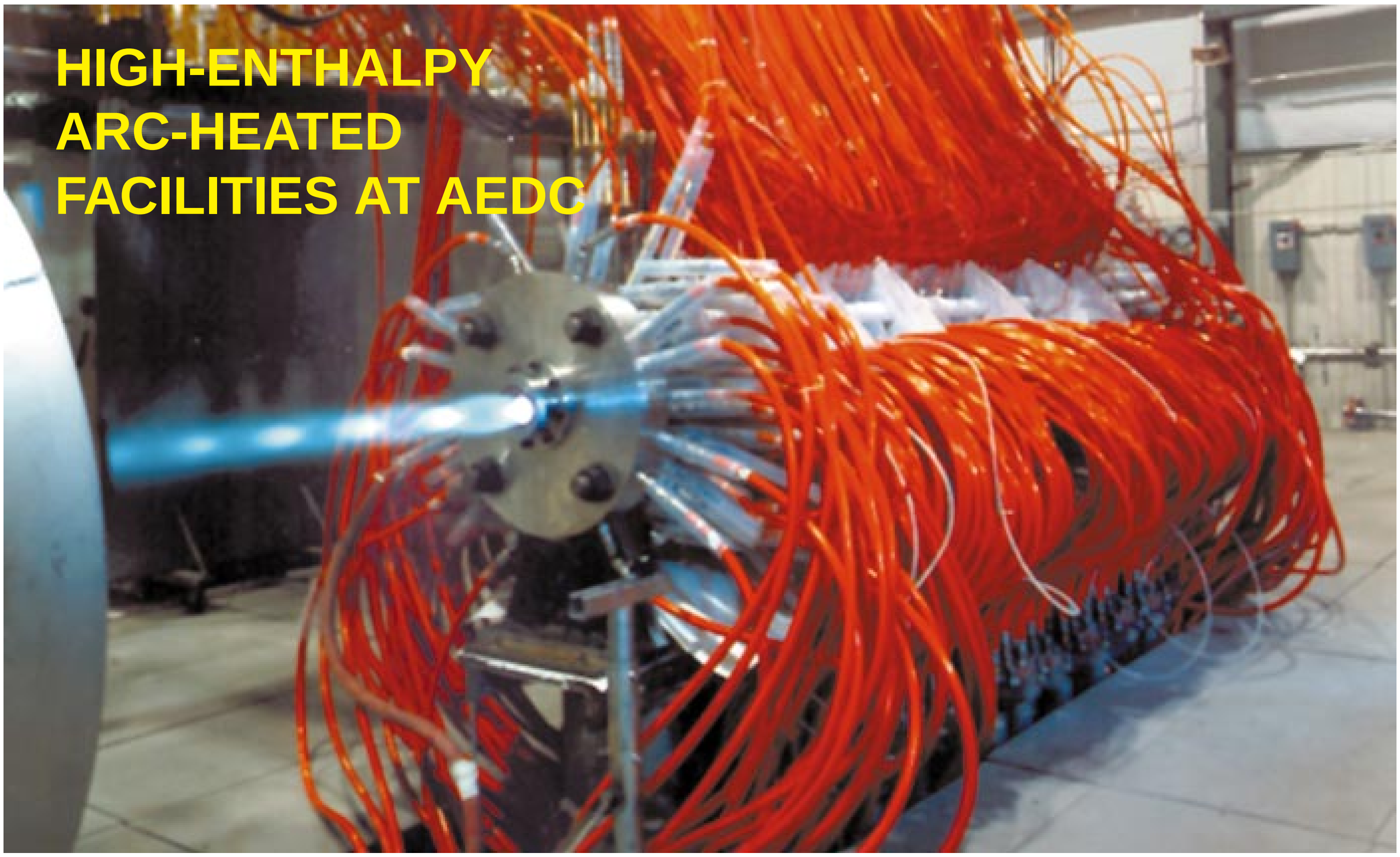
from http://www.arnold.af.mil/aedc/factsheets/Arcs.pdf, Feb. 2003

AEDC

See also AIAA Paper 98-0146, "Survey of Current and Future Plasma Arc-Heated Test Facilities ...", Smith et al. Jan. 1998

Arnold Engineering Development Center
Arnold Air Force Base, Tenn. 37389
An Air Force Materiel Command Test Facility

