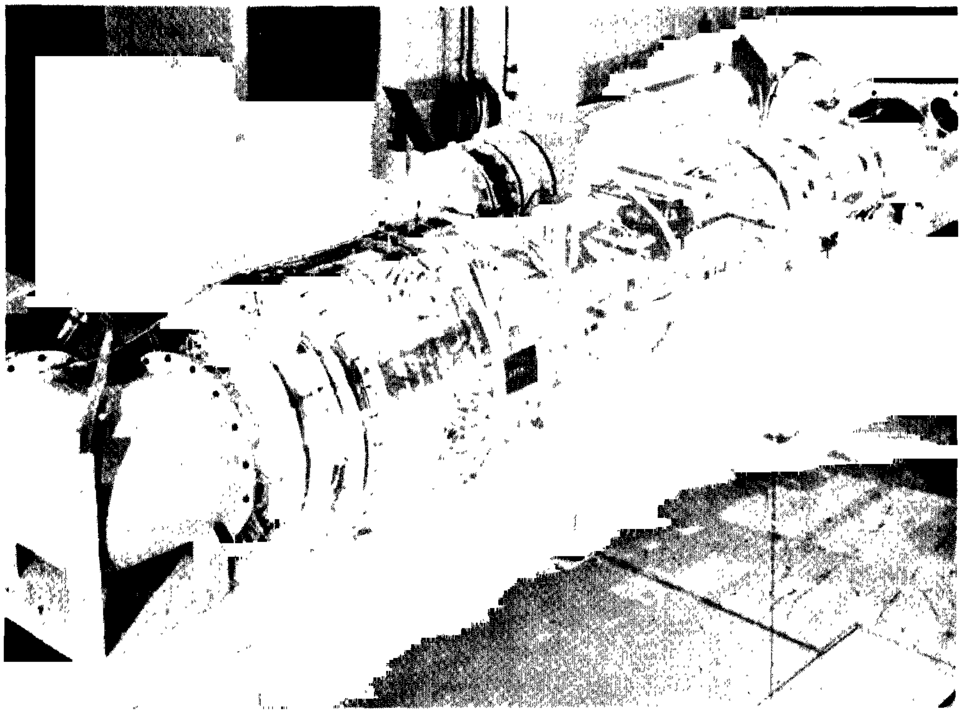
General Comments: The tunnel was decommissioned and will be disassembled.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-10 (in German).

Date of Information: October 1989

Figure X.18: DLR Koln-Porz Test Rig for the European Transonic Windtunnel



Source: DLR

DLR Koln-Porz Test Rig for the European Transonic Windtunnel

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-60-11

Test Section Size: 270 mm x 228 mm^2

Operational Status: Dismantled (see General Comments)

Utilization Rate: Not operational

Performance
Mach Number: 0 to 0.9
Reynolds Number: Not available
Total Pressure: 2 bars
Dynamic Pressure: Not available
Total Temperature: Not available
Run Time: Not available
Comments: Not available

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Koln-Porz Test Rig was a subsonic wind tunnel used to conduct pre-tests for the European Transonic Windtunnel. The tunnel was decommissioned and will be dismantled. The ETW's flow was simulated in the ETW Test Rig in correct scale up to Mach 0.9 at the temperature of the environment to investigate the flow quality based on the chosen contraction, nozzle, and diffusor geometry.

Testing Capabilities: The tunnel had numerous probes for cross section pressure distributions, angle of attack, and unsteady pressure measurements.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not applicable

Unique Characteristics: None

Applications/Current Programs: The test rig conducted pre-tests for the European Transonic Windtunnel.

Applications/Current Programs: The tunnel is used to test transonic airfoil designs, especially for transport aircraft, helicopters, and propeller blade profiles. The tunnel can accommodate a profile chord length from 100 to 200 mm.

General Comments: Reynolds Number can be varied independently of Mach number through variation of the static pressure. Static temperature is not independently variable.

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-4 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 143. Puffert-Meissner, Wolfgang. Der Transsonische Windkanal (TWB) der DFVLR in Braunschweig (Stand 1987) (The Transonic Windtunnel (TWB) at DFVLR in Braunschweig (Status 1987)). Koln, West Germany: DFVLR, 1987 (DFVLR-Mitteilung 88-01) (in German and translated in ESA-TT-1114, 1988).

Date of Information: October 1989

DLR Braunschweig Transonic Wind Tunnel (TWB)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Braunschweig, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Braunschweig
Flughafen
D-3300 Braunschweig
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Dr. Gerhard Kausche, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(531)-395-2450

Test Section Size: 0.34 m x 0.6 m^2

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.4 to 0.95
Reynolds Number: 2 to 7 x 10^7/m
Total Pressure: 1.4 to 5 bars
Dynamic Pressure: 10 to 50 kN/m^2
Total Temperature: 250 to 270 degrees Kelvin
Run Time: 5 to 30 s
Comments: See General Comments

Cost Information
Date Built: 1965
Date Placed in Operation: 1966
Date(s) Upgraded: 1972
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Depends on test requirements
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 2
Scientists: 1
Technicians: 2
Others: 1 (data acquisition)
Administrative/Management: 0
Total: 6

Description: The DLR Braunschweig Transonic Wind Tunnel is an intermittently operating blowdown transonic wind tunnel. The tunnel has a transonic test section with dimensions of 0.34 m × 0.6 m^2. A two-dimensional test section has slotted upper and lower walls with an open area ratio of 2.35 percent for testing profiles in the range from Mach 0.4 to 0.95 at Reynolds Numbers from 4 to 14 × 10^6/m (relative to 200 mm profile chord length).

