N88-15927

Ames Research Center Cryogenics Program

Peter Kittel

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Objective:

Develop the cryogenic technology needed for future space missions

Emphasis:

Developing the technology needed for infrared astronomy missions

Current Program:

A two part program

Technology development in support of the SHOOT (Superfluid Helium On-Orbit Transfer) Project

OAST Sponsored Technology development in support of future missions generic technologies and on-going development efforts

Brief History of the Ames Program:

OAST-funded program for more than ten years (started FY 77)

Thrust: Develop the cryogenic technology for space based science

Emphasis: Needs of future IR missions

Selected Accomplishments:

- -1g cryogen containment
- Superfluid leak sealant
- Thermoelectric cooler (80K)
- Self-contained He3 cooler (0.27K)
- Portable He3 Cooler (0.3K)
- ADR temperature stability theory
- VCS optimization
- Mini ADR (0.05K)
- Pressed contact conductivity
- TAO predictor
- PODS-IV
- Low cavitation helium pump
- He-II flow meter
- JTX demo (1.5K)
- Temperature stabilized ADR (0.2K)
- Cryo valve
- Ruggedized thermometers
- -1g He3 Cooler
- VCS heat exchange model
- O-g He3 design guide
- PODS-III
- Helium transfer workshop
- Theory of FEP limits
- Orifice pulse tube refrigerator (60K)
- High Reynolds No. He-II dynamics

SHOOT Program Summary

Joint GSFC/ARC/JSC Program (Overview given in companion presentation)

ARC responsible for selected technologies

Centrifugal pump
Including fluid management device

Flow meter

Friction factor of superfluid helium

EVA
Including transfer line

Data/command system
Including AFD controller

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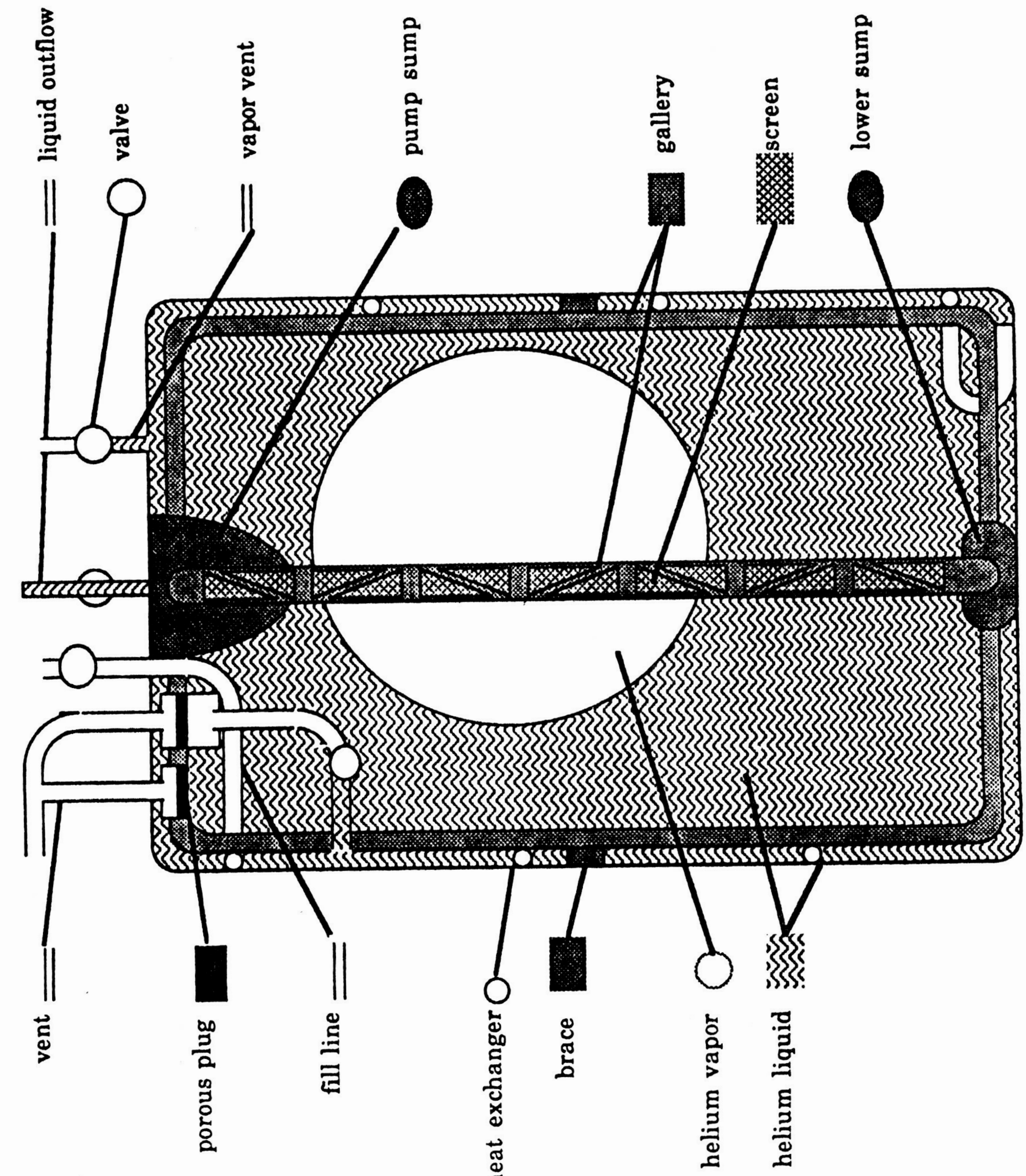
Fluid Management System



