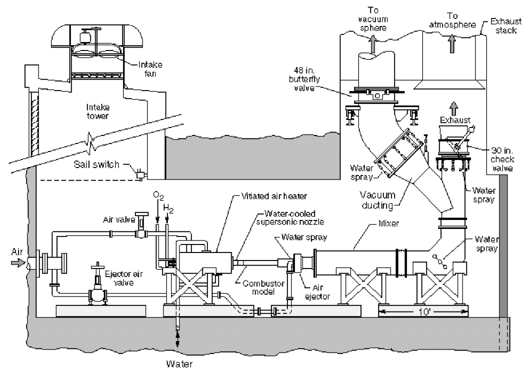
Purpose

The Langley Direct-Connect Supersonic Combustion Test Facility is used to test ramjet and scramjet combustor models in flows with stagnation enthalpies duplicating that of flight at Mach numbers between 4 and 7.5. Results of the tests are typically used to assess the mixing, ignition, flameholding, and combustion characteristics of the combustor models. The facility operates "directly-connected" to the combustor model with the entire facility test gas mass flow passing through the model. The combustor model may exhaust freely (into the test cell), or directly (connected) to an air-ejector or to a 70-ft diameter vacuum sphere. Nozzle geometric simulations can also be added at the exit of the combustor models. The stagnation enthalpy necessary to simulate flight Mach number for the combustor test is achieved through hydrogen-air combustion with oxygen replenishment to obtain a test gas with the same oxygen mole fraction as atmospheric air (0.2095). The flow at the exit of the facility nozzle simulates the flow entering the combustor of a ramjet or a scramjet in flight.

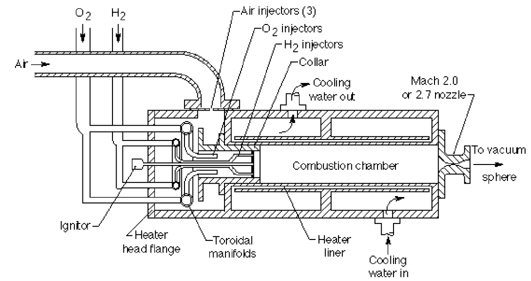
Facility Layout and Operation

As shown in the schematic, the DCSCTF is located in a 16- by 16- by 52-ft test cell with forced-air ventilation. Test air is supplied from a high-pressure bottle field and is regulated to 550 psia (nominal) prior to entering the test cell. Gaseous hydrogen is supplied from 60,000 ft^3 tube trailers at a maximum pressure of 2400 psia and is regulated to 720 psia. Similarly, oxygen is supplied from trailers at a maximum pressure of 2400 psia and is regulated to 720 psia prior to entering the test cell. Purge nitrogen is also supplied from a tube trailer at a maximum pressure of 2400 psia with the pressure regulated to 230 psia.



Direct-Connect Supersonic Combustion Test Facility

The DCSCTF uses a hydrogen and air combustion heater, which is shown in the schematic. During facility heater operation, oxygen is injected into the airstream from 12 in-stream injectors and pre-mixed before injecting hydrogen. The hydrogen is injected into the air and oxygen mixture from 12 in-stream injectors centered in holes located in a baffle/mixing plate upstream of the water-cooled combustor section. Ignition of the gas mixture is achieved using an electric-spark-activated hydrogen and oxygen torch igniter.



DCSCTF H_2-O_2-Air combustion heater

Calculated test gas compositions for the standard operating conditions of the DCSCTF are tabulated for simulated flight Mach numbers of 4.0 and 7.5. The data are listed only for species mole fractions that are 0.0001 or greater. These calculations were made with finite-rate chemistry during the expansion through the facility nozzle. The primary contaminant in the test gas is water vapor, which varies from 0.083 mole fraction at Mach 4 conditions to 0.358 at Mach 7.5 conditions. A small amount of nitric oxide (0.004 mole fraction) is also present in the test stream at the Mach 7.5 condition.

M_∞	P_t (atm)	H_t (BTU/lb_m)	T_t (°R)	m (lb_m/s)	M_{tg}	P_{tg} (atm)	T_{tg} (°R)
4.0	7.8	430	1640	4.34	2.0	0.990	959
7.5	26.5	1290	3780	7.21	2.7	1.021	1905

Standard test conditions

M_∞	N_2	O_2	Ar	H_2O	CO_2	NO	OH
4.0	.6987	.2095	.0083	.0832	.0003	-	-
7.5	.4248	.2074	.0051	.3584	.0002	.0039	.0002

Standard test conditions-mole fractions

Various facility nozzles can be attached to the facility combustion heater to simulate scramjet combustor entrance conditions. Two nozzles are currently available for use in the DCSCTF; both are two-dimensional (rectangular) contoured nozzles. The first is a Mach 2 nozzle with throat dimensions of 0.846 by 3.46 in and exit dimensions of 1.52 by 3.46 in; the second is a Mach 2.7 nozzle with throat dimensions of 0.356 by 6.69 in and exit dimensions of 1.5 by 6.69 in. An air ejector or a 70-ft diameter vacuum sphere and steam ejector system (requiring up to 25,000 lbm per hr of steam) provides vacuum for altitude simulation. Gaseous hydrogen (at ambient temperature) is the primary fuel used in the combustors tested in the DCSCTF, although other types of gaseous fuels are used occasionally. The hydrogen fuel for the combustors comes from the same trailers as the hydrogen for the facility heater but may be used at the maximum trailer pressure of 2400 psia. Gaseous oxygen may also be supplied to the combustor models at the full (2400 psia) trailer pressure. A 20-percent silane and 80-percent hydrogen mixture (by volume) is supplied from K-size cylinders (maximum storage pressure of 2400 psia) for use as an igniter and pilot of the primary fuel in the combustor models.