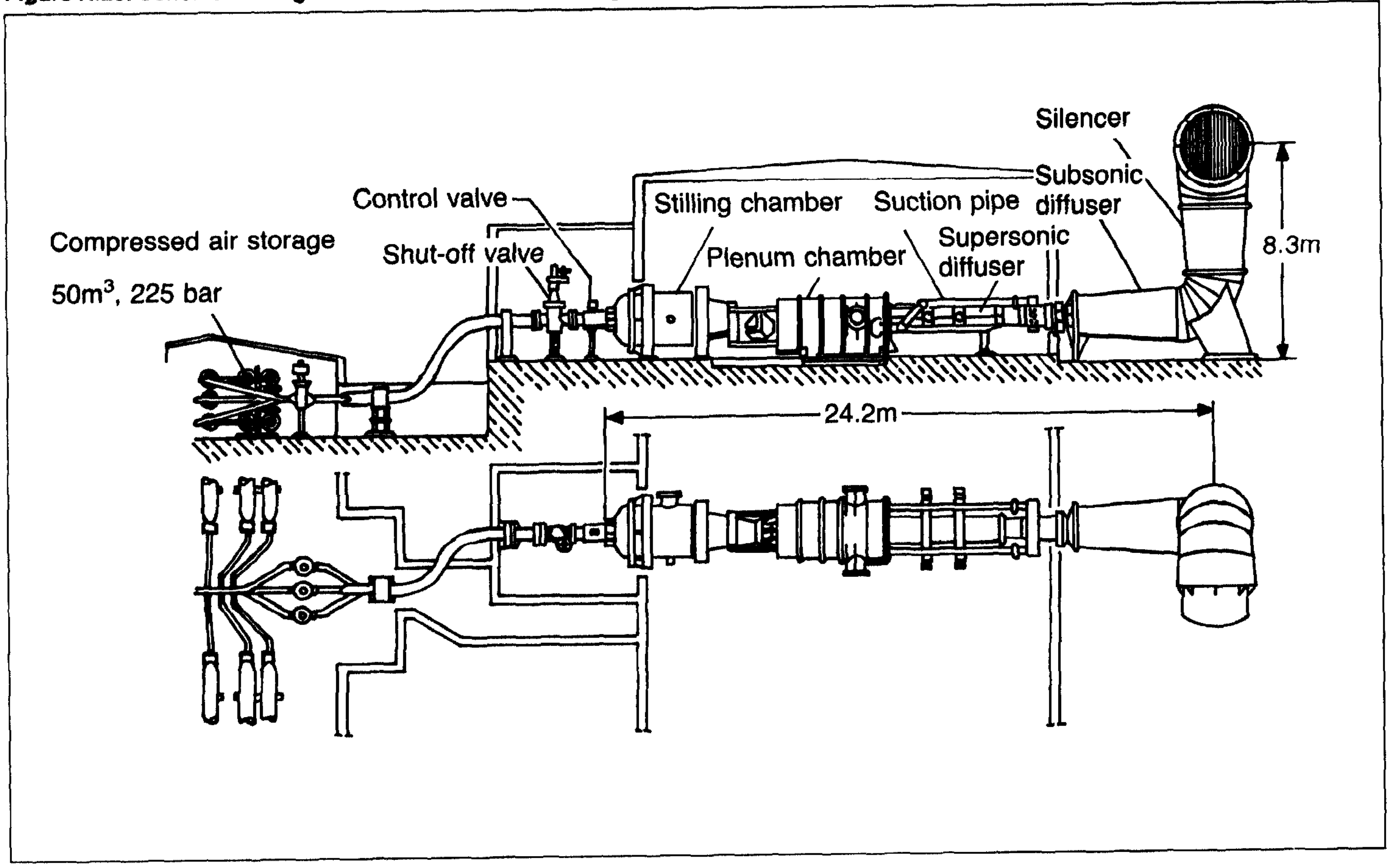
Testing Capabilities: The tunnel has a two-dimensional test section for airfoil chord lengths up to 250 mm. It has the capability to conduct measurements of airfoil surface pressures, wake pressure measurements, and flow visualization tests. The tunnel also has schlieren optic equipment.

Data Acquisition: The tunnel has an electronic data acquisition system with a process computer, on-line data evaluation, and a multiport pressure measurement system with 192 transducers.

Planned Improvements (Modifications/Upgrades): None

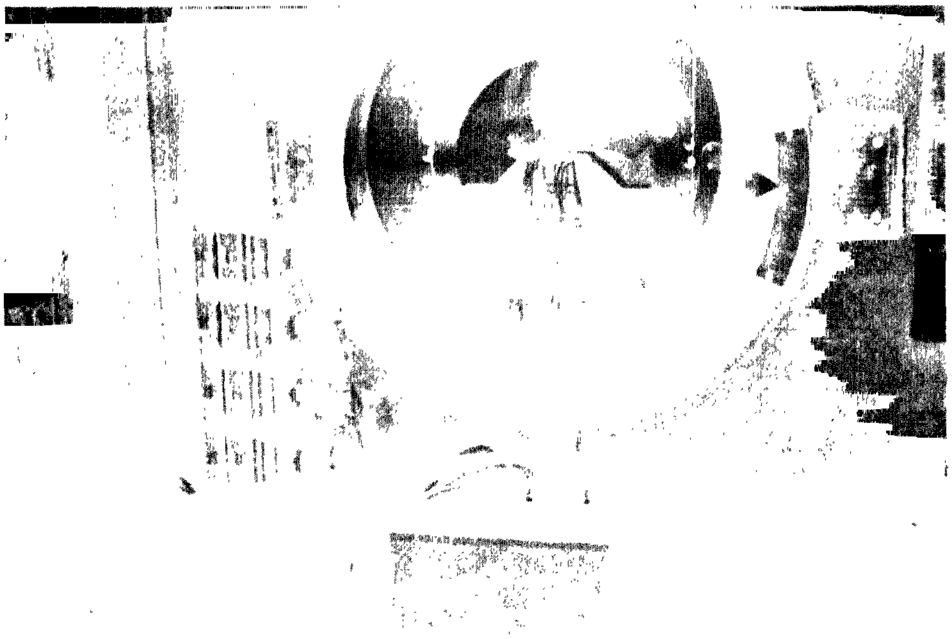
Unique Characteristics: None

Figure X.20: Schematic Diagram of the DLR Braunschweig Transonic Wind Tunnel (TWB)



Source: DLR

Figure X.19: DLR Braunschweig Transonic Wind Tunnel (TWB)



Source: DLR

Unique Characteristics: Many existing European wind tunnels have the ability to reach Reynolds Numbers up to a maximum of only about 10×10^6/m. This tunnel is expected to be able to reach Reynolds Numbers up to approximately 50×10^6/m.

Applications/Current Programs: When the tunnel becomes operational, Europe will have high Reynolds Number wind tunnel technology in the transonic range, which will be unique to Europe.

General Comments: The tunnel will provide European industry with the capability to simulate full-scale flows of large transport aircraft at cruise conditions. Capital shares are divided among the tunnel's owners as follows. DLR, ONERA, and RAE each own 31 percent, and NLR owns 7 percent. A parity agreement between France, The Netherlands, the United Kingdom, and West Germany, was signed on April 28, 1988.

Photograph/Schematic Available: Yes

References: ETW. European Transonic Windtunnel. Koln, West Germany: ETW, 1988.

Date of Information: September 1989

European Transonic Windtunnel (ETW)

Country: West Germany

Location: European Transonic Windtunnel, Koln, West Germany

Owner(s):
European Transonic Windtunnel
Linder Hoehe
Postfach 90 61 16
D-5000 Koln 90
West Germany

Operator(s): European Transonic Windtunnel

International Cooperation: France, The Netherlands, the United Kingdom, and West Germany

Point of Contact: Uso Walter, European Transonic Windtunnel, Tel.: [49]-(2203)-609-124

Test Section Size: 2.4 x 2 m

Operational Status: Planned (Construction is expected to begin in 1990.)

Utilization Rate: Unknown

Performance
Mach Number: 0.15 to 1.3
Reynolds Number: About 50 x 10^6/m (maximum)
Total Pressure: 1.25 to 4.5 bars
Dynamic Pressure: Not available
Total Temperature: 90 to 313 degrees Kelvin
Run Time: Not available
Comments: Test gas will be cryogenic nitrogen.

Cost Information
Date Built: 1993 (estimated)
Date Placed in Operation: 1995 (estimated)
Date(s) Upgraded: Not applicable
Construction Cost: $312,743,460 (1987)
Replacement Cost: Not applicable
Annual Operating Cost: Unknown
Unit Cost to User: Unknown
Source(s) of Funding: DLR, ONERA, RAE, and NLR

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The European Transonic Windtunnel, due to become operational in 1995, will be a cryogenic transonic wind tunnel. It will have a closed aerodynamic circuit and compressor drive power of about 50 MW, which is needed to move nitrogen test gas around the tunnel. Up to 250 kg/s of liquid nitrogen will have to be injected into the circuit during operation to achieve a temperature of −180 degrees Celsius, required for cryogenic test conditions. A 1 to 8 scale pilot tunnel has been constructed at NLR in Amsterdam in which aerodynamic performance has been tested.