Centrifugal Pump

Single stage centrifugal pump (flow >800 1/hr, head <170 torr)

Two inducers tested:

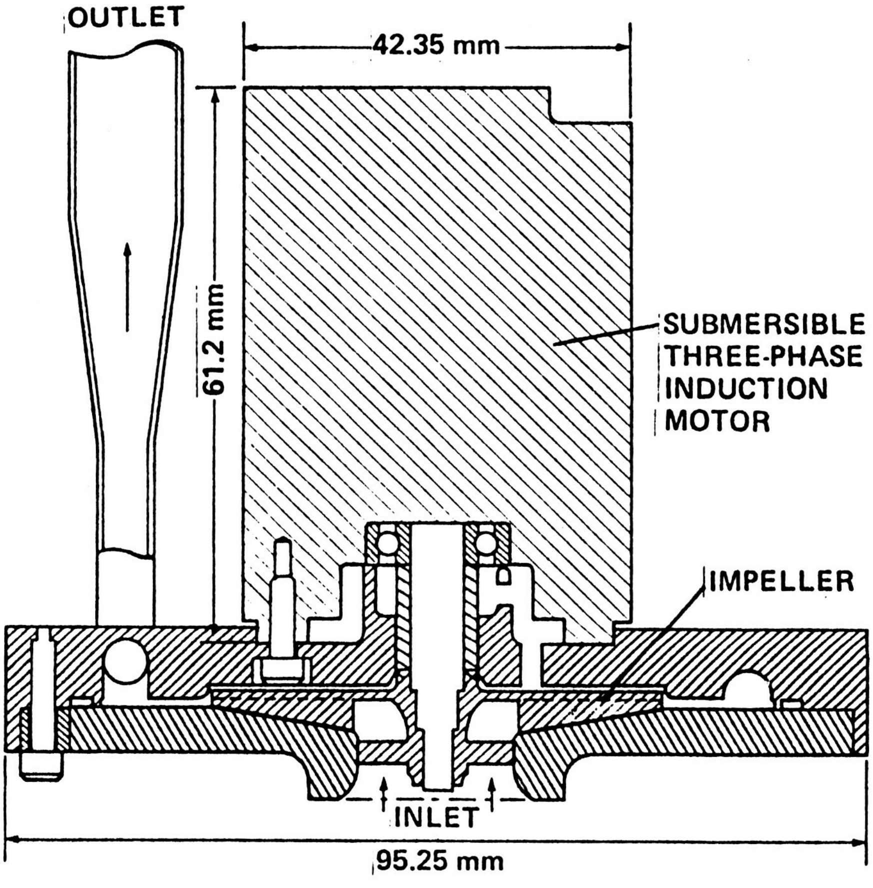
6-bladed fan type
Pump cavitates for <300 mm NPSH in superfluid (desired 0 NPSH)

