Cryogenics Testbed Technology Focus Areas

James E. Fesmire
NASA Kennedy Space Center
Spaceport Engineering and Technology

Cryogenics Test Laboratory
Kennedy Space Center, FL 32899
Mail Code: YA-F2-T
(321) 867-4550 office, (321) 867-7280 lab
james.fesmire@ksc.nasa.gov

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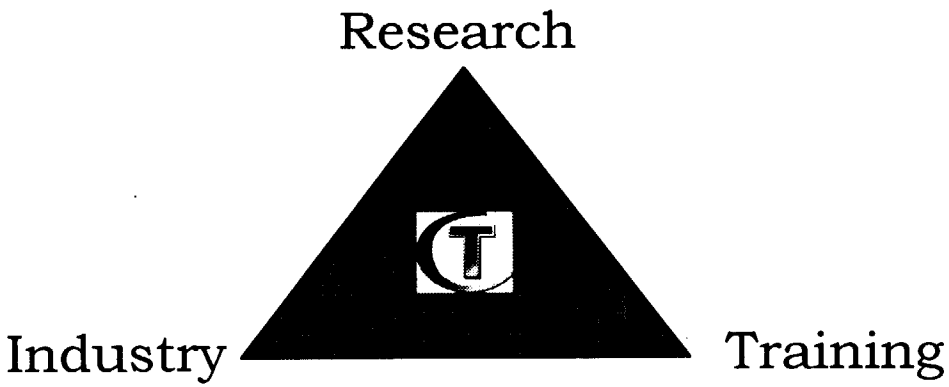
CRYOGENICS TESTBED OVERVIEW

- Our mission is to bring together the mutual elements of research, industry, and training in the field of cryogenics to advance technology development for the spaceports of the future.
- Successful technology and productive collaboration comes from the these three ingredients working together in a triangle of interaction.



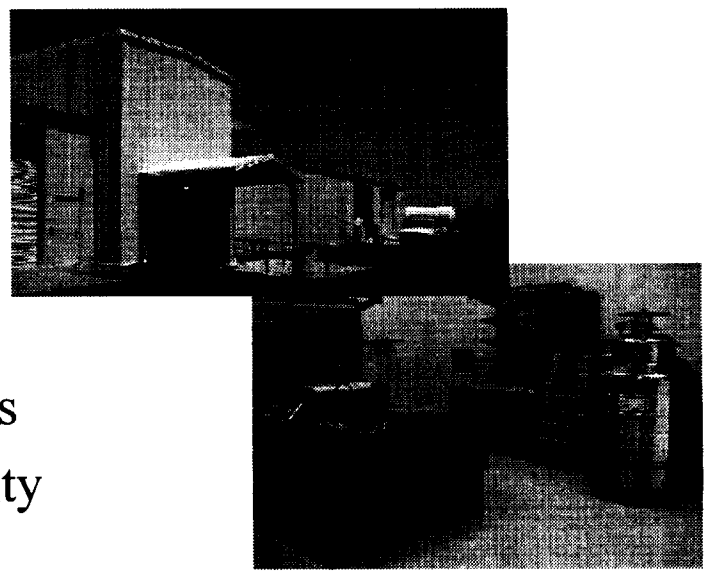
CRYOGENICS TESTBED OVERVIEW

Collaboration

- Research ⟶ *energy efficient cryogenics*
- Industry ⟶ *engineering, test, and evaluation*
- Training ⟶ *international school of excellence*

Facilities

- Cryogenics Test Laboratory
- LN2 Flow Test Area
- Launch Systems Test Area
- Materials Science Laboratories
- Launch Equipment Test Facility



CRYOGENICS TESTBED TASK AREAS

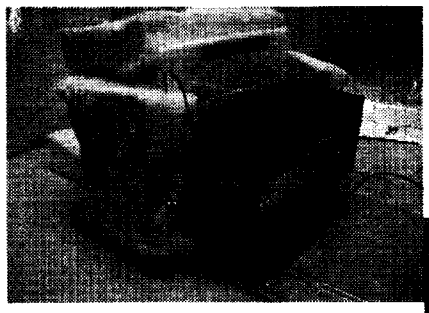
Aerospace

- Exploration initiatives
- Future launch vehicle servicing
- Space Shuttle technology upgrades
- Experiment design and setup
- Spaceport 2050 (energy integrated launch site)

