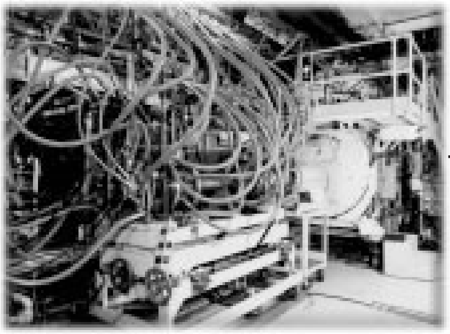


Arc-Heated Scramjet Test Facility

NASA Langley Research Center

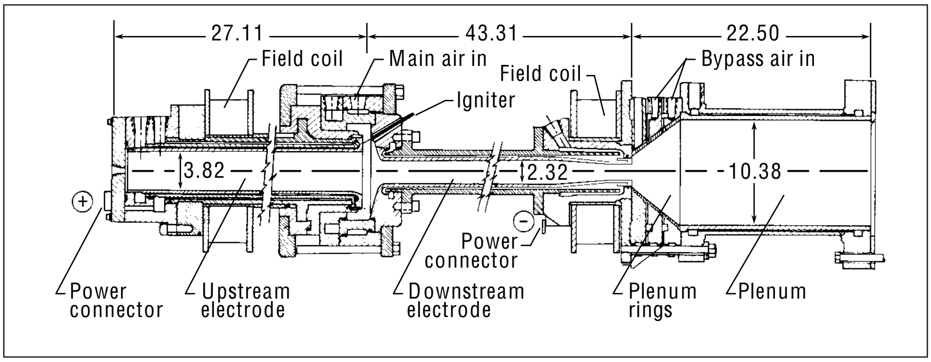
The Langley Arc-Heated Scramjet Test Facility is part of the NASA Langley Scramjet Test Complex.
The Facility is used to test complete subscale, scramjet component integration models at conditions simulating flight Mach numbers from 4.7 to 8.

Wind Tunnel
ENTERPRISE
NASA Langley Research Center

The Langley Arc-Heated Scramjet Test Facility (AHSTF) is used for tests of component integration models of airframe integrated scramjet engines at conditions experienced at flight Mach numbers, M_∞, of 4.7 to 8. Results are used to assess the performance of the scramjet, to optimize the design of the components, and to optimize fueling schemes.

The arc heater and test section of the facility are located in room 111 of building 1247B. The facility is remotely operated with controls located in the adjacent room110. The arc heater, facility nozzle, and test section are shown in the photograph on the front of this brochure. A cross-sectional view of the heater and an elevation view of the facility are shown in the figures. Typical models include the inlet, isolator, combustor, and a significant portion of the nozzle and are hydrogen and silane fueled. The flow at the exit of the facility nozzle simulates the flow entering a scramjet engine module in flight which has been processed by the forebody shock of the vehicle. The total enthalpy of the flight condition is achieved by electrically heating the air with a Linde arc heater.

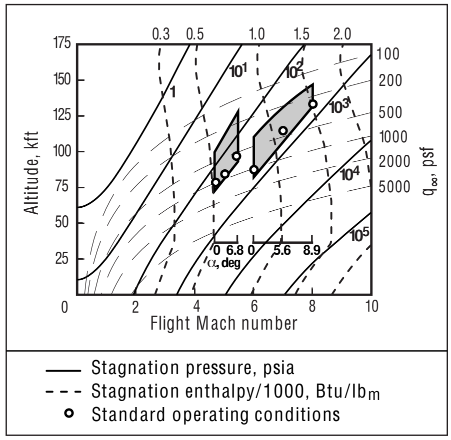
The AHSTF range of operation is shown by the chart of standard test conditions and a Mach number/altitude map.



Cross-sectional view of the Arc-Heated Scramjet Test Facility heater and plenum chamber. Dimensions in inches.

The map shows simulation envelopes for the Mach number 4.7 and the Mach number 6 nozzles. Higher Mach number simulation is achieved by increasing the stagnation enthalpy of the flow. For any flight Mach number there is an oblique shock that will reduce the Mach number to that of the facility nozzle. The turning angle (α) in the figure indicates the turning angle of the oblique shock that reduces the simulated flight Mach number to the facility nozzle Mach number. Thus, scramjet tests in the facility at stagnation enthalpies greater than that corresponding to the nozzle exit Mach number represent various degrees of aircraft forebody precompression.

The normal test schedule of the AHSTF is two test days per week with four to six runs per test day. Run times normally range from 30 sec at flight Mach number of 8 simulated conditions to 60 sec at flight Mach number of 4.7 simulated conditions.