3-bladed screw
Pump cavitates for <100 mm NPSH in superfluid
<-100 mm NPSH in normal fluid

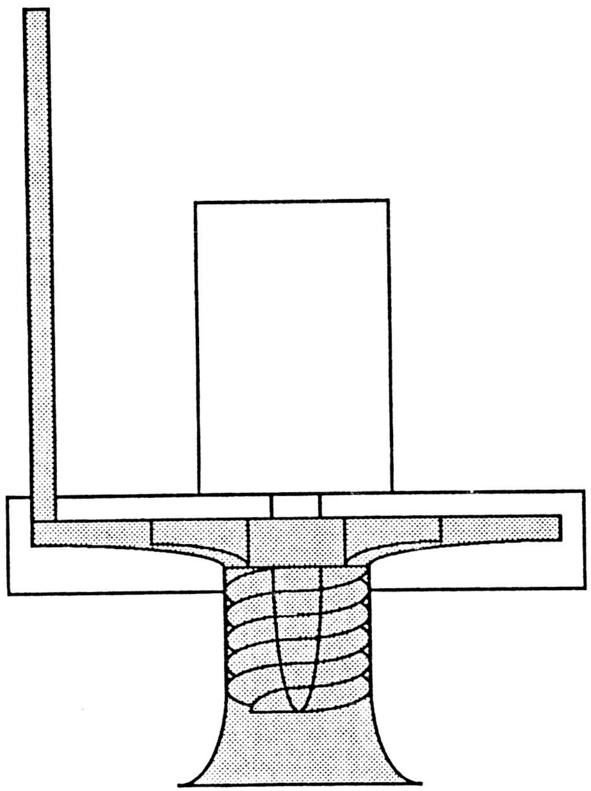
New inducer to be tested:

Jet type (part of pump's output is diverted to the inlet to entrain the fluid)

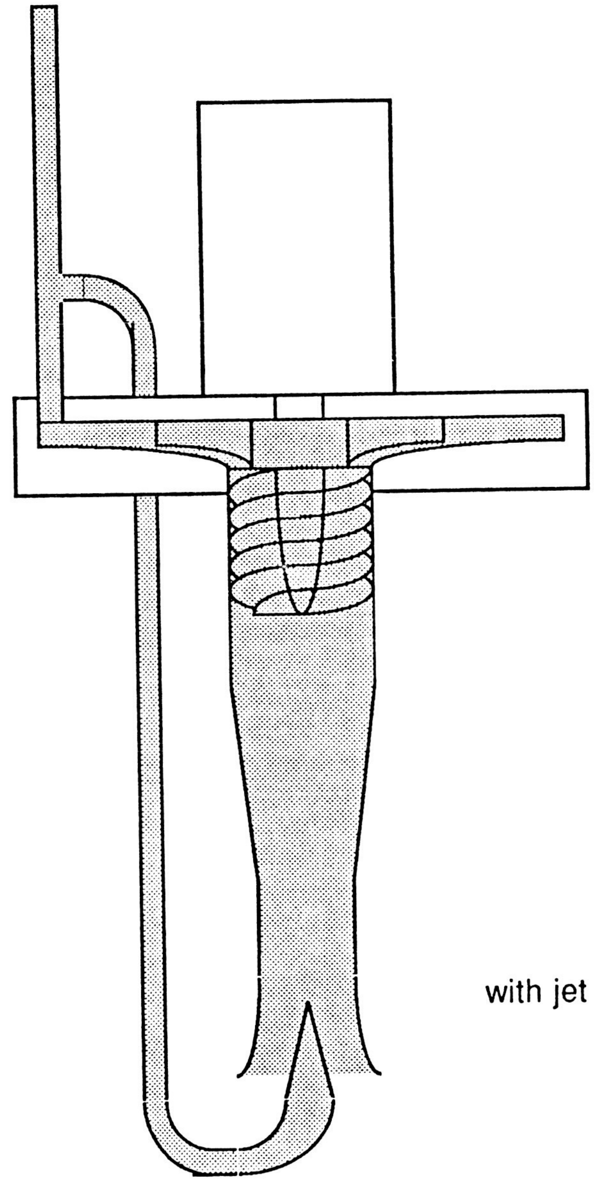
There is some evidence that the heat flowing from the pump through the screen can cause an additional head rise in the smallest sized screens, due to the thermomechanical effect.