Commercial

- Cryogenic and vacuum testing
- Specialized system design engineering
- Component test and evaluation
- Prototype construction
- Cryobiology, food technology, electronics, materials, and other low temperature applications

CRYOGENICS TESTBED
EXAMPLE AREAS OF WORK



- Thermal insulation testing
- Liquid nitrogen flow testing
- Engineering test and evaluation
- Equipment qualification testing
- Propellant systems planning and integration
- High vacuum measurement and leak detection
- Conceptual design and prototype construction
- Low-temperature applications such as energy transfer, superconductivity, medical, food industry
- International school of excellence in cryogenics (charter)

CRYOGENICS TESTBED TECHNOLOGY FOCUS AREAS

Thermal Insulation Systems

Cryogenic Components

Propellant Process Systems

Low-Temperature Applications

- The focus areas comprise the core work which is the technical foundation of the testbed
- The focus areas are linked to the long range strategic goals of NASA

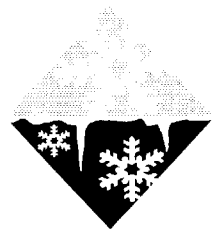
THERMAL INSULATION SYSTEMS TECHNOLOGY FOCUS AREA

Energy Efficient Cryogenics

Objective: ***Develop the materials, the testing technologies, and the engineering for the efficient storage, transfer, and use of cryogens and cryogenic propellants on Earth and in space.***

THERMAL INSULATION SYSTEMS TECHNOLOGY FOCUS AREA

- Insulation Testing Technology
- Efficient, Robust Insulation Systems
- Applications

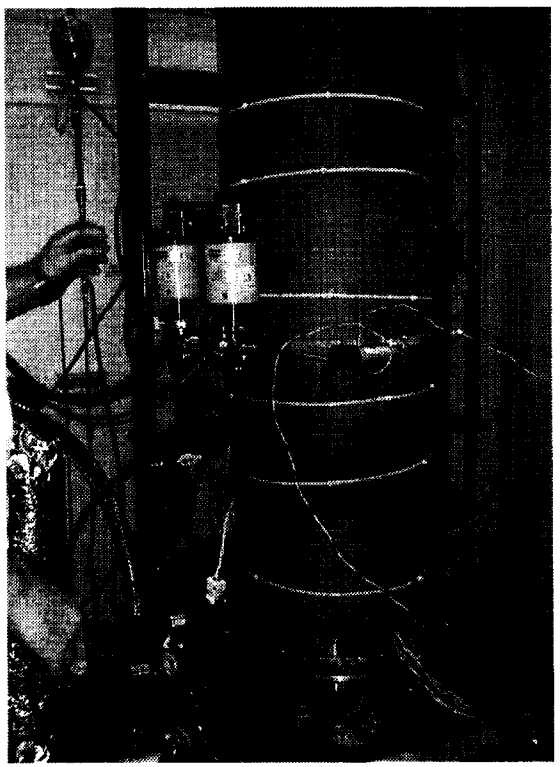


INSULATION TESTING TECHNOLOGY

- Cryostat-1
- Cryostat-2
- Cryostat-3
- Dewar Test Apparatus
- Pipeline Test Apparatus

