NASA

Lewis Research Center
Space Flight Systems Directorate

CFTO

ORBITAL STORAGE & SUPPLY

OF

SUBCRITICAL LIQUID NITROGEN

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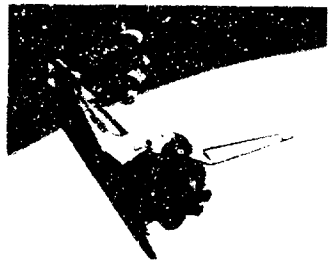
Cryogenic Fluids Technology Office

Cryogenic Fluid Management Technology

Subcritical cryogenic fluid management has long been recognized as an enabling technology for key propulsion applications, such as Space Transfer Vehicles (STV) and the on-orbit cryogenic fuel depots which will provide STV servicing capability. The LeRC Cryogenic Fluids Technology Office (CFTO), under the sponsorship of OAST, has the responsibility of developing the required technology via a balanced program involving analytical modeling, ground-based testing and in-space experimentation.

CRYOGENIC FLUID MANAGEMENT TECHNOLOGY

GOAL:
DEVELOP THE TECHNOLOGIES ESSENTIAL FOR THE EFFICIENT STORAGE, SUPPLY AND TRANSFER OF SUBCRITICAL CRYOGENIC FLUIDS IN THE ENVIRONMENT OF SPACE

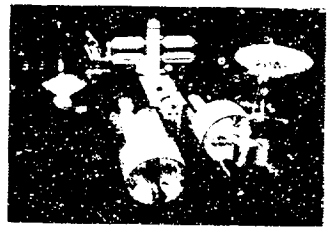


IN SPACE EXPERIMENTATION

ANALYTICAL MODELS

GROUND BASED TESTING

SPACE OPERATIONS



SPACE DEFENSE SYSTEMS

TRANSFER VEHICLE

Cryogenic Management Technologies

The overall objective of the CFTO program is to develop the technology required to perform storage, supply and transfer of subcritical cryogenic liquids in the low-gravity environment of space. In addition, the program is addressing fluid handling issues and developing advanced cryogenic system instrumentation.