Testing Capabilities: The tunnel will be pressurized at very low, or cryogenic, temperatures and will be able to achieve Reynolds Numbers very close to those in flight by both increased pressure and decreased temperature. Mach number, Reynolds Number, and dynamic pressure will be individually varied, keeping the other variables constant so that their effects can be studied independently.

Data Acquisition: Not available

Planned Improvements (Modifications/Upgrades): Not applicable

DLR Goettingen 1 × 1 m Transonic Wind Tunnel (TWG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Goettingen
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Dr. Fritz Lehthaus, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(551)-709-2148

Test Section Size: 1 x 1 m

Operational Status: Active

Utilization Rate: Continuous operation (4 hours per day)

Performance
Mach Number: 0.5 to 2
Reynolds Number: 0.3 to 1.2 x 10^7/m
Total Pressure: 0.2 to 1.6 bars
Dynamic Pressure: 60 kN/m^2 at Mach 1
Total Temperature: 300 degrees Kelvin
Run Time: Not available
Comments: None

Cost Information
Date Built: 1963
Date Placed in Operation: Not available
Date(s) Upgraded: 1966
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

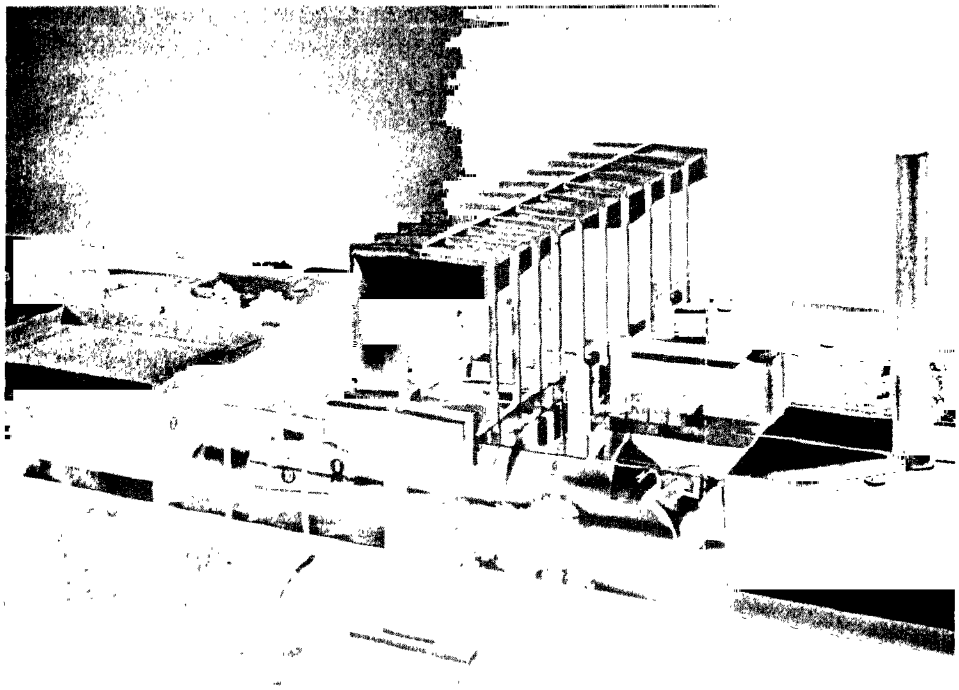
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Goettingen Transonic 1 × 1 m Wind Tunnel is a continuous-flow, closed-circuit, trisonic wind tunnel. It has a slotted test chamber for subsonic and transonic velocities as well as a continuously adjustable Laval nozzle for supersonic velocities (maximum Mach number is 2). An 8-step 12-MW axial blower provides the air circulation in the tunnel.

Testing Capabilities: The tunnel is capable of conducting force and pressure distribution tests with six-component strain-gauge balances and piezobalances. It has model supports for vertical or rear stings, a PSI pressure-measuring system, three-component strain-gauge half-model balances, an angle of roll adjusting device, an angle of sideslip adjusting system device, probe adjustment devices, a schlieren system, and flow visualization by colored liquid. The tunnel uses the laser light sheet technique.

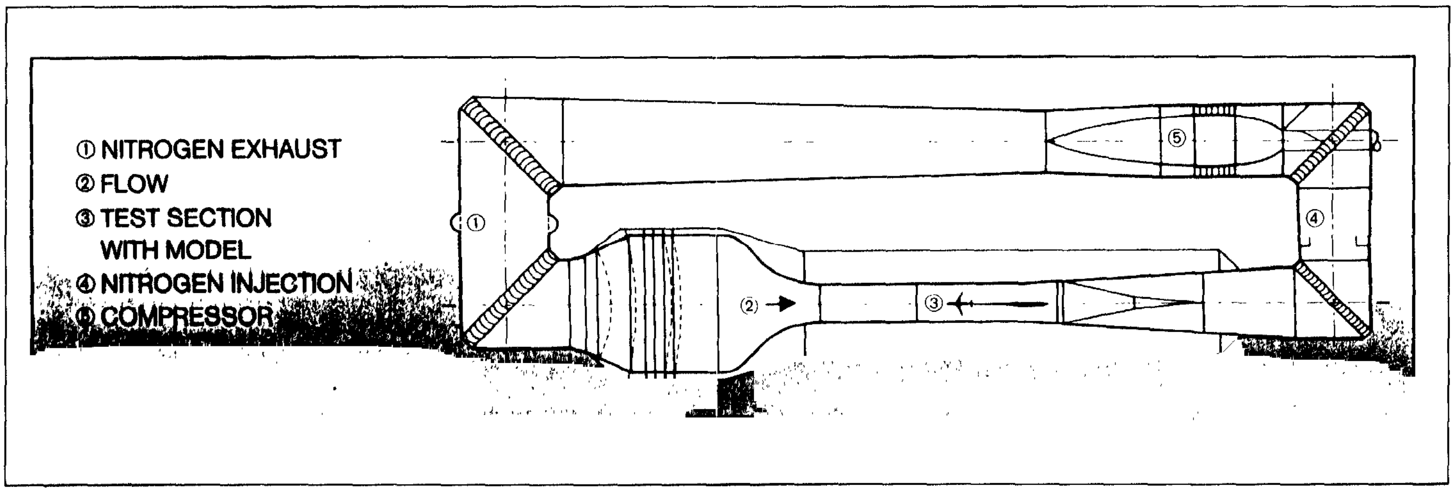
Data Acquisition: The tunnel has 98 channels integrating digital voltmeters; an automatically controlled test cycle for force, pressure distribution, and flow measurings with the process computer; and on-line data connection to the DLR computer center. The tunnel uses a DEC computer, which is capable of providing numerical and graphic real-time

Figure X.21: European Transonic Windtunnel (ETW)