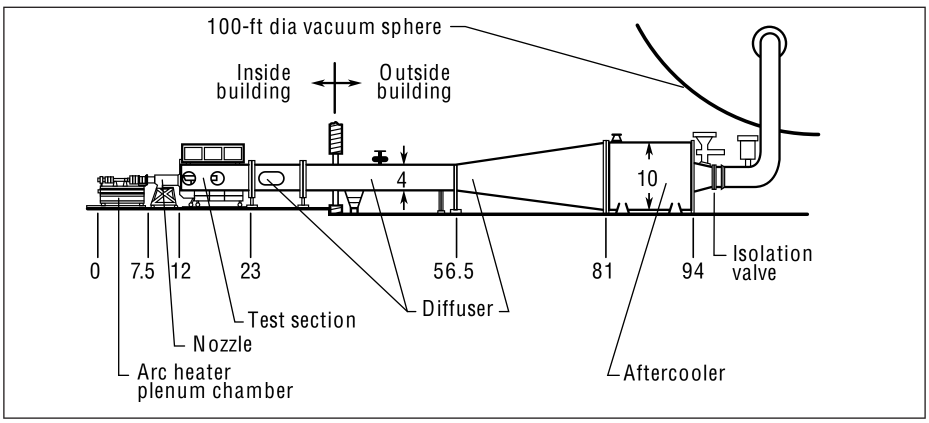
Arc-Heated Scramjet Test Facility Mach number/altitude map.

M_∞	P_t (atm)	H_t (BTU/lbm)	T_t (°R)	$\dot{m}$ (lbm/s)	M_{tg}	P_{tg} (atm)	T_{tg} (°R)
4.7	13.6	514	2021	11.0	4.8	.033	381
5.0	13.1	572	2251	10.0	4.8	.031	424
5.5	11.2	692	2642	7.9	4.8	.027	513
6.0	35.1	792	2979	6.41	6.1	.018	391
7.0	28.6	1108	3989	4.51	6.0	.014	550
8.0	23.0	1531	5183	3.16	6.0	.012	768

Standard test conditions.

	Test gas mole fractions				
M_∞	N_2	O_2	Ar	NO	NO_2
4.7	0.7756	0.2034	0.0093	0.0111	0.0006
5.0	0.7749	0.2028	0.0093	0.0125	0.0005
5.5	0.7735	0.2014	0.0093	0.0154	0.0004
6.0	0.7699	0.1978	0.0093	.02240	0.0006
7.0	0.7704	0.1985	0.0093	0.0216	0.0002
8.0	0.7659	0.1940	0.0093	0.0306	0.0002

Test gas compositions.



Elevation of the Arc-Heated Scramjet Test Facility heater and plenum chamber. Dimensions in feet.

Model Supports

Test articles are typically provided with a support structure that interfaces with the facility balance housing. Changes in horizontal position or angular orientation are accommodated in the test article support structure. The facility hardware provides for adjustment in the vertical direction only. Test articles are mounted in the test section so that they ingest the free jet flow from the facility nozzle.

AHSTF Characteristics

Simulated flight Mach number . . . 4.7 to 8

Flight Reynolds number, ft^{-1} . . . . 3.5×10^4 to 2.2×10^6

Nozzle exit area, in
- Mach number of 4.7 . . . 11.17 x 11.17
- Mach number of 6 . . . . 10.89 x 10.89

Test medium . . . . dried air

Heater
- Total pressure limit, psia 675
- Total temperature, degrees R 2000 to 5200

Safety and Design Criteria

Langley's LHB 1710.15 *Wind Tunnel Model System Criteria* is used only as a guideline for model design and fabrication of test articles. This document is available on the Wind Tunnel Enterprise web site at the URL http://wte.larc.nasa.gov.

Test articles are typically considered expendable. Failure of a test article will not result in catastrophic damage to the facility or place any personnel at risk. Specific questions should be addressed to the AHSTF Safety Head.

Facilities Available to Users

Models can be prepared in either the test room or an adjoining shop. Two full time facility technicians are available to assist in model preparation.

Data Acquisition and Processing

Data are acquired primarily through a data amplifier/multiplexer with 192 general purpose analog channels and 16 digital channels and a pressure scanner with up to 448 channels. Approximately 60 analog channels and the 16 digital channels are dedicated to facility parameters. Pressure scanner transducer modules are available with various pressure ranges. A 6-component force balance that can support test articles weighing up to 1500 lb is available for measuring forces and moments on test articles. The data acquisition system is controlled with a microcomputer that interfaces with a UNIX workstation which is used for posttest data analysis. A secure operating mode is provided for classified projects.

