Facility Description #372

# Description of the Rocket Engine Test Facility Complex

The Rocket Engine Test Facility (RETF) Complex is an integrated stand-alone test facility dedicated to the testing of full scale rocket thrust chambers. The complex is located at the south end of the Lewis Research Center (LeRC), Cleveland, Ohio, and occupies approximately ten acres of land. The complex includes two major buildings and extensive on-site support services. The RETF (Building 202) is used for sea level testing of vertically mounted rocket thrust chambers and space simulation testing of hoizontally mounted rocket engines. The Rocket Operations Building (ROB) (Building 100) is located one-quarter mile north of RETF and contains the facility remote control room, a shop area, and general office space. This unique test complex has high pressure capabilities, the ability to test with a wide variety of rocket propellants and a space simulation, large area ratio rocket nozzle test capability. Propellant run tank pressure levels of 5000 psi can be achieved.

The RETF Complex was completed in the fall of 1957 at a cost of $2.5 million to test hydrogen-fluorine and hydrogen-oxygen rocket thrust chambers. The facility test capabilities have been significantly upgraded since it was built. The complex carries a FY 1983 replacement value of $23.0 million.

## Test Facility Capability

RETF has the flexible capability to test using cryogenic and earth storable propellants at high and low pressures. Liquid and gaseous hydrogen, oxygen and fluorine as well as liquid hydrocarbon, nitrogen tetroxide and hydrazine propellants have all been successfully used at RETF. Rocket test firings of a single short (0.3 sec duration) burst, of multiple pulses (1.5 sec. duration), and of a single long run of up to 100 second duration are all performed. Liquid oxygen/hydrocarbon rocket tests with chamber pressure of 2000 psia and with liquid oxygen cooling at 4500 psia are currently tested on the vertical "A" stand.

Liquid and gaseous hydrogen-liquid oxygen rocket chambers have been tested at 5000 $lb_f$ thrust and 600 psia chamber pressure on test stand "A." However, the system can accommodate thrust levels to 20,000 $lb_f$ and chamber pressures up to 3300 psia.

The horizontally firing test stand "B" is currently testing rocket chambers with GOX/GH2 with chamber pressures ranging from 30 to 1000 psia at thrust levels from 10 to 1000 $lb_f$.

Since 1958 RETF has been in continuous operation and has conducted hot fire rocket tests on 2000 test days.

## Programs

The RETF facility is used for experimental investigations of rocket enabling technology (cryogenic and earth storable propellants) with emphasis on reusability, high performance, advanced thrust chamber cooling techniques, low thrust-high performance and stability. This work is directed toward specific propulsion needs envisioned for future NASA missions.

Significant contributions to the U.S. Space Program have resulted from the work performed at RETF. Testing at RETF has: provided rocket injector technology for the RL-10 (Centaur), J-2 (Saturn vehicle), and the SSME (Space Shuttle) hydrogen-oxygen rocket engines; developed rocket combustion stability technology; developed liquid hydrogen chamber cooling technology; recently demonstrated the first liquid oxygen cooled rocket chamber and worked toward extending the life of reusable engines like those presently used on the Space Shuttle.

The RETF space simulation test stand is used to evaluate space performance and advanced cooling systems for the low thrust orbital transfer vehicle program. General research and technology programs include testing stowable nozzles and advanced unconventional nozzles for space rocket propulsion applications. Data will be accumulated on rocket engine ignition, life and durability of the engine walls, heat transfer information, nozzle boundary layer conditions and engine efficiency at space simulation conditions.

The RETF Complex will be used on a continuing basis beyond the year 2000 to conduct rocket technology programs supporting Advanced Space Shuttle, Orbit Transfer Vehicles and the Space Station Project.

Facility Systems

RETF is comprised of a 1325 sq. ft. test cell containing two test stands, pressurized propellant run tanks and propellant flow line systems, and a rocket exhaust gas treatment combination scrubber and silencing muffler. A 4800 sq. ft. shop service building and 16 large volume high pressure (4000 to 6000 psi) gas storage bottles are located adjacent to the test cell. The support systems include permanent on-site bulk storage dewars for cryogenic liquid hydrogen, liquid oxygen, and liquid nitrogen and a large water reservoir; all are connected to the test cell by permanent pipelines. Four small buildings including a pump house, helium compressor shelter, liquid hydrogen pump-vaporizer shelter, and an observation block house are part of the test complex.