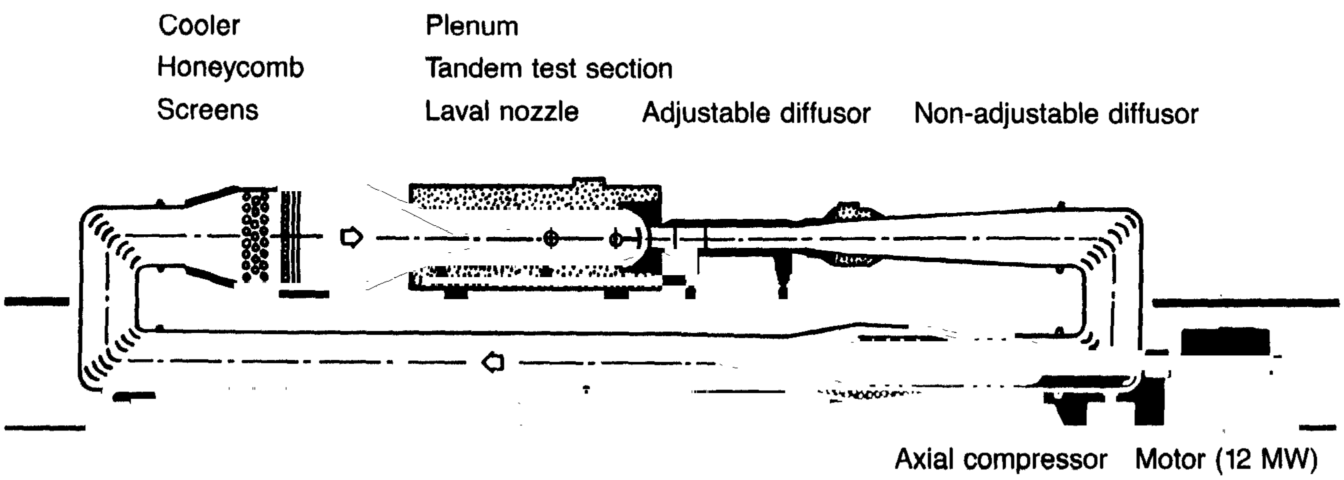
Source: ETW

Figure X.22: Schematic Diagram of the European Transonic Windtunnel (ETW)



Source: ETW

Figure X.23: Schematic Diagram of the DLR Goettingen 1 × 1 m Transonic Wind Tunnel (TWG)



Source: DLR

representation. Results are presented on a printer and graphic display in the tunnel's control room. The duration of a typical force measuring cycle is 100 measuring positions in 3 to 5 min.

Planned Improvements (Modifications/Upgrades): A completely new stagnation chamber and plenum chamber for exchangeable test sections as well as an adaptive wall test section are planned.

Unique Characteristics: The tunnel's cross section is the largest of its kind in West Germany.

Applications/Current Programs: These include aerodynamic investigations on airplane models with a wing surface less than 600 cm^2, wing span less than 60 cm, front surface less than 100 cm, and a length of 80 cm; flying objects with a front surface of 100 cm^2 and a length less than 80 cm; and an airfoil with a wingspan of 100 cm and a wing chord less than 20 cm. Research is being conducted on the improvement of wind tunnel simulation and on the modeling of fluid-mechanical relations. The tunnel is also used for collecting data for systematic flight vehicle development for DLR institutes and for complex models of components (such as high-speed inlets).

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-1 (in German). Penaranda, Frank E., and M. Shannon Freda, eds. Aeronautical Facilities Catalogue: Wind Tunnels. Washington, D.C.: National Aeronautics and Space Administration, 1985, vol. 1, p. 176.

Date of Information: October 1989

DLR Goettingen Plane Cascades Wind Tunnel (EGG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: None

Point of Contact: Dr. Amecke, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.: [49]-(551)-709-2183

Test Section Size: 125 x 380 mm

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.5 to 1.6 (downstream)
Reynolds Number: 5 to 10 x 10^5/m (based on downstream velocity and 60 mm blade chord length)
Total Pressure: Ambient
Dynamic Pressure: Not available
Total Temperature: Ambient
Run Time: Continuously
Comments: None

Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

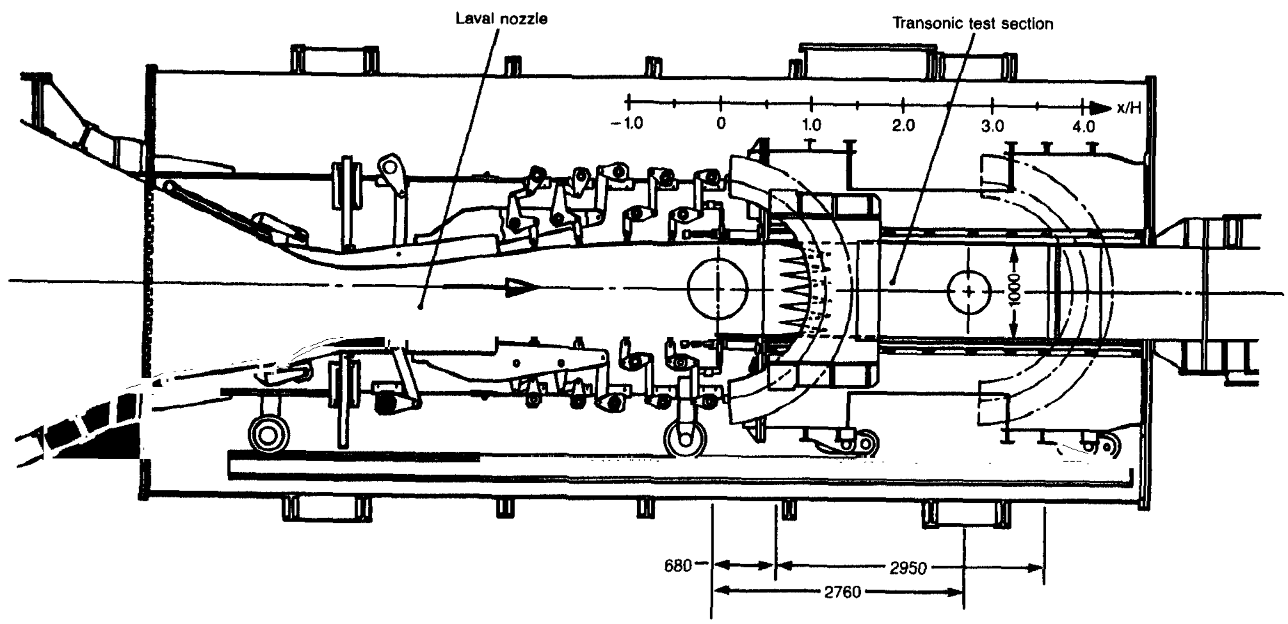
Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Gottingen Plane Cascades Wind Tunnel is a continuous-flow trisonic wind tunnel. When investigating turbine cascades, the upstream velocity is subsonic, while the downstream velocity varies from low subsonic to supersonic due to a choking diffusor. Atmospheric air passes the dryer, settling chamber, cascade, and diffusor on its way into the vacuum vessel (10,000 m^3). The test section size varies from 200 to 380 mm (maximum). The cascade to be investigated consists of up to 20 blades depending on the upstream flow angle, pitch-to-chord ratio, and chord length (generally 60 mm). To simulate coolant ejection, additional air supply is available. The installed power is 315 kW for pumps evacuating the 10,000-m^3 vacuum vessel.

Testing Capabilities: The tunnel is capable of conducting wake flow measurements, pressure distribution, and heated thin film measurements on the blade surface, flow visualization using oil flow patterns, schlieren techniques, and holographic interferometry.