INSULATION TESTING TECHNOLOGY

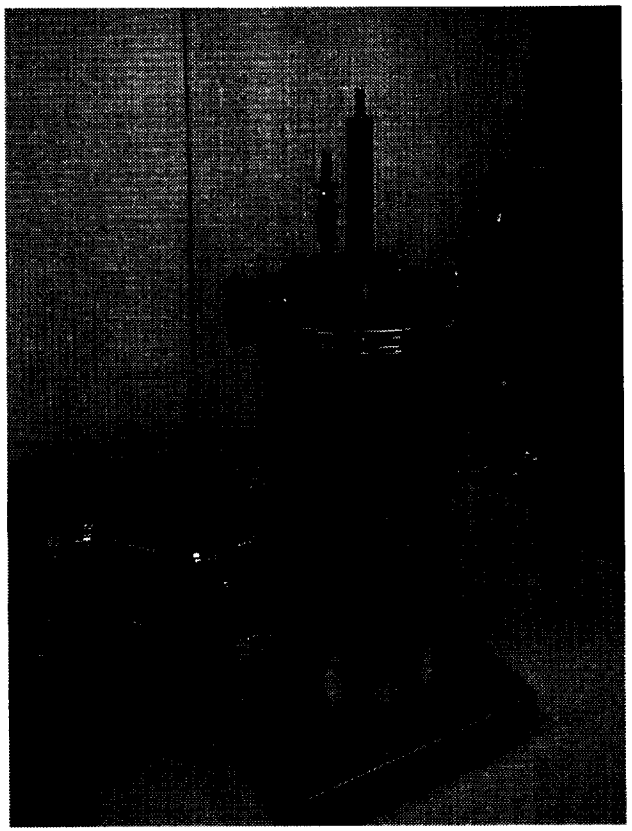
Cryostat-1 is a liquid nitrogen boiloff calorimeter apparatus for direct measurement of the apparent thermal conductivity (k-value) of a material system at a fixed vacuum level. The configuration includes a 1 m long cylindrical cold mass with liquid nitrogen guard chambers. The steady-state measurement of the apparent k-value is made when the vacuum level, all temperatures, and the boiloff flow are stable.



INSULATION TESTING TECHNOLOGY

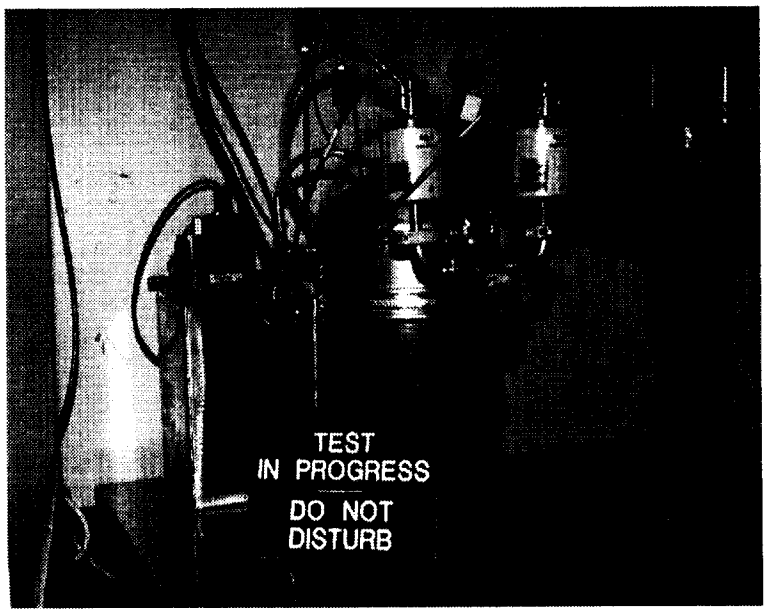
Cryostat-2 is a liquid nitrogen boiloff calorimeter apparatus for calibrated measurement of the k-value. The configuration is _ m long cylindrical with aerogel disks for thermal guards. This apparatus with its removable cold mass allows a quicker testing of different specimens, is convenient for materials screening, and can also be configured for flat plate geometries.

Cryostat-3 is a similar test apparatus used for testing insulation materials in specialty environments such as carbon dioxide.