Both the high thrust (20,000 lb) vertical test stand and the low thrust (to 1000 lb) horizontal stand exhausts discharge into the common scrubber muffler system for toxicity and sound control. The scrubber system and facility foundations are designed to accommodate rocket engines up to 100,000 lb. thrust while the present engine mounting and plumbing, controls and instrumentation limit testing to a maximum of 20,000 $lb_f$ thrust.

The scrubber system consists of a 100 foot long horizontal 25 feet in diameter tank containing six water spray banks connected to a vertical stack 20 feet in diameter (which necks down to 6 feet in diameter) by 118 feet high. During a run, water from the reservoir tank flows to the exhaust scrubber at a rate of 50,000 gallons per minute. The hot gases, emerging from the rocket nozzle at velocities of 9000 to 12,000 feet per second and temperatures of about 6000°F, are met with a drenching spray of water and quickly cooled to steam temperature and slowed to a velocity of about 25 feet per second. Additional water sprays condense the steam, and non-condensable exhaust gas emerges from the stack below 160°F and a velocity of about 20 feet per second. Water from the scrubber is ducted to a detention tank for treatment and then discharged to the ground water system.

The 1984 modifications provide a space simulation test capability for the study of extremely large area ratio nozzles (to 1000:1) on small, low thrust rocket engines. The modifications include a large vacuum tank which houses the rocket engine, a long, water cooled diffuser section into which the hot engine exhaust is funneled, an inter-cooler for cooling the exhaust gases, and two gas ejectors to provide the pumping necessary to maintain the low vacuum environment during testing.

Nine individual propellant systems comprised of run dewars and tanks with working pressure ranging from 1500 to 6000 psi are operational and permanently connected to the test stands with stainless steel, vacuum or liquid nitrogen jacketed pipelines. These systems provide the capability to test thrust chamber without the need for high pressure rocket turbomachinery and pumps. The separate propellant systems are integrated to support a particular rocket technology program on an as-required basis. Hydraulic, variable position valves control both the pressurant gas flow to the run tanks and the propellant flow the rocket chambers under tests.

The primary liquid hydrogen, liquid oxygen, cooling water and hydrocarbon propellant systems are rated at 5000 psi working pressure. Currently, gaseous hydrogen at 4000 psi, gaseous helium at 6000 psi, and gaseous nitrogen at 3000 psi are being stored. A nominal 500,000 gallon water storage reservoir supplies the scrubber and muffler as well as providing a source of water for the 650 gal/min and 1400 gal/min (at 450 psi) pumps and for cooling the rocket altitude simulation system. On-site bulk storage of liquid nitrogen (28,000 gal.), liquid oxygen (2,000 gal.), liquid hyudrogen (18,000 gal.) support RETF. On-site gas pumping equipment in service at RETF supply gaseous hydrogen at 4000 psi, gaseous helium (automated) at 6000 psi, and gaseous nitrogen (automated) at 3000 psi to the various gas bottle farms.

A flare stack, located at the top of the scrubber stack, provides the facility with the capability for open air burnoff of non-regenerative hydrogen, discharged from thrust chambers at rates up to 5 pounds per second.

In the test cell integral $CO_2$ and water deluge fire suppression systems and strategically located concrete blast walls aid in damage control if a rocket chamber fails under test. Hydrogen gas detectors are located throughout the facility to warn of potentially hazardous hydrogen leaks.

Control and Instrumentation

The RETF test stands are remotely controlled from the well equipped control room in ROB. Manual, automatic timed, and computer electrical units control the facility instrumentation, data acquisition, hydraulic servo systems, valve operation and the rocket engine operation from that location.

Solid state, programmable flow controllers and sequence timers provide automatic propellant flow control, remote sequence timing, and automatic permissive and cut-off control for the rocket engine under tests. Facility safety monitoring is also provided.

Data are processed through a 200 channel high speed (31K Hz) digitizer multiplexer data acquisition system and fed by a direct digital data link to the Lewis Research Center central data system (IBM 3033 TSS and Cray 1-S computers). This system provides on-line data reduction capabilities to the control room via hardcopy terminals and CRTs located at ROB. Analog data systems provide "quick look" test data through four oscillograph recorders. System pressures are displayed on panel meters in the control room for facility remote control.

Closed circuit television systems and a sound monitoring system provide real time data necessary for the remote control of rocket tests. A facility intercommunication system, an emergency communication system, and two independent telephone systems all provide the communications network necessary for safe rocket test operations.

Prepared by Wayne Thomas
Lewis Research Center
January 24, 1984