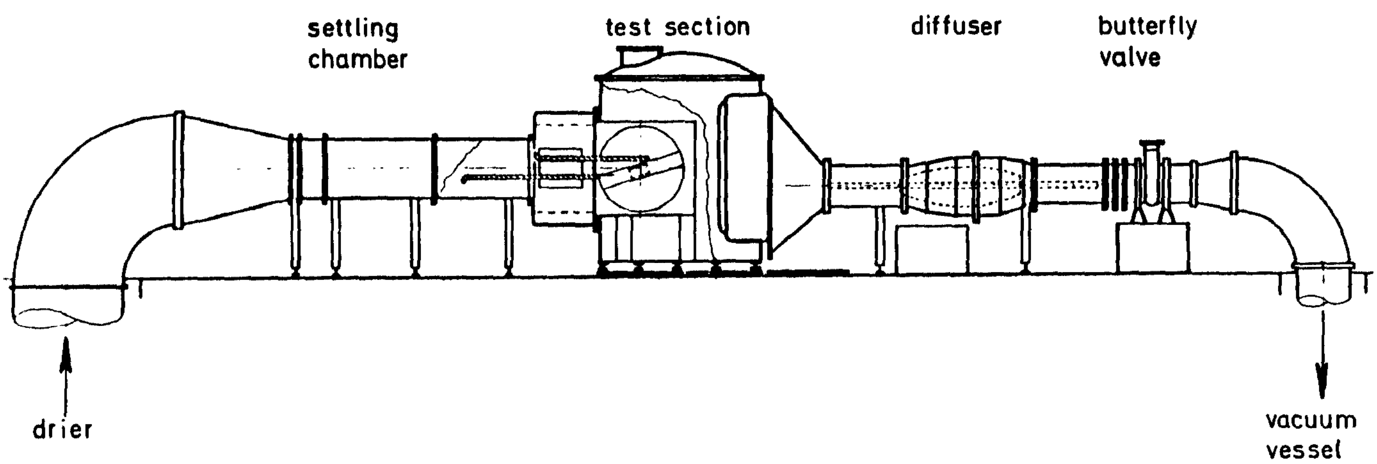
Data Acquisition: The tunnel's electronic data acquisition system can store signals from pressure transducers, thin films, thermocouples, and a video system for flow visualization.

Figure X.24: Schematic Diagram of the Test Section of the DLR Goettingen 1 × 1 m Transonic Wind Tunnel (TWG)



Source: DLR

Figure X.25: Schematic Diagram of the DLR Goettingen Plane Cascades Wind Tunnel (EGG)



Source: DLR

Planned Improvements (Modifications/Upgrades): These include installation of a contoured (flexible) inlet duct to improve the flow quality (especially periodicity) upstream of the cascade. Other improvements include variable total pressure capability for independent variation of Mach number and Reynolds Number.

Unique Characteristics: None

Applications/Current Programs: Under industrial contracts, the tunnel is used to investigate very different cascades to be used in steam and gas turbines. Contracts from West German and European research programs include AG-TURBO and EURAM-BRITE. Basic research on flow phenomena such as shock boundary layer interaction in connection with air injection and heated thin film measurements to determine boundary layer characteristics are also conducted.

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B4.1-6 (in German).

Date of Information: October 1989

DLR Goettingen Rotating Cascades Wind Tunnel (RGG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Institut fuer Experimentelle Stroemungsmechanik
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik

International Cooperation: None

Point of Contact: Dr. Amecke, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Institut fuer Experimentelle Stroemungsmechanik, Tel.:[49]-(551)-709-2183

Test Section Size: 0.512 m (mean diameter), 0.9 m (ratio of casing diameter to hub diameter), and half cone angles up to 45 degrees

Operational Status: Active

Utilization Rate: Not available

Performance
Mach Number: 0.5 to 1.8 (relative system, downstream)
Reynolds Number: Up to 1.2×10^7/m
Total Pressure: 5 to 150 kPa
Dynamic Pressure: Not available
Total Temperature: 15 to 50 degrees Celsius
Run Time: Continuously
Comments: None

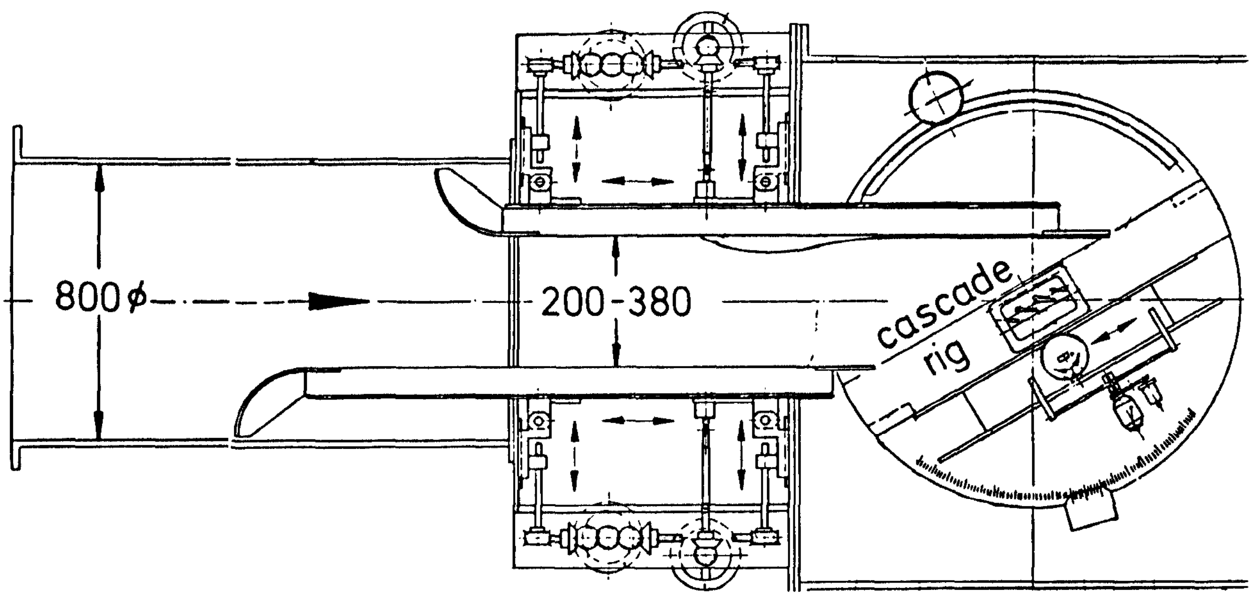
Cost Information
Date Built: Not available
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

Description: The DLR Goettingen Rotating Cascades Wind Tunnel is a continuous-flow, closed-circuit trisonic wind tunnel. The flow medium (dried air) is driven by a radial compressor. The flow conditions in the relative system are determined by the circumferential velocity of the rotor as well as by the pressure difference due to the compressor. When investigating turbine cascades, the upstream velocity is subsonic, while the downstream velocity varies from low subsonic to supersonic. Variation of the total pressure allows the independent variation of Reynolds Number and Mach number. Different test sections serve to investigate flow fields on cylindrical stream surfaces as well as on conical surfaces (half cone angle up to 45 degrees). For probe calibration (especially temperature probes), some calibration nozzles are available. The installed power is 1 MW for a compressor and 0.5 MW for a motor to drive the rotor.