SPACE FLIGHT SYSTEMS DIRECTORATE

CRYOGENIC FLUIDS TECHNOLOGY OFFICE

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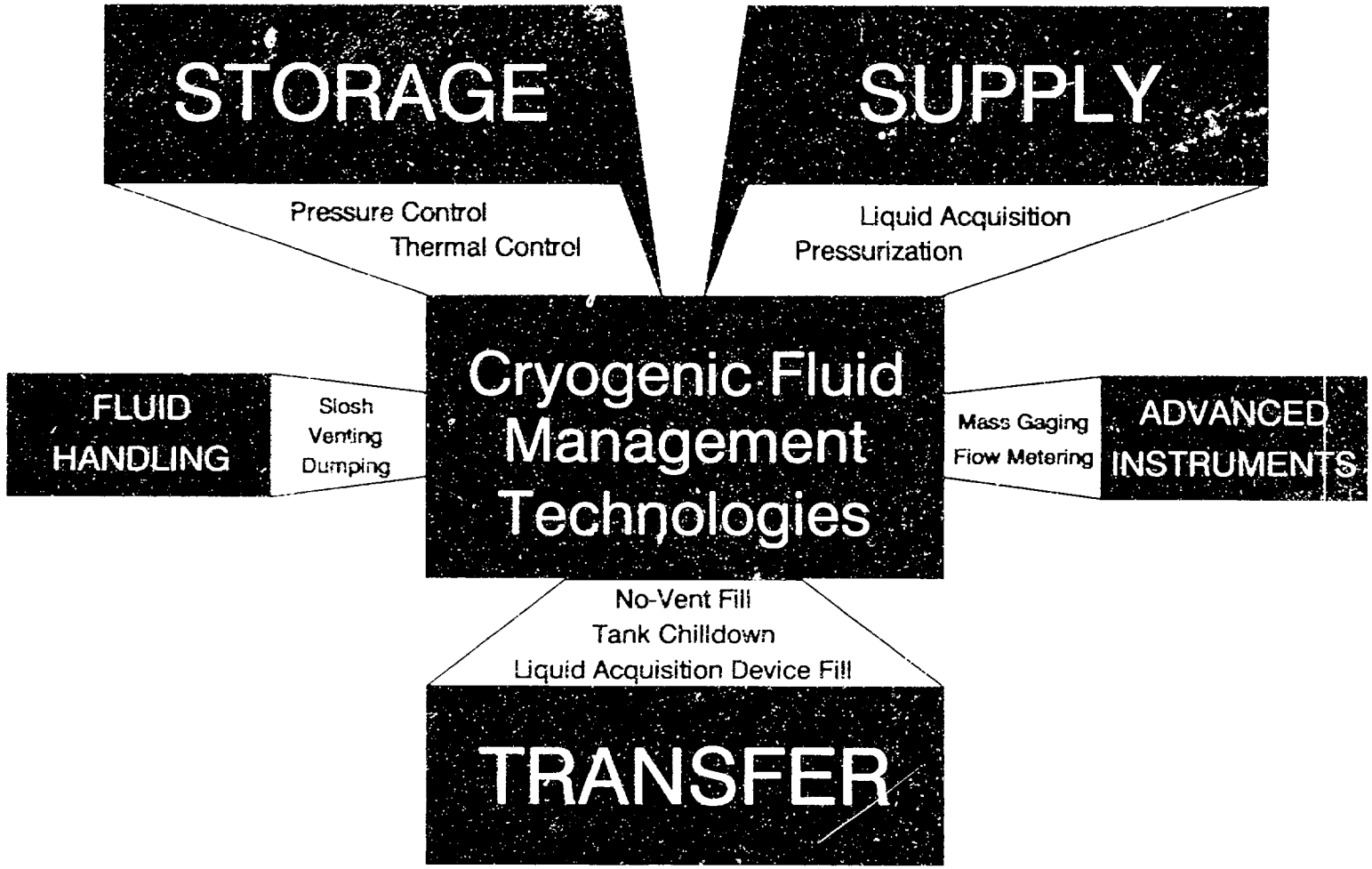


Nitrogen Storage and Supply

With the currently envisioned definition of the Evolutionary Space Station Freedom, cryogenic liquid requirements for experiment cooling applications have increased the importance of developing subcritical fluid management technology. In addition, the requirements for gaseous nitrogen to be used in the environmental control and life support system, particularly to meet the anticipated growth beyond the initial operating capability, suggests that subcritical cryogen resupply also be considered as a potentially enhancing technology which would reduce earth-to-orbit hardware weight and on-orbit power requirements.

NITROGEN STORAGE AND SUPPLY

SPACE STATION FREEDOM NEEDS

- ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (GN_2)
- EXPERIMENT COOLING (LN_2)

STATE-OF-THE-ART SUPERCRITICAL CRYOGEN STORAGE SYSTEM

- HEAVY STORAGE VESSEL CONSTRUCTION (≈ 25 LB/100 LB OF FLUID)
- HEATERS TO MAINTAIN PRESSURE (≈ 2 KWH/100 LB OF FLUID)
- FLUID DENSITY AND COOLING ABILITY CONTINUOUSLY REDUCED AS CRYOGEN IS UTILIZED