Test Techniques

The Langley 5000 psig air system provides main air at flow rates of 0.50 to 2.20 lb_m per sec to the arc heater. Power to the arc heater is provided by 2 10-MW direct-current power supplies connected in series with stabilizing ballast resistors. The arc operates at up to 13 MW and can deliver up to approximately 6.5 MW to the air. The air is heated to a stagnation enthalpy of approximately 3000 Btu per lb_m and at stagnation pressures up to 660 psia. The air from the heater enters a plenum chamber where it is diluted with bypass air to achieve the required total enthalpy, usually between 500 and 1600 Btu per lb_m. The bypass air, also from the 5000-psig air system, is controlled to flow rates of approximately 1 to 10 lb_m per sec. The arc heater and nozzle throat sections are cooled with de-ionized water which can be supplied at pressures up to 1400 psig.

From the plenum, the air enters the facility nozzle. The facility has available two fixed geometry contoured nozzles with square cross sections: a Mach number 4.7 nozzle with an 11.17-in^2 exit and a Mach number 6.0 nozzle with a 10.89-in^2 exit. The installed nozzle produces a free jet into a 4-ft diameter test section, which is 11-ft in length.

The test gas and scramjet exhaust gases are diffused to subsonic velocities in a 33.5-ft long, 4-ft diameter, straight-pipe diffuser prior to entering a subsonic diffuser. A 100-ft diameter vacuum sphere, which can be evacuated to 0.02 psia, is used to maintain low test section pressures.

Models are fueled with hydrogen (at ambient temperature), which is stored in a 31.46-ft^3 bottle with a usual fill pressure of 1200 psig. The pressure is regulated to a maximum of 625 psig in two facility manifolds that feed 12 choked venturis, which in turn feed the model fuel manifolds. A 20-percent silane and 80-percent hydrogen mixture (by volume) is supplied from 4 K-size cylinders at 2400 psia for use as an igniter and pilot gas to aid in the combustion of the hydrogen fuel. The silane mixture is regulated to a maximum of 650 psig and fed through two choked venturis.

Test Medium

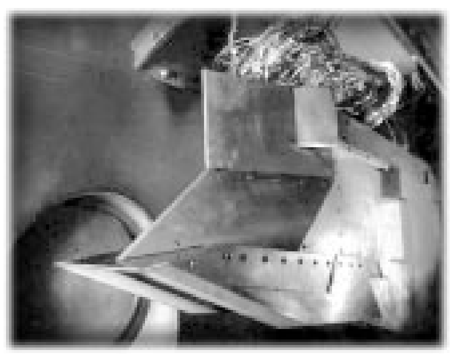
The test medium at the AHSTF is dried air heated in an electric arc. Such flows are contaminated by the copper and copper oxides that erode from the electrode. Levels have not been measured, but evidence indicates that it is in the form of small particles that have a wearing effect on test articles but do not affect the combustion processes significantly. Varying levels of nitrogen oxides are also produced in the arc and by stagnating the high enthalpy flow. Calculated test gas compositions for the standard operating conditions are tabulated below. The calculations employed finite-rate chemistry throughout the arc heater, plenum chamber, and the facility nozzles. The levels of NO in the test flow, verified by measurement, range from 0.0111 mole fraction at $M_\infty = 4.7$ to 0.0306 mole fraction at $M_\infty = 8$. Oxygen deficits due to the formation of NO are not replenished, and the facility operates at $M_\infty = 4.7$ with 0.2034 oxygen mole fraction and at $M_\infty = 8$ with 0.1940 oxygen mole fraction.

Test Request Procedures

Contact the AHSTF facility manager to request use of the facility. Contact information is on the back of this brochure.

Type of Testing

The AHSTF has been in operation for scramjet testing since 1976. Scramjet engines tested in this facility include the NASA 3-Strut; NASA Parametric; Rocketdyne A, A1, A2, and A2+; Pratt and Whitney C; NASP SX-20; and the NASP SXPE. Currently the AHSTF is testing the Hyper-X DFX engine. Since December 1976, over 1300 scramjet tests have been conducted in the AHSTF.



NASA SXPE model at Arc-Heated Scramjet Test Facility.

Document Version 1.0

Operating Hours

The AHSTF operates 7:30 am - 4:00 pm for two days per week. Intervening days are used for facility and test article maintenance and moditfications.

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For more information contact

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