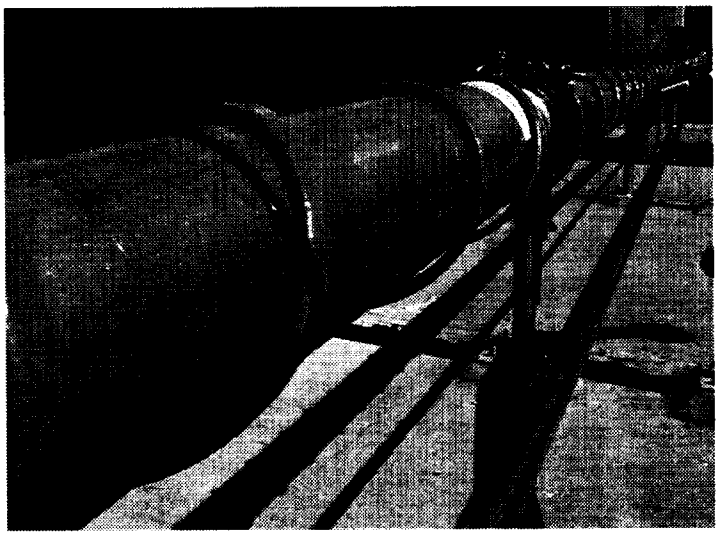
INSULATION TESTING TECHNOLOGY

The ***Dewar Test*** is an apparatus to determine the "real world" performance of an insulation system with consideration given to the fabrication, quality control, testing, and operation of the cryogenic tank. This method gives a direct measure of actual system performance as a function of cold vacuum pressure. The weight loss due to the boiloff of nitrogen gas is proportional to the total system heat leak rate.



INSULATION TESTING TECHNOLOGY

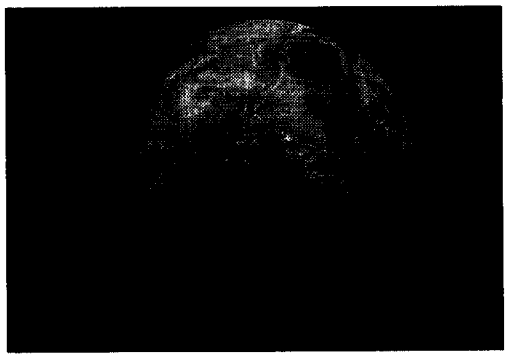
The ***Pipeline Test Apparatus*** is designed for precision thermal performance measurements of complete assemblies. The pipelines may be rigid (up to 60 feet) or flexible (any length). Three pipelines with outside diameters of up to 8 inches may be installed at one time. Both ends are thermally guarded by liquid nitrogen reservoirs with special mounting adapters. Test article surfaces are maintained at a constant warm temperature using a heater jacket. Static nitrogen boil-off flow rates are recorded after a suitable stabilization period. A field portable property measurement and data acquisition system is used. The system may be adapted for use with other process fluids under dynamic (flow through) conditions.



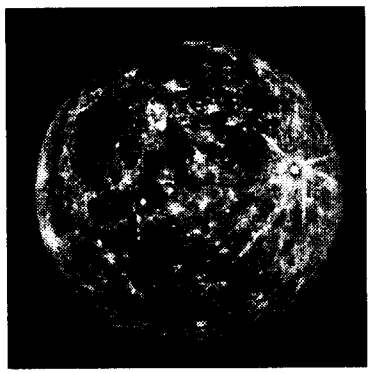
EFFICIENT, ROBUST INSULATION SYSTEMS

- Technological developments of the last century have led to insulation systems that have approached the ultimate limit of performance. More technologies and markets forecast for rapid expansion into the 21st century will require, in many cases, not superinsulations but more efficient systems for a wide variety of cryogenic applications. The development of **efficient, robust thermal insulation systems** is a target area of work.
- Liquid nitrogen boiloff methods are used to test both conventional and new materials in **high vacuum, soft vacuum, and no vacuum** environments. Materials include combinations of reflection shields, fiberglass papers, polyester fabrics, aerogel composite blankets, fumed silica, aerogel powders, aerogel beads, and foams.
- A new **layered composite insulation** under development should benefit industry for the storage, transfer, or handling of low temperature fluids, by lowering the manufacturing and life-cycle costs for equipment. These insulation systems should also allow for more flexibility in the overall design and implementation of cryogenic systems, a key benefit to the cryogenic equipment on Earth and in Space.