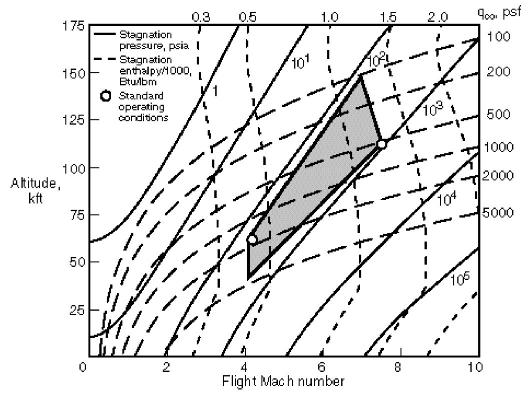
Data Acquisition

The data acquisition system (DAS) for the DCSCTF consists of a commercially available software package (AutoNet) running on a Pentium processor. The DAS incorporates a NEFF 300 signal conditioner and NEFF 600 amplifier and multiplexer capable of supporting 128 data channels.

In addition to the A/D capabilities of the NEFF, up to 256 static pressure measurements can be recorded using a Pressure System Incorporated (PSI) 8400 electronic sensing pressure (ESP) system and 8 32-port modules. Nonintrusive laser-based diagnostics are commonly used in the DCSCTF and the combustor test section can be mounted on a thrust-measuring system. Additional optical systems such as Schlieren and shadowgraph, infrared thermography, and OH visualization are also available. Test data is visualized and may be reduced on a UNIX workstation. A secure operating mode is provided for classified projects.

Test Capabilities

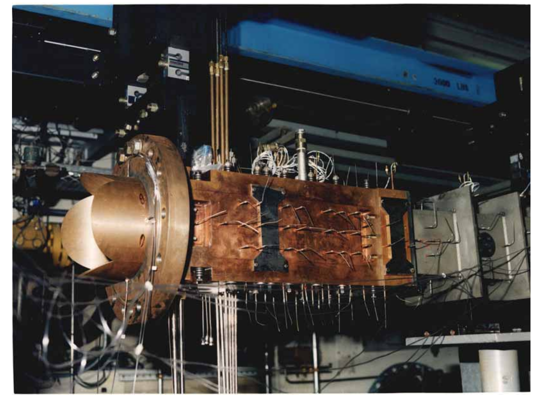
The DCSCTF normally operates at heater stagnation pressures between 115 and 500 psia and at heater stagnation temperatures between 1600 and 3800 °R. Test gas mass flow rates range from 1 to 7 lb_m per sec. The facility operational range is shown by the Mach number/altitude simulation envelope. The left boundary is the lower temperature limit of stable operation of the heater (~1600 °R) and the right boundary represents the maximum operational stagnation temperature (~3800 °R). The lower (diagonal) boundary reflects the maximum allowable heater pressure (~500 psia) and the upper boundary reflects the lowest pressure for stable heater operation (~ 115 psia). However, these pressures translate into higher simulated stagnation pressures on the flight envelope when typical scramjet inlet and aircraft bow shock losses are included. (An inlet kinetic energy efficiency of 0.985 was assumed.) The standard operating conditions of the DCSCTF are shown by the symbols on the figure and are tabulated in the previously described tables. The normal test schedule is 2 or 3 test days per week. Run duration averages 20 to 30 sec with multiple runs (5 to 20) per day.



DCSCTF flight simulation envelope

Recent Tests

Most recently the DCSCTF has been utilized to test a strut-ducted (H_2/O_2) rocket in support of the Rocket Based Combined Cycle (RBCC) engine program. The rocket has operated at simulated flight Mach numbers of 0, 4.0, 4.5, 5.5 and 6.5 with oxygen-to-hydrogen ratios of 4, 6 and 8, and rocket chamber pressures up to 800 psia. Previously, the DCSCTF was used to carry out mixing and combustion tests in support of Generic Hypersonics and the National AeroSpace Plane (NASP) program.


Strut-ducted rocket assembly

Additional Information

Additional information can be found at the Wind Tunnel Enterprise server at URL

http://wte.larc.nasa.gov

For further information please contact:

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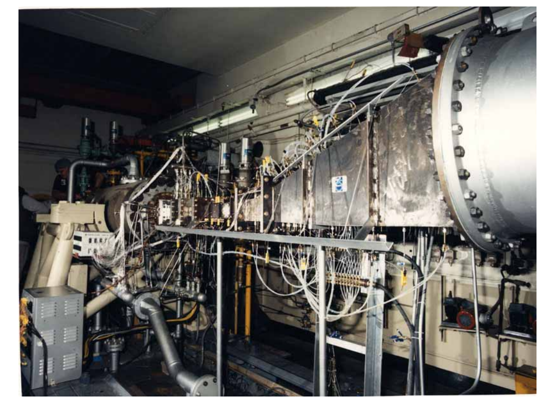
National Aeronautics and Space Administration

Langley Research Center

The Langley Direct-Connect Supersonic Combustion Test Facility, DCSCTF



The Direct-Connect Supersonic Combustion Test Facility, DCSCTF, is part of the NASA Langley Scramjet Test Complex. The facility is used to test ramjet or scramjet combustors at conditions simulating flight Mach numbers from 4 to 7.5.