OUTLET
42.35 mm
61.2 mm
SUBMERSIBLE
THREE-PHASE
INDUCTION
MOTOR
IMPELLER
INLET
95.25 mm

Centrifugal Pump



with screw inducer



with jet inducer

Flow Meter

Two type tested:

Turbine meter

Repeatable readings in both superfluid and normal fluid helium

Cavitates easily in superfluid helium if backpressure is low

Difficult to cryo rate the small bearings

Gas flow/2-phase flow can over-spin rotor

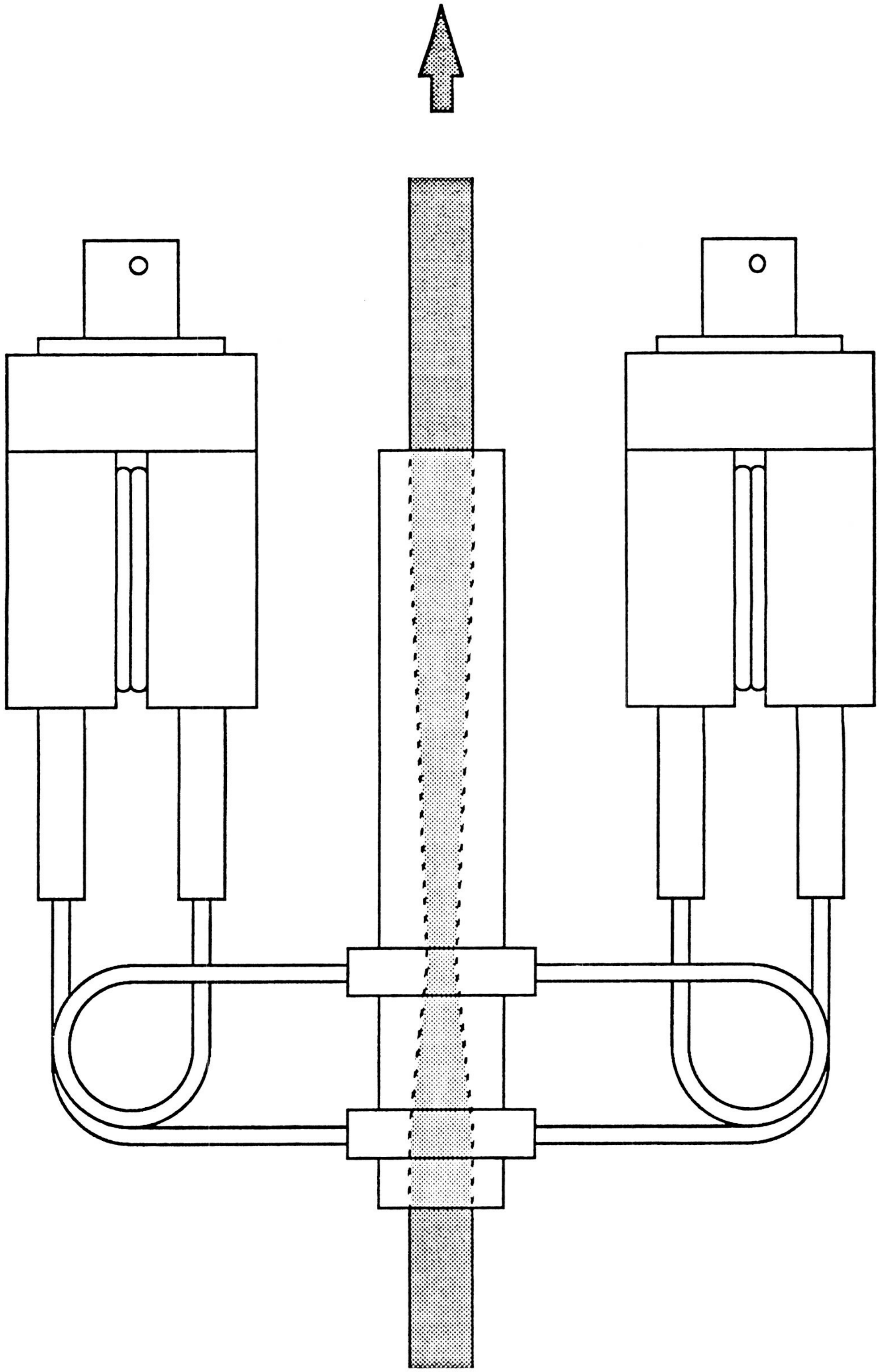
Not selected

Venturi meter

Repeatable readings

Cavitates easily in superfluid helium if backpressure is low
(at about 0.05 psi below saturation)

Candidate meter to be used with 2 differential pressure guages venturi meter



Friction Factor of Superfluid Helium