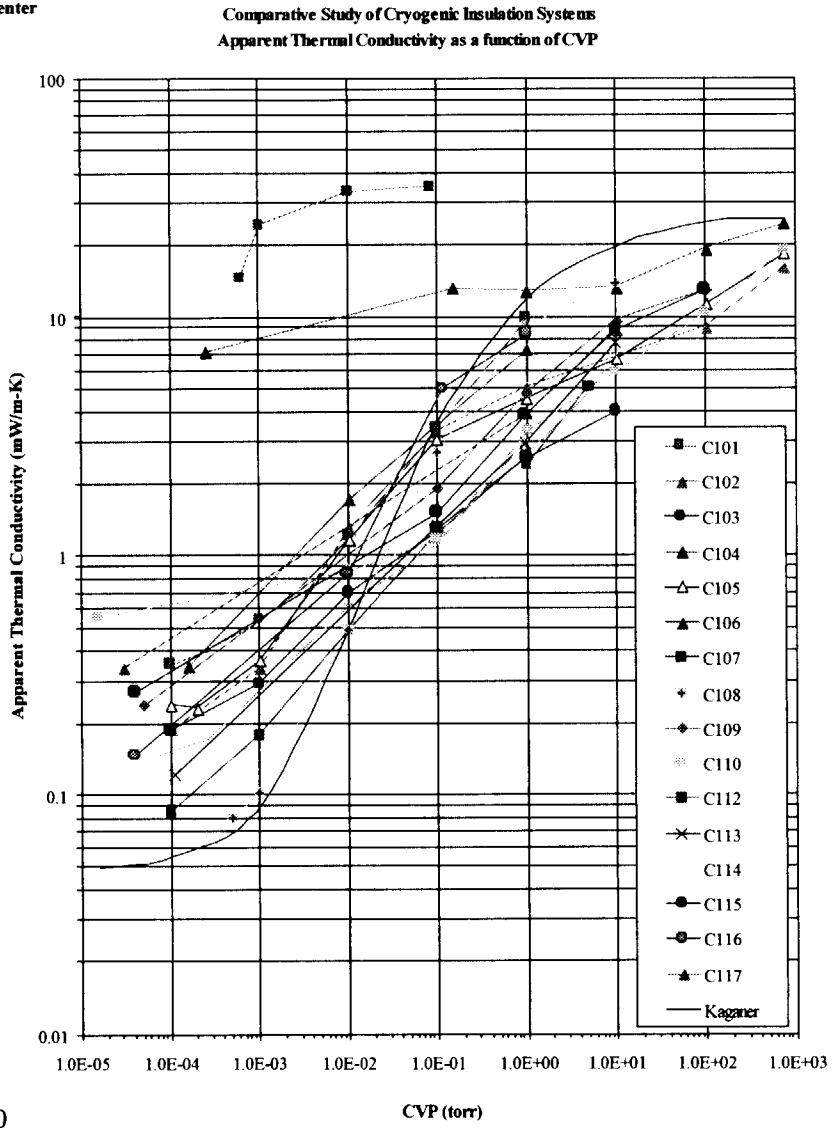
NO VACUUM



SOFT VACUUM



HIGH VACUUM



TEST SUMMARY CRYOSTAT-1

- Boundary temperatures were approximately 80 K and 280 K
- Typical installed thickness was 25-mm.
- Residual gas was nitrogen.
- Layered composite C107 gave superior performance of 2.4 mW/m-K (R-60) at 1 torr which is about four times better than the benchmark MLI C108.
- C107 was comparable to the benchmark MLI at high vacuum (0.09 versus 0.08 mW/m-K).

APPLICATIONS

- Low Cost High-Efficiency Pipelines for Long Distance Transfer of Cryogens
- Long Term Storage of Cryogens on Mars Using Soft Vacuum Thermal Insulation System
- Long Flexible Cryostats for High-Temperature Superconducting Cables

APPLICATIONS

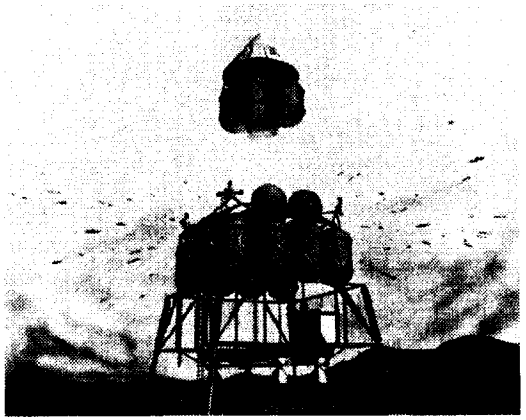
Low Cost High-Efficiency Pipelines for Long Distance Transfer of Cryogens

- Thriving spaceports of the future will rely on new approaches to supply of the requisite propellants and gases. Services built around thermally efficient, integrated launch pads supplied by centralized plants for both energy conversion and cryogenic production are envisioned. A key part of these services will be the transfer pipelines to deliver the cryogenic fluids (helium, hydrogen, nitrogen, and oxygen) across long distances. Achieving the goal of an "energy integrated" launch site can be done if all elements are given due economic consideration at the start of the design concept.
- Current work includes the development of low-cost high-efficiency pipelines for the long distance transfer of cryogens. Two commercial off-the-shelf products are being tested: a vacuum-jacketed pipeline with multilayer insulation and two standard bayonet joints and a foam insulated pipeline (both are 60 foot length). The heat leak of this pipeline, which will be determined through a series of liquid nitrogen boil-off tests, will also serve as a benchmark for thermal performance comparison. New pipelines, both rigid and flexible, using experimental insulation materials, will be fabricated and tested.