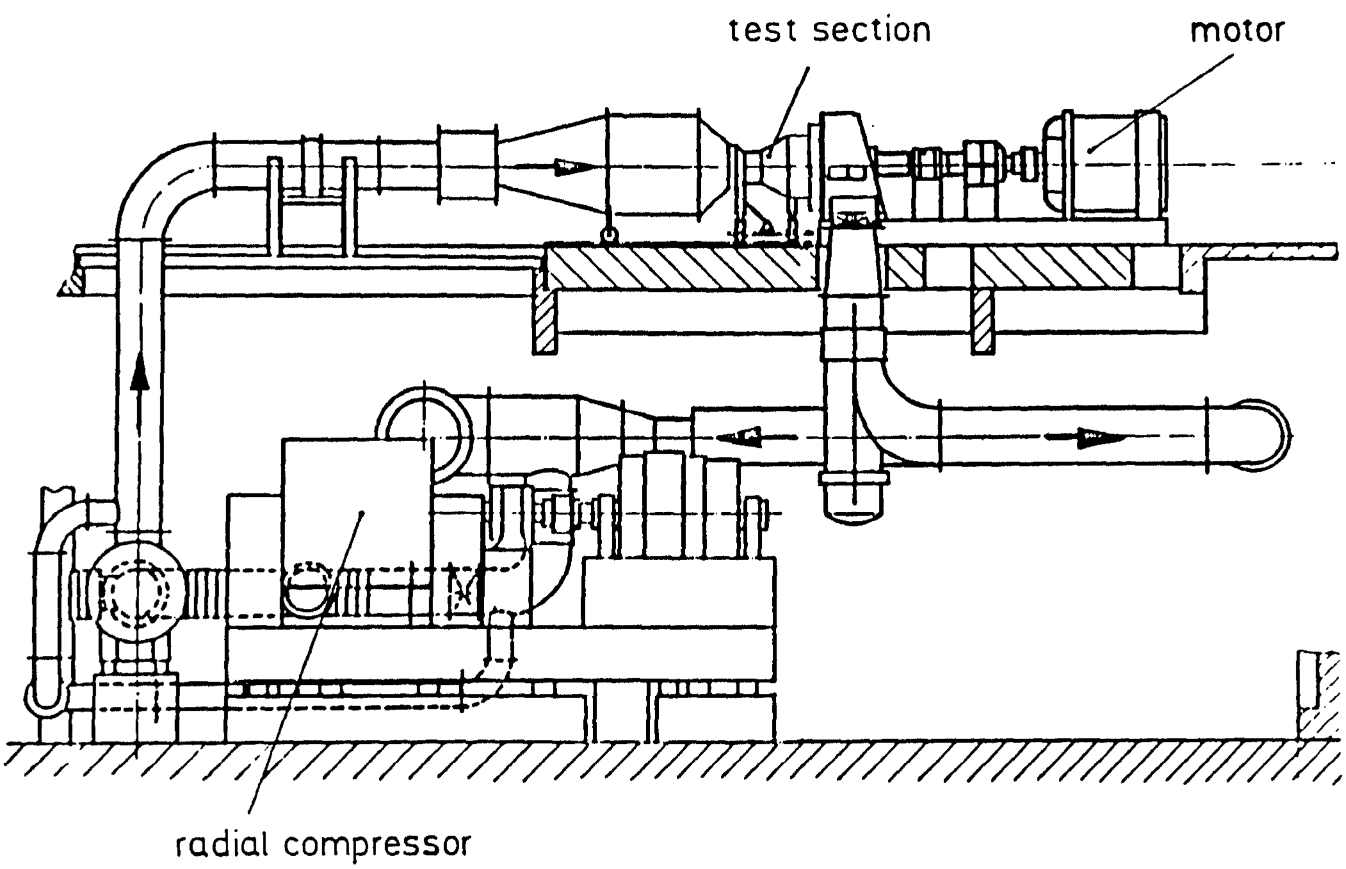
Testing Capabilities: The tunnel is capable of conducting wake flow and laser-2-focus measurements. Pressure distributions within the rotating system can achieve up to 14,000 rpm.

Figure X.26: Schematic Diagram of the Test Section of the DLR Goettingen Plane Cascades Wind Tunnel (EGG)



Source: DLR

Figure X.27: Schematic Diagram of the DLR Goettingen Rotating Cascades Wind Tunnel (RGG)



Source: DLR

Data Acquisition: The tunnel's electronic data acquisition system can store signals from temperature probes, pressure transducers, and the laser-2-focus system.

Planned Improvements (Modifications/Upgrades): These include a cylindrical test section to allow for rotor-stator interference.

Unique Characteristics: None

Applications/Current Programs: The tunnel is used to conduct systematic research of flow fields on conical stream surfaces using the laser-2-focus system. It is also used for wake flow and pressure distribution measurements on the blade surface.

General Comments: None

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B4.1-7 (in German).

Date of Information: October 1989

DLR Koln-Porz Trisonic Wind Tunnel (TMK)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Koln-Porz, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Koln-Porz
Linder Hoehe
D-5000 Koln 90
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Helmut Esch, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(2203)-601-2345

Test Section Size: 60 cm x 60 cm^2

Operational Status: Active

Utilization Rate: 1 shift per day

Performance
Mach Number: 0.5 to 4.5
Reynolds Number: 1 to 8 x 10^7/m
Total Pressure: 1 bar for speeds lower than Mach 1.2
Dynamic Pressure: 1 bar for speeds greater than Mach 1.5
Total Temperature: 300 to 550 degrees Kelvin
Run Time: 60 s
Comments: Test frequency is 20 min.

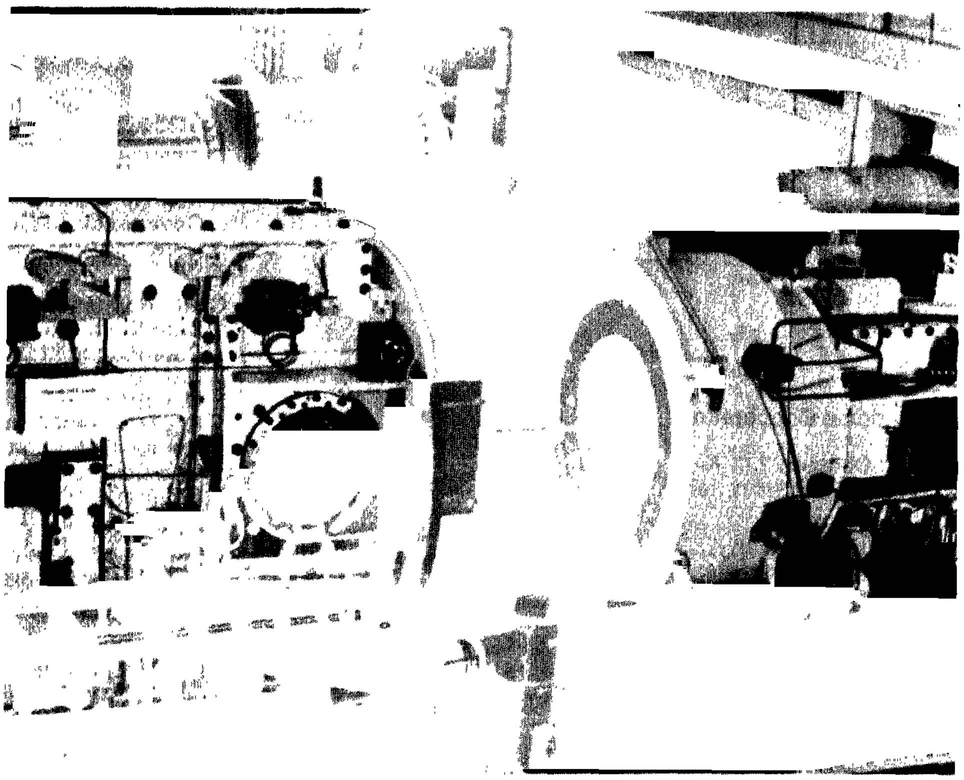
Cost Information
Date Built: 1964
Date Placed in Operation: 1965
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: 2
Scientists: 1
Technicians: 2
Others: 1
Administrative/Management: 0
Total: 6