BENEFITS OF SUBCRITICAL CRYOGEN STORAGE AND SUPPLY SYSTEM

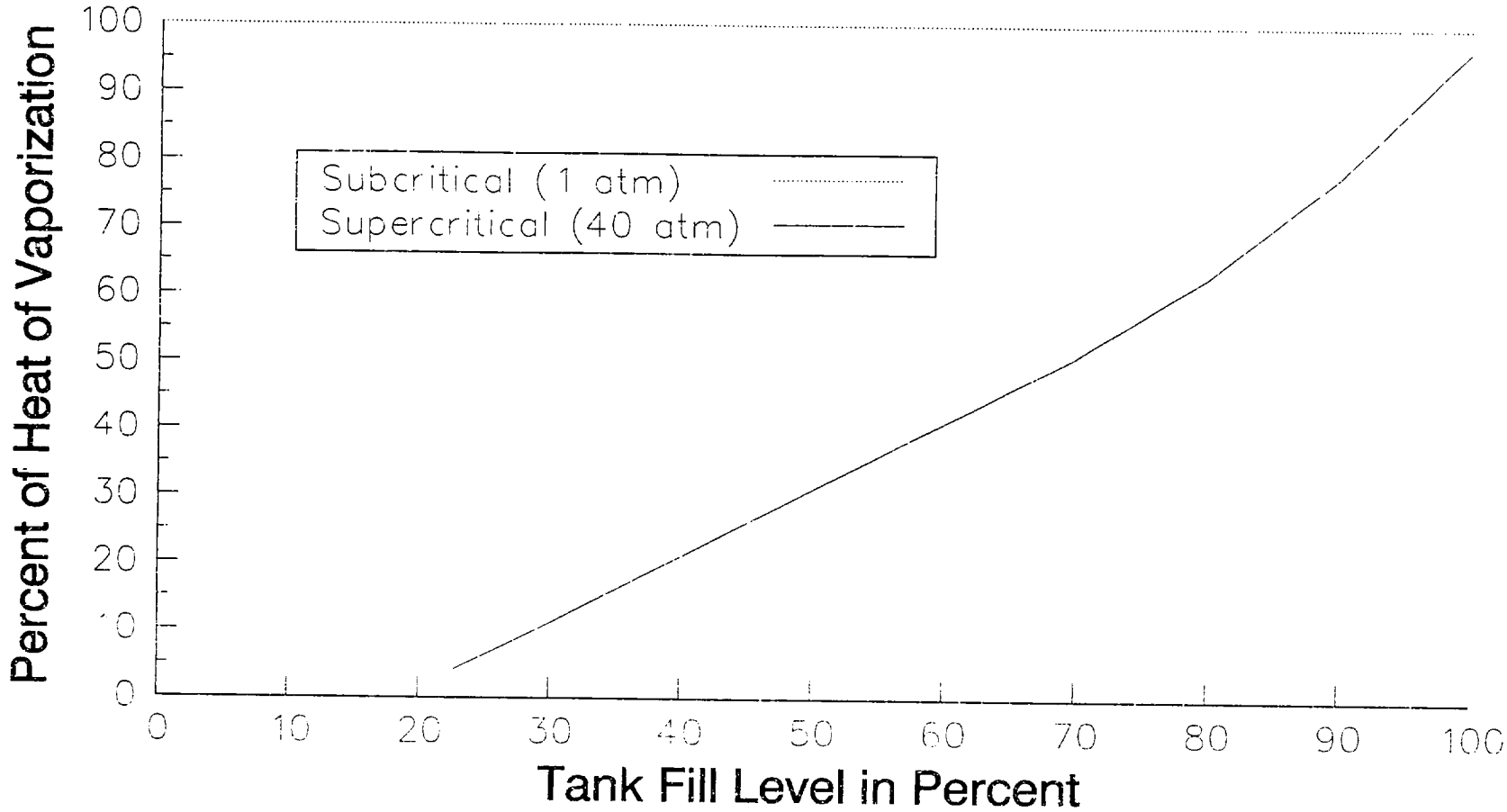
- REDUCED WEIGHT AND ELECTRICAL POWER
- CONSTANT COOLANT THERMODYNAMIC CHARACTERISTICS

Cryogenic Nitrogen Cooling Capability

The obvious disadvantage of supercritical systems is the high pressure levels required which translates directly into greater system weight. Less obvious disadvantages of supercritical systems are associated with the need to maintain the required supercritical pressure level, as fluid is withdrawn from the system, by adding energy to the tankage, usually in the form of heat. For some applications, there is also a disadvantage resulting from the fact that the fluid is continually decreasing in density (mass is being removed from a constant volume system) and increasing in enthalpy (due to the heat addition required to maintain pressure) thus reducing the fluid's cooling capability.