HIGH-ENTHALPY ARC-HEATED FACILITIES AT AEDC



MISSION

Provide aerothermal ground test simulations of hypersonic flight over a wide range of velocities and pressure altitudes in support of materials and structures development by the Department of Defense and the commercial aerospace industry

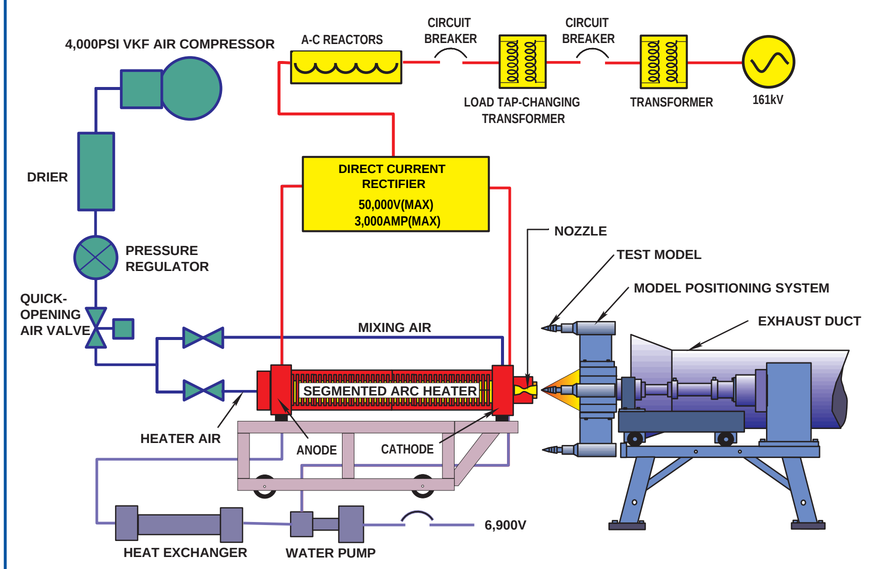
INTRODUCTION

The Role of Arc Facilities in Aerospace RDT&E. Hypersonic flight vehicles of all types face rigorous aerothermal and structural demands. Arc facilities are unique in their ability to reproduce thermal environments simulating flight from Mach 8 to 20 for the long exposure periods required to validate thermostructural performance and survivability of materials and components. Arc heaters have found widespread usage in the development of high-speed vehicles, including hypersonic missiles, reentry vehicles, high-speed transports, military/civil space transportation and space access vehicles, and ordnance and munitions systems.

The Arnold Engineering Development Center. The Arnold Engineering Development Center, Arnold AFB, TN, was created by the Department of Defense to provide ground test support for

the development of advanced aerospace systems. Since its inception over 50 years ago, the AEDC has played a vital role in development efforts for a wide range of aerospace vehicles and sub-systems.

The AEDC HEAT Facilities. The High-Enthalpy Aerothermal Test (HEAT) arc-heated facilities at AEDC fill a unique niche in providing high-pressure, high-enthalpy ground test simulations. These test units are the sole DoD arc facilities in operation, and represent the only state-of-the-art, high-pressure arc facilities in the world, providing high-enthalpy test conditions simulating aeroheating environments at velocities from 5,000 ft/sec up to and exceeding 20,000 ft/sec.



Heat-H1 Facility Components

FACILITY DESCRIPTION

The AEDC arc-heated test facilities include two high-pressure segmented arc heaters (HEAT-H1 and H3) and two Huels arcs (H2 and HR). 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 (i.e., low altitude flight simulation).

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. HEAT-H1 utilizes a segmented arc heater with 200 electrically isolated segments which form the heater plenum. The unique segmented construction, with the anode and cathode at opposite ends of the plenum, 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 about 20,000 volts and 1,200 amps, providing heater chamber pressures up to 120 atm at high stagnation enthalpies. The centerline enthalpy, inferred from measurements of the stagnation point heat flux on calibration probes and measured pitot pressures, can be varied from less than 1,000 to 8,500 Btu/lbm over the pressure range of the heater (20 to 120 atm). A stilling/mixing chamber can be installed to mix cold air with the arc-heated air, thereby decreasing the total enthalpy, increasing the flow Reynolds number, and improving the uniformity of the flow enthalpy across the test jet.

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. Transient calibration probes of various configurations are available to define heat flux and pressure conditions inside the test jet.