Description: The DLR Koln-Porz Trisonic Wind Tunnel is an intermittently operating blowdown trisonic wind tunnel. It covers the entire Mach number range from subsonic to high supersonic. The Mach number can be varied during tests by position-controlled flexible walls. Velocity of change (for example, from Mach 1.2 to 2) is 3 s. The transonic start reduces the start stress of the model. The tunnel has a closed test chamber of 60 cm × 60 cm^2. It has a test chamber with perforated walls for tests in the transonic range. The static temperature of the flow is maintained constant during the test by a heat reservoir and can be raised from room temperature to about 550 degrees Kelvin. The tunnel is primarily used for applied research in the flying object and space vehicle regime. It has a wide range of velocity with information in the subsonic, transonic, and supersonic (trisonic) areas up to Mach 4.5.

Testing Capabilities: The tunnel has six-component built-in balances, a testing device for dynamic derivatives, Magnus models, an electronic pressure scanner system, and a high-speed camera. It can conduct flow visualization tests using schlieren and oil film pictures and power jet simulations with cold air.

Figure X.29: DLR Koln-Porz Trisonic Wind Tunnel (TMK)



Source: DLR

Planned Improvements (Modifications/Upgrades): None

Unique Characteristics: None

Applications/Current Programs: These include tests of supersonic intakes, ramjet engines, jet interference problems, and heat transfer.

General Comments: The tunnel shares a common storage heater and pressure regulation with the DLR Koln-Porz High-Speed Wind Tunnel (HMK).

Photograph/Schematic Available: Yes

References: DFVLR. Experimental Plants. Koln, West Germany: DFVLR, 1983, p. B3.2-8 (in German). Triesch, K., and E.O. Krohn. Die Vertikale Messtrecke (VMK) der DFVLR in Koln (The Vertical Test Section (VMK) at DFVLR in Koln). Koln, West Germany: DFVLR, 1986 (DFVLR-Mitteilung 86-22) (in German and translated in ESA-TT-1053, 1987).

Date of Information: October 1989

DLR Goettingen High-Speed Wind Tunnel (HKG)

Country: West Germany

Location: Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany

Owner(s):
Deutsche Forschungsanstalt fuer Luft- und Raumfahrt
Hauptabteilung Windkanale
Abteilung Goettingen
Bunsenstrasse 10
D-3400 Goettingen
West Germany

Operator(s): Deutsche Forschungsanstalt fuer Luft- und Raumfahrt

International Cooperation: None

Point of Contact: Dr. Fritz Lehthaus, Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Tel.: [49]-(551)-709-2148

Test Section Size: 0.75 x 0.75 m (subsonic free-jet cross section) and 0.71 x 0.725 m (supersonic adjustable nozzle cross section)

Operational Status: Active

Utilization Rate: 3 tests per hour

Performance
Mach Number: 0.4 to 0.95 (subsonic) and 1.22 to 2.5 (supersonic)
Reynolds Number: 0.8 to 1.6 x 10^7/m
Total Pressure: 1 bar
Dynamic Pressure: 35 kN/m^2 at Mach 0.95
Total Temperature: 300 degrees Kelvin
Run Time: 15 to 30 s
Comments: None

Cost Information
Date Built: 1959
Date Placed in Operation: Not available
Date(s) Upgraded: Not available
Construction Cost: Not available
Replacement Cost: Not available
Annual Operating Cost: Not available
Unit Cost to User: Not available
Source(s) of Funding: Not available

Number and Type of Staff
Engineers: Not available
Scientists: Not available
Technicians: Not available
Others: Not available
Administrative/Management: Not available
Total: Not available

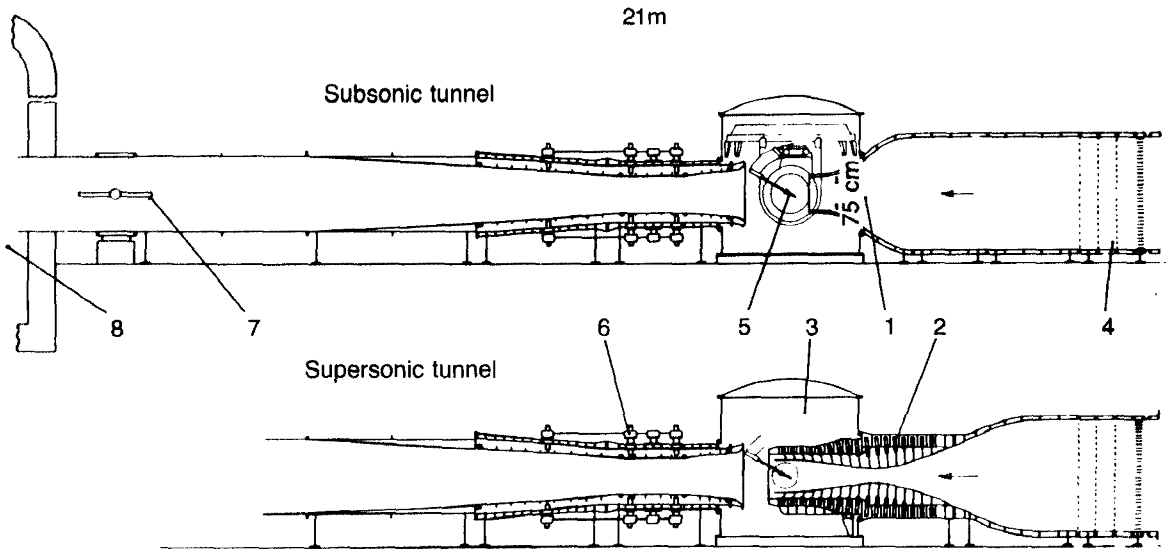
Description: The DLR Goettingen High-Speed Wind Tunnel is an intermittently operating subsonic/supersonic wind tunnel with a vacuum container. The container has a volume of 10,000 m^3. Atmospheric air flows through a dryer and smoothing chamber into the test chamber, which is surrounded by a vacuum-tight cabin. The tunnel has a subsonic free-jet and supersonic adjustable nozzle. The test gas then flows through a convergent/divergent adjustable diffusor and fast-acting gate valve in the vacuum vessel that is evacuated by rotary pumps.

Testing Capabilities: The tunnel is capable of conducting force and pressure distribution tests. The tunnel has special equipment including a strain-gauge balance, half-model balance, schlieren optics, programmable angles of attack adjuster for stepwise or continuous operation, and a PSI-system. The tunnel uses the laser light sheet technique.

Data Acquisition: The tunnel has 12 channels integrating digital voltmeters. The data acquisition system is connected to a local computer for real-time data reduction. The results are presented on a printer. The local computer is connected with DLR's computing center.