Helium flow test facility:

Flow path:	Multiples of 5 m	< 20 cm diameter
Temp/pres:	1.5-5 Kelvin	svp - 5 bar
Flow rates:	< 2500 l/hr	

Straight tube results:

At high Reynold numbers (10^4 - 10^6) superfluid helium behaves like a Newtonian fluid

Bellows section results:

Pressure drop approx. 50% greater than predicted

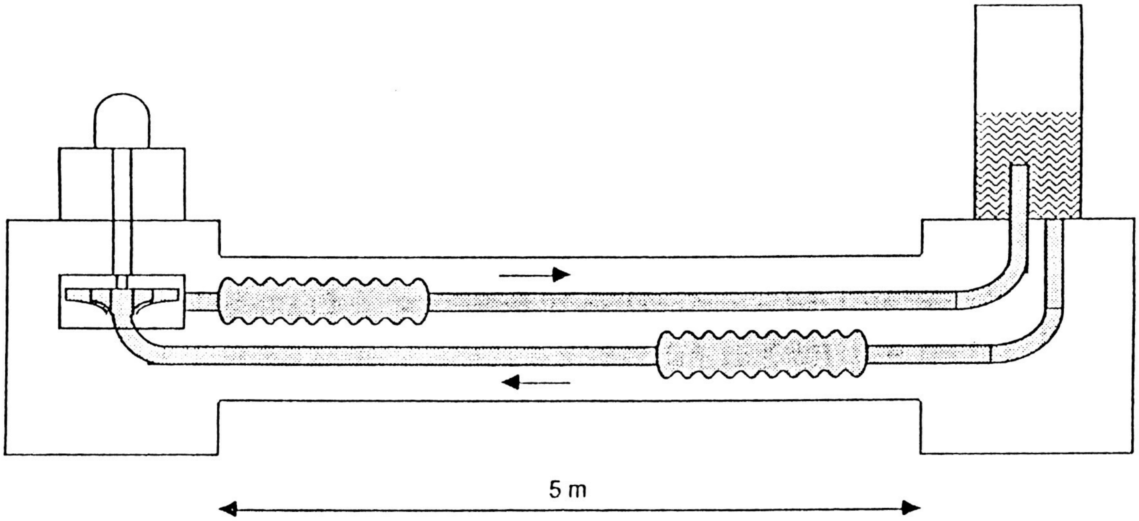
Based on modelling bellows as a series of orifices (a correlation that works for water and for liquid nitrogen

Planned work:

More tests with bellows

Flow coefficient for valves

Liquid Helium Flow Test Facility



EVA

Purpose:

Demonstrate the human factors associated with helium resupply handling transfer line