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

AEDC ARC-HEATED TEST FACILITIES

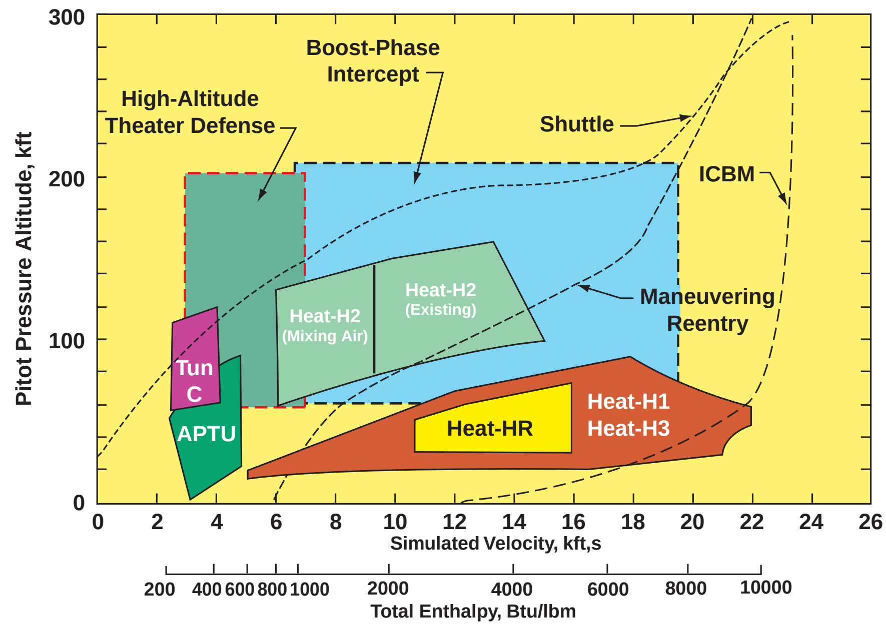
Facility Name	Facility Type	Maximum Run Time (min)	Nozzle Mach No.	Nozzle Exit Diam (in.)	Stagnation Pressure (atm)	Stagnation Enthalpy (Btu/lb)	Mass Flow Rate (lbm/sec)	Facility Power (MW)
HEAT-H1	Arc Heater (Atm. Exhaust)	1 – 2	1.8 to 3.5	0.75 to 3.0	Up to 90	600–6,500	0.5–8	30
HEAT-H2	Arc-Heated (Subatm. Exhaust)	3 – 30	4.0 to 8.3	9.0 to 42.0	Up to 3.5	1,200–3,000	2–10	42
HEAT-H3	Arc Heater (Atm. Exhaust)	1 – 2	3.5	5.0	Up to 90*	600–6,500*	3–18	60
	*HEAT-H3 is a technology test bed for arc heater development. Flow-field properties are uncalibrated.							
HEAT-HR	Arc Heater (Atm.Exhaust)	3 – 30	1.8 to 3.1	1.1 to 4.0	Up to 75	2,000–5,200	2–10	42

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. Direction and distribution of the injected air can be selected to optimize the enthalpy distribution across the flow to match specific test requirements. Run times of 30 minutes or longer are available in HEAT-H2 for selected operating conditions. In addition to material testing, H2 can be configured for direct-connect scramjet combustor testing. Critical components have been demonstrated for such a test capability.

HEAT-HR. The HEAT-HR heater is identical to the H2 arc heater, but operates with smaller nozzles, and atmospheric exhaust in the free jet mode to provide test conditions similar to HEAT-H1. The HR facility, currently in inactive status, is available for user testing given sufficient lead time.

HEAT-H3 and the Arc Heater Development Program. A technology program is ongoing at AEDC to develop the next generation of high-pressure, high-enthalpy segmented arc heaters. The primary objective of the program is the design, development, and evaluation of a 3-inch bore segmented arc heater with operational performance up to 150 atm. The larger heater, designated H3, will ultimately provide a proportionately larger high-enthalpy freejet for testing of materials and aerothermal structures. Other objectives of the arc heater technology program include:

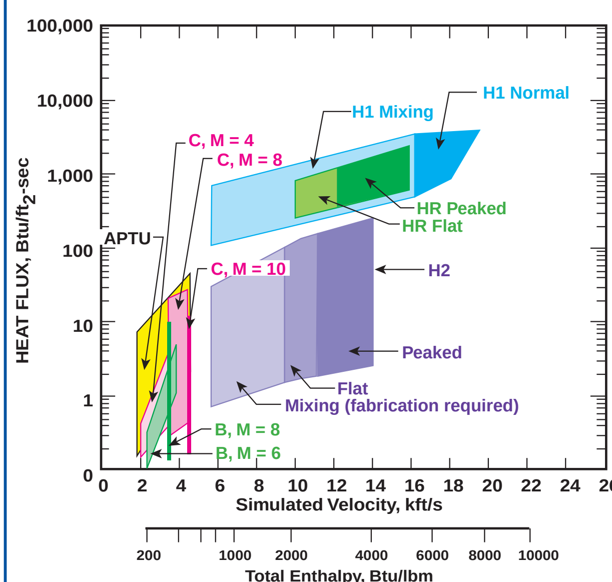
- Development of operational concepts to improve reliability and performance of segmented arc heaters.
- Analytical modeling of the primary physics and fluid mechanics of arc heater operation.
- Development of a validated procedure for designing nozzles and throats for high-pressure arc heaters.



Altitude/Velocity Simulation in the AEDC ARCS

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; and wedge tests where two-dimensional material samples are exposed to various pressure/heat-transfer rate combinations. The wedge test article heating rate envelopes (heat flux/velocity) shown in the figure below represent duplication of heat transfer rates and stagnation enthalpy, with simulated velocity controlled by the test unit total enthalpy. Other types of testing include 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



Test Section Size

Test Unit	Diam, in.
H1, HR	2.2-4
H2	9,24,42
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.)

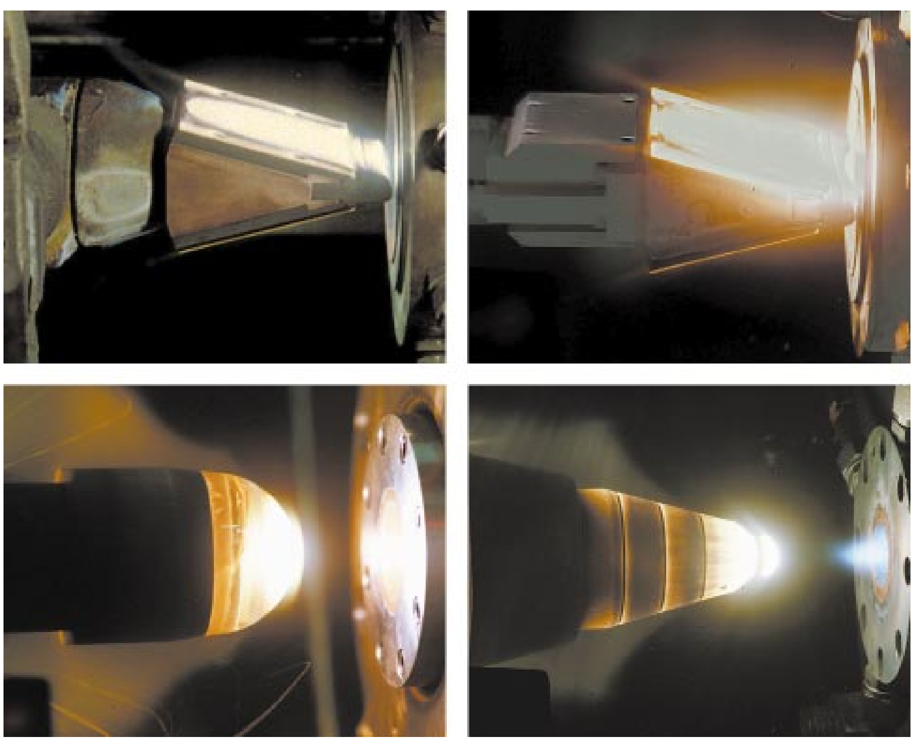
Wedge Heat Flux Simulation Envelopes

testing of antenna window materials. The facility is under continuous development, and other special testing techniques, such as variation of nosetip/wedge angle-of-attack scramjet combustor testing, and other nonstandard test techniques can be implemented with sufficient lead time.

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. Model support hardware including test wedges, angle-of-attack adapters, heat shield materials, calibration probes, and other test hardware items are available at AEDC for the convenience of the test user.

REENTRY NOSETIP TEST IN HEAT-H1



TYPICAL TEST ARTICLES IN H1 ARC HEATER

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