Cryogenic Nitrogen Cooling Capability

Subcritical vs. Supercritical Storage



LN_2 System Demonstration Technical Objectives

Cryogenic Liquid Storage: The specific objective of this test is o evaluate the ability of passive thermodynamic vent systems (TVS) to maintain nearly constant cryogenic tank pressure. The TVS will incorporate a heat exchanger either mounted on the tank wall or attached to the liquid acquisition device (LAD). Experimentally determined vent rates will be compared with analytical performance predictions for heat fluxes typical of both vacuum jacketed and foam/MLI insulated cryogen storage systems.

Liquid Nitrogen Supply: The specific objective of this test is to demonstrate the ability to supply subcooled liquid nitrogen to a simulated user. A total communication capillary device fabricated from fine mesh screen shall be employed for liquid acquisition. Gaseous nitrogen, stored in high pressure bottles, shall be used for liquid expulsion. Experimentally determined rates of pressurant consumption will be compared with analytical predictions for several initial liquid fillings, two discrete values of liquid expulsion rate, and at least two values of liquid subcooling.

Pressurant Bottle Recharging: This test will demonstrate the ability to resupply a gaseous nitrogen pressurant bottle by injection of a metered quantity of liquid nitrogen. One of the pressurant bottles will be depleted during the course of the liquid supply tests and then evacuated to space. The pressurant bottle will be sequentially chilled down to an analytically determined "target temperature," once again evacuated to space and then no-vent filled with a small quantity of liquid nitrogen. The bottle will be allowed to self-pressurize due to environmental heating and the final tank pressure will be compared with analytical prediction.

ON-ORBIT NITROGEN STORAGE AND SUPPLY SYSTEM DEMONSTRATION

TECHNICAL OBJECTIVES

- CRYOGENIC LIQUID STORAGE
- LIQUID NITROGEN SUPPLY
- PRESSURANT BOTTLE RECHARGING
- LIQUID ACQUISITION DEVICE PERFORMANCE
- ACTIVE PRESSURE CONTROL EXPERIMENTATION*

ANTICIPATED APPROACH

- SHUTTLE CARGO BAY PAYLOAD
- HITCHHIKER "M" CLASS CARRIER
- DESIGNED AND QUALIFIED FOR THREE FLIGHTS

MILESTONES

- PARALLEL PHASE A/B STUDY CONTRACTS AWARDED JANUARY 1990
- FY92 PHASE C/D COMPETITIVE PROCUREMENT
- LAUNCH LATE IN 1994

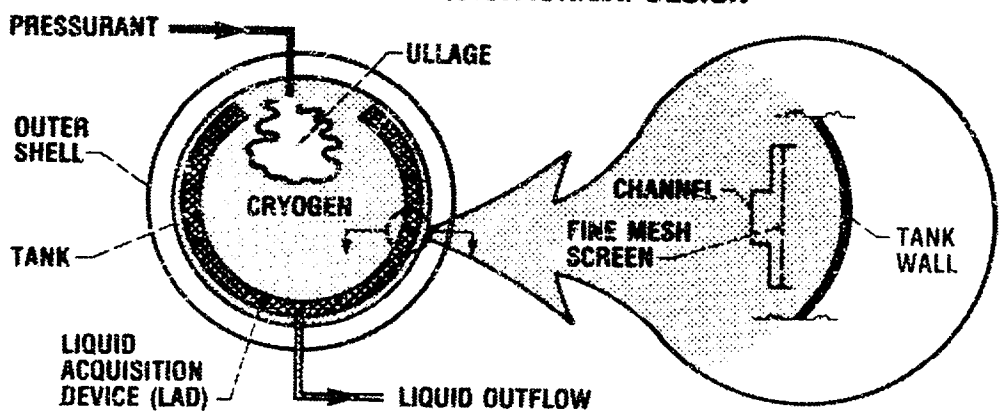
*INTERIM STV TECHNOLOGY NEED, NOT REQUIRED FOR SSF