Planned Improvements (Modifications/Upgrades): None

Figure X.31: Schematic Diagram of the DLR Goettingen High-Speed Wind Tunnel (HKG)



1. Subsonic nozzle (75 x 75 cm^2)
2. Supersonic adjustable nozzle (71 x 72.5 cm^2)
3. Test chamber
4. Sieves and honeycomb
5. Scales and model
6. Adjustable diffuser
7. Test section gate valve
8. Vacuum container (10,000 m^3)

Source: DLR

Arc-Heated
The heating of the test gas by the heat energy from an electric arc, which has a very high temperature and concentration of heat energy. It is also referred to as electric arc-heated.

Atmosphere
A unit of pressure approximately equal to the pressure of the earth's atmosphere at sea level. One atmosphere is about 1 million dynes per square centimeter (1.01325×10^6 dynes/cm^2), which is the air pressure at mean sea level.

Bar
A unit of pressure equal to about 1 million dynes per square centimeter (1.01325×10^6 dynes/cm^2). One bar is Normal Atmospheric Pressure.

Blowdown Wind Tunnel
An open-circuit wind tunnel in which gas stored under pressure is allowed to expand through a test section to provide a stream of gas or air to test a model. The gas then escapes into the atmosphere or into an evacuated chamber.

Boundary Layer
A region of the flow of a retarded viscous fluid near the surface of a body which moves through a fluid or past which a fluid moves.

Calorimeter
An instrument for measuring heat quantities generated in or emitted by materials in processes such as chemical reactions, changes of state, or formation of solutions.

Celsius
A temperature scale in which the freezing point of water at standard atmospheric pressure is 0 degrees Celsius and the corresponding boiling point is 100 degrees Celsius. Zero degrees Celsius equals 273.16 degrees Kelvin.

Chord
The straight line joining the leading and trailing edges of an airfoil.

Dynamic Pressure	The pressure of a fluid resulting from its motion when brought to rest on a surface. It is also known as impact pressure, stagnation pressure, and total pressure.
Dyne	A unit of force sufficient to accelerate 1 gram 1 centimeter per second squared (1 g x 1 cm/s^2) or 2.248 x 10^{-6} lb.
Empennage	The assembly at the rear of an aircraft comprising the horizontal and vertical stabilizers and control surfaces. Empennage is also known as the tail assembly.
Enthalpy	The total energy (heat content) of a system or substance undergoing change from one stage to another under constant pressure. Enthalpy is expressed as the sum of the internal energy of a system plus the product of the system's volume multiplied by the pressure exerted on the system by its surroundings. Enthalpy is also known as heat content, sensible heat, and total heat.
Euler Codes	Computer software that is a mathematical representation of the motion of a fluid whose behavior and properties are described at fixed points in a coordinate system.
Expansion Tube	A wind tunnel for conducting tests at hypervelocity speeds in which fluid (such as air or some other test gas) at high pressure, usually involving rapid combustion to increase energy, is released by rupturing a diaphragm and accelerating through an evacuated working section (test chamber) containing the model. The major difference between a shock tube and an expansion tube is that in an expansion tube the isentropic flow is exact.
Flow Visualization	A method of making visible the disturbances that occur in fluid flow. Light passing through a flow field of varying density exhibits refraction and a relative phase shift among different rays. At low speeds, smoke and tufts are often used to show flow direction. At velocities near or above the speed of sound, some flow features may be made visible by using coatings and optical devices.

Hotshot Tunnel	A hypervelocity wind tunnel in which electrical energy is discharged into a pressurized arc chamber, increasing the temperature and pressure so that a diaphragm separating the arc chamber from an evacuated chamber is ruptured. The heated gas from the arc chamber is then accelerated in a conical nozzle to provide flows with Mach numbers of 10 to 27 for durations of 10 to 100 ms.
Hot-Wire Anemometer	An anemometer used in research on air turbulence and boundary layers in which the resistance of an electrically-heated fine wire placed in a gas stream is altered by cooling. The amount of cooling depends on the fluid velocity.
Hypersonic	A range of speed that is five times or more the speed of sound in air.
Hypervelocity	A range of speed that is about 12 times or more the speed of sound in air.
Interferometer	An optical instrument that uses mirrors to produce and measure light interference from two or more coherent wave trains (a succession of similar light waves at equal intervals) from the same source. Interferometers are used to measure wavelengths and show flow patterns.
Interferometry	The design and use of optical interferometers to conduct, for example, precise measurements of wavelength, very small distances and thickness, and indices of refraction, and to study the hyperfine structure of spectral lines.
Intermittent Wind Tunnel	A wind tunnel in which energy is stored, usually as compressed air, and then released suddenly to force a large quantity of air through the small throat of the nozzle and over the test model in the test section in a short period of time. The test gas is then captured in a vacuum dump tank or released into the atmosphere.
Inviscid Core Flow	The central flow of a fluid that has no viscosity.

Laser Doppler Velocimeter	A device that uses the Doppler effect to measure the velocity of fluid flow. When a light is scattered from a moving object, a stationary observer will see a change in the frequency of the scattered light (Doppler shift) proportional to the velocity of the object. The Doppler shift is used to measure the velocity of the object in the laser Doppler velocimeter.
Laval Nozzle	A converging-diverging nozzle. It is also known as a de Laval nozzle.
LICH Mode	A Ludwieg tube with isentropic compression heating.
Ludwieg Tube	A wind tunnel capable of achieving high Reynolds Numbers.
Mach Number	A number representing the ratio of the speed of an object to the speed of sound in the surrounding atmosphere. An object traveling at the local speed of sound is traveling at Mach 1.
Mach-Zehnder Interferometry	The design and use of a type of optical interferometer that depends on amplitude splitting of the wavelength. It is used mainly in measuring the spatial variation of the index of refraction of a gas. The device has two semitransparent mirrors and two wholly reflecting mirrors at alternate corners of a rectangle. Half the beam of light travels along each side of the rectangle. The major application of the Mach-Zehnder interferometer is studying the airflow around models of aircraft, missiles, and projectiles.
Manometer	An instrument consisting of liquid-column gauges for measuring the pressure of gases and vapors both above and below atmospheric pressure.
Mass Flow	The quantity (or mass) of a fluid in motion that crosses a given area per unit of time.

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Mass Spectrometry	An analytical technique for identification of chemical structures, determination of mixtures, and quantitative elemental analysis, based on application of the mass spectrometer.
Megahertz	One million hertz (a unit of frequency equal to one cycle per second).
Megajoule	One million joules (a unit of energy in the meter-kilogram-second system of units equal to the work done by a force of magnitude of 1 N when the point at which the force is applied is displaced 1 m in the direction of the force).
Micron	A unit of length equal to one-millionth of a meter.
Microsecond	One-millionth of a second.
Millisecond	One-thousandth of a second.
Monochromator	A spectrograph using a narrow band of wavelengths for refocusing on a detector or test object.
Navier-Stokes Codes	Computer software that contains the mathematical equations of motion for a viscous fluid.
Nozzle	The narrow duct of a wind tunnel used for accelerating a fluid and producing a desired direction, velocity, or shape of discharge. The fluid's pressure decreases as it leaves the nozzle.
On-Line Data Reduction	The processing and displaying of information as rapidly as it is received by the measurement and computing systems.
Particle Image Velocimeter	A continuous-wave reflection Doppler system used to measure the radial velocity of a very small piece of matter.