APPLICATIONS

Long Term Storage of Cryogens on Mars Using Soft Vacuum Thermal Insulation System

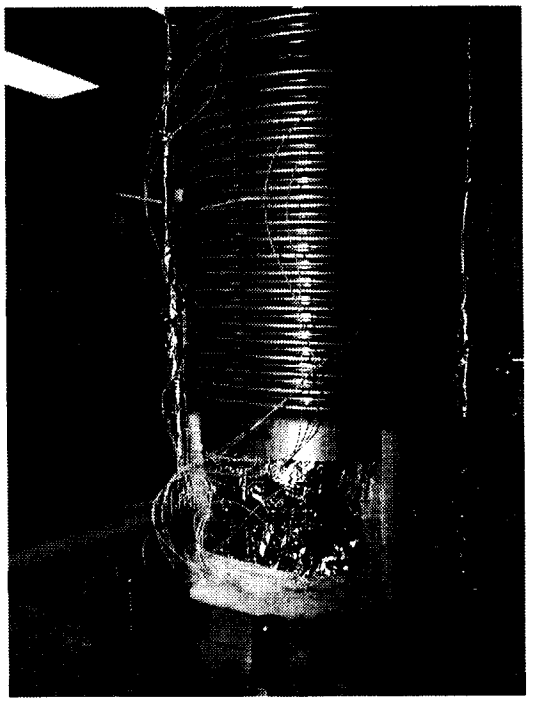
- Missions to explore Mars will require complex, autonomous systems that are highly energy efficient, integrated across all subsystems, and rugged. The long term storage of cryogens, in particular liquid oxygen and liquid methane, is an important challenge for the planned step by step success of these missions. Liquid oxygen supplies for life support and for return trips to Earth will be produced well in advance of the human missions and must remain ready to use for a variety of contingency scenarios. The atmosphere on Mars is a "soft vacuum" (about 5 torr) composed primarily of carbon dioxide.
- Current work is focused on the test and evaluate the thermal performance of experimental materials in the approximate Martian environment. This region is very dynamic because radiation, gas conduction, and convection (as well as solid conduction) are all significant contributors to the total heat leak rate. Tests are typically conducted in nitrogen (for comparison), in carbon dioxide, and in high vacuum as well. Materials tested to 77 K include aerogels in loose fill, blanket, and layered composite forms.



APPLICATIONS

Long Flexible Cryostats for High-Temperature Superconducting Cables

- High temperature superconducting (HTS) materials for power transmission applications are now being demonstrated in prototype situations. Future space applications for HTS materials, in addition to power transmission, include areas such as microwave communications, quantum devices, propulsion by plasma beams, and electromechanical actuators. Global proliferation of long length power cable systems, from the refrigeration point-of-view, will depend on an energy efficient cryogenic system that is economical to manufacture and operate. An inherent element of these supporting cryogenic systems is the thermal insulation system.
- Current work is focused on thermal management of HTS power transmission equipment for future energy needs. Insulation performance levels of materials versus those of typical systems in operation have been described through extensive cryostat tests in the 77 K temperature range. A simulated section (1 meter) of a flexible cryo power cable has been constructed. Measurement of the overall thermal performance under varied conditions of vacuum level and mechanical loading is being performed. This research study being done in cooperation with Oak Ridge National Laboratory through the Department of Energy's Superconducting Partnership Initiative.



CRYOGENICS TESTBED TECHNOLOGY FOCUS AREAS

SUMMARY

Thermal Insulation Systems

- Energy efficient cryogenics

Cryogenic Components

- Valves, pumps, and sensors

Propellant Process Systems

- Liquid hydrogen, liquid oxygen densification

Low-Temperature Applications

- High temperature superconductivity