LN_2 System Demonstration Technical Objectives (Continued)

Liquid Acquisition Device Performance (Expulsion Efficiency): The specific objective of this experiment is to determine the quantity of vapor-free liquid that can be removed from a cryogen storage tank which employs a total communication liquid acquisition device fabricated from fine mesh screen material. The Shuttle OMS or primary RCS will be employed to provide a relatively high acceleration environment which will stress the LAD retention capability during the final liquid expulsion. The experimentally determined value of liquid residuals will provide a single data point for partial verification of the analytical models describing LAD performance.

LIQUID SUPPLY

FLUID ACQUISITION/EXPULSION



CURRENT STATUS
- LAD ONLY FLOWN WITH NON CRYOGENIC LIQUIDS
- GROUND BASED CHARACTERIZATION OF SCREEN MATERIAL

ISSUES/CONCERNS
- LAD PERFORMANCE/EXPULSION EFFICIENCY
- IMPACT OF HEAT ADDITION/SCREEN DRYOUT
- LONG TERM CONTAMINATION/DEGRADATION
- ON ORBIT REFILLING

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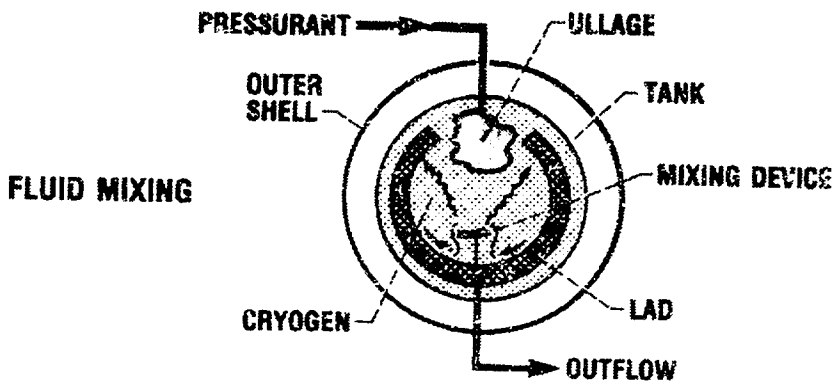
LN_2 System Demonstration Technical Objectives (Continued)

Active Pressure Control: The objective of this experiment is to evaluate the ability of jet-induced mixer, coupled with a compact TVS heat exchanger, to control cryogenic storage tank pressure. Experimental data will be acquired for comparison with analytical predictions of the performance of the active pressure control system and to provide partial verification of the analytical models which describe the physical processes involved. Specifically, the experiment will be designed to parametrically investigate the effects of tank heat flux, axial-jet flow rate, TVS heat exchanger flow rate, tank liquid fill level, and the acceleration environment on: (1) thermal stratification of the test fluid, (2) thermal destratification of the test fluid by axial-jet induced mixing and, (3) tank pressure decay during TVS operation.

LIQUID STORAGE

PRESSURE CONTROL TECHNIQUE FOR LONG TERM CRYOGENIC LIQUID STORAGE IN SPACE



CURRENT STATUS
- NO IN SPACE DEMONSTRATION WITH SUBCRITICAL LIQUIDS

ISSUES/CONCERNS
- MIXING FANS REQUIRE POWER - INCREASE HEAT INPUT
- INCREASE COST AND COMPLEXITY
- FLUID DYNAMICS GRAVITY DEPENDENT

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