- Operating coupling
- Interface with control/data system

Demonstrate EVA coupling and transfer line

- Measure thermal performance before and after coupling operation
- Measure flow impedance before and after coupling operation

Procedure:

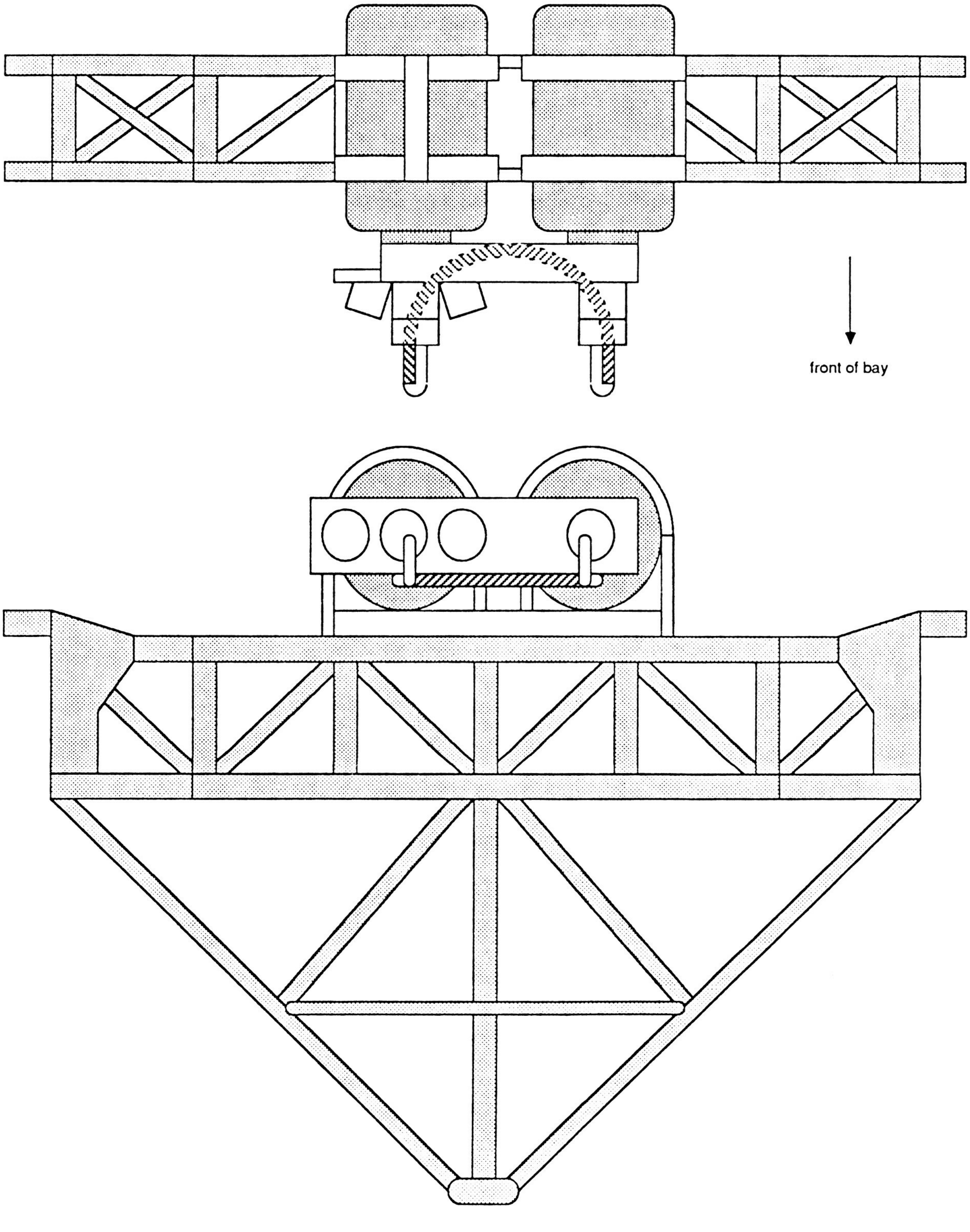
Launch with coupