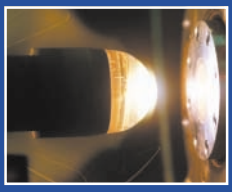
High-Enthalpy Arc-Heated Test Facilities



Arnold Engineering Development Center

Arnold Air Force Base, Tennessee

An Air Force Materiel Command Test Center

Aerothermal Materials and Structures Testing in the AEDC High-Enthalpy Arc-Heated Facilities

The High-Enthalpy Aerothermal Test (HEAT) arc-heated facilities at the Arnold Engineering Development Center (AEDC), Arnold AFB, TN, provide unique aerothermal test capability for evaluation of thermal protection materials, airframe components, and integrated systems designed for hypersonic flight. These test units, the only Department of Defense (DoD) arc facilities in operation, represent the only state-of-the-art, high-pressure arc facilities in the world, simulating aeroheating environments consistent with flight at velocities from 5,000 ft/sec up to and exceeding 20,000 ft/sec.

Facility Description

The AEDC arc-heated test facilities include two high-pressure segmented arc heaters (HEAT-H1 and H3) and one Huels arc (H2). Both types utilize a high-voltage, d-c electric arc discharge to heat air to total temperatures up to 13,000 degrees Rankine. High-pressure test flows are achieved by confining the electrical arc discharge to a water-cooled plenum section capable of withstanding high chamber pressures above 100 atm. The combination of high-enthalpy test gas and high plenum pressure makes possible heat flux simulations representative of flight at speeds in excess of Mach 20 at high dynamic pressures.

HEAT-H1

The HEAT-H1 Test Unit is an advanced performance arc-heated facility providing high-pressure, high-enthalpy test conditions for qualification of thermal protection materials, nosetips, and electromagnetic apertures and structures for hypersonic missiles, space access systems, and reentry vehicles. The unique segmented construction allows the arc to be held at a fixed length to optimize heater efficiency, total enthalpy at high pressure, and flow uniformity. Normal operating conditions for the heater are

AEDC ARC-HEATED TEST FACILITIES

Facility Name	*H1*	*H2*	*H3*
Facility Type	**Arc Heater** *(Atm. Exhaust)*	**Arc-Heater** *(Subatm. Exhaust)*	**Arc Heater** *(Atm. Exhaust)*
Max. Run Time *(min.)*	**1 - 2**	**3 - 30**	**1 - 2**
Nozzle Mach No.	**1.8 to 3.5**	**4.0 to 8.3**	**1.8 to 3.5**
Nozzle Exit Diam *(in.)*	**0.75 to 3.0**	**5.0 to 42.0**	**1.2 to 4.5**
Stagnation Pressure *(psia)*	**Up to 1,300**	**Up to 50**	**Up to1,300**
Stagnation Enthalpy *(Btu/lbm)*	**600-8,500**	**1,200-6,000**	**600-8,500**
Mass Flow Rate *(lb/s)*	**0.5-8**	**2-10**	**3-18**
Facility Power *(MW)*	**30**	**50**	**70**

about 20,000 volts and 1,200 amp, providing heater chamber pressures up to 120 atm at high stagnation enthalpies. The H1 test cell is equipped with a multiple-strut, programmable rotary model injection system capable of positioning one to seven test models sequentially into the test free jet for preset dwell times.

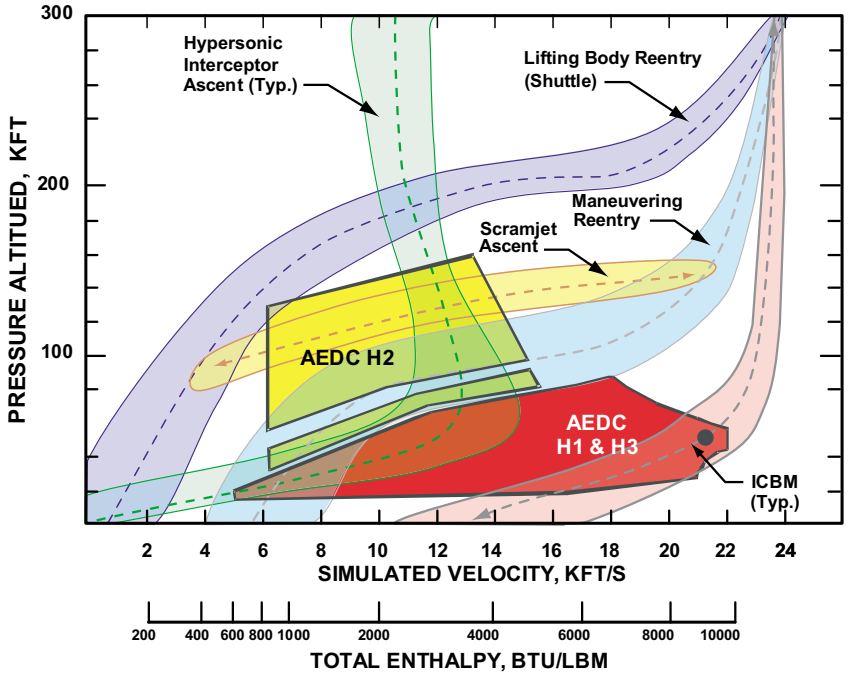
HEAT-H2

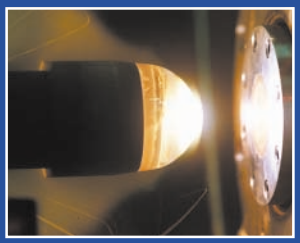
The HEAT-H2 Test Unit is an arc-heated aerothermal tunnel providing high-enthalpy flow at high Mach numbers and dynamic pressures simulating hypersonic flight at pressure altitudes from 70 to 160 kft. H2 utilizes an N-4 Huels-type arc heater to generate high-temperature, high-pressure air for expansion through a hypersonic nozzle into the evacuated test cell. The combination of the arc heater driver, various nozzle/throat combinations, the evacuated test cell, and exhauster makes possible high-enthalpy flows at Mach numbers from 5 to 9.

HEAT-H3

The 70-MW H3 arc heater was developed at AEDC during the 1990s to provide a large, high-pressure, arc facility with sufficient size and performance for testing of full- and large-scale missile and reentry samples and structures. H3 is a 12-module, 50-percent geometric scale-up of the H1 segmented arc heater, and is designed to operate at over twice the available power level and mass flow of the H1 arc, while providing essentially the same flow field enthalpy and pres-

Altitude/Velocity Simulation in the AEDC ARCS





Missile Nosetip

Scramjet Leading Edge

Missile Nosetip

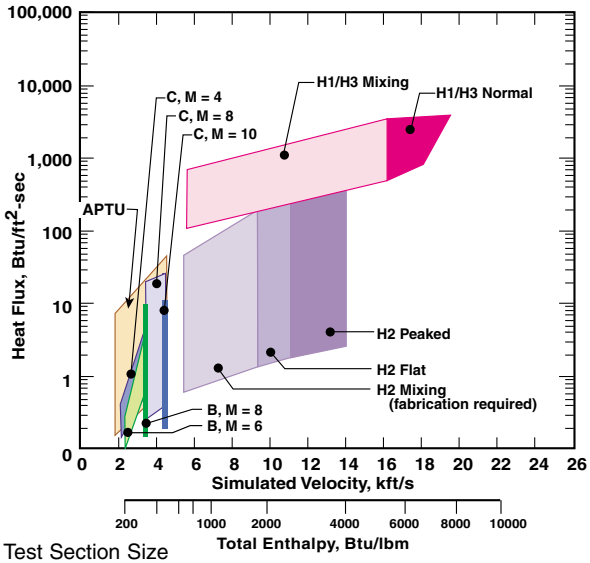
Reentry Vehicle Heat Shield

sure. The H3 heater plenum is designed as a 3.0-in. bore pressure vessel with a design operational pressure up to 150 atm. Performance envelopes for the H3 arc have been estimated using empirical scaling relations derived from data of three high-pressure segmented arc heaters. Since 1995, an extensive series of checkout runs in H3 have been completed to verify operation over a wide range of heater chamber pressures and flow enthalpies. Successful runs up to the 70-MW power level have been completed, and the H3 arc has demonstrated performance commensurate with analytical predictions, along with a high reliability rate. Testing of high-value materials samples for hypersonic customers began in early 2003, and the facility is scheduled for transition to full operational testing with a multi-sting model injection system by 2005.

Aerothermal Test Techniques

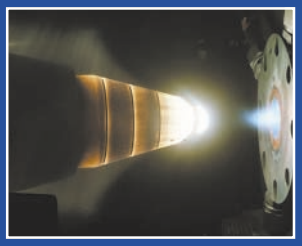
A variety of test techniques are available to evaluate material performance under realistic conditions. Typical test techniques include steady-state ablation testing of nosetip materials; nosetip boundary-layer transition tests during which the nosetip is subjected to a Reynolds number variation of a factor of five during the run; wedge tests where two-dimensional material samples are exposed to various pressure/heat-transfer rate combinations; combined ablation/erosion tests using graphite dust particles accelerated in the arc heater to high velocity; cooling-effectiveness tests on actively-cooled electromagnetic apertures or transpiration-cooled nosetips; and hot transmission testing of antenna window materials.

Wedge Heat Flux Simulation Envelopes



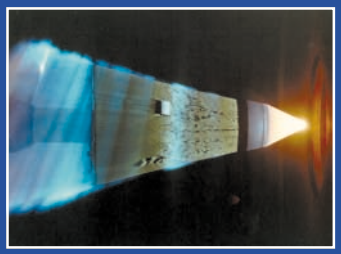
Test Unit	Test Section Size Diam, in.
H1	1 - 3.5
H2	5,9,24,42
H3	1.5 - 5
B	50
C	24,25,50
APTU	38

Envelope values are for 0 to 30-deg wedge angle and at axial locations of one-half the nozzle diameter from leading edge (to a maximum of 12 in.)

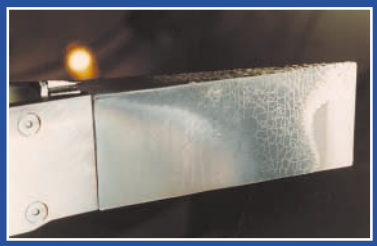


d Reentry Nosetip

Actively-Cooled Antenna Window



Missile Forebody



Scramjet Leading Edge

Test Support Services

A complete range of test support services are available at AEDC in connection with the aerothermal test facilities. Support services include model design, fabrication, and assembly, test article instrumentation, instrument calibration, and data analysis. Test articles can be provided ready to test by the test user, or fabricated and instrumented at AEDC to user specifications. In addition to the Arc facilities, the AEDC Aerothermal Tunnel C and/or AEDC Tunnel 9 may be of interest for aerothermal test conditions which are below the enthalpy threshold achievable in the arcs.

Mission

Provide aerothermal ground test simulations of hypersonic, endoatmospheric flight over a wide range of velocities and pressure altitudes in support of materials/structures development by the DoD and the commercial aerospace industry.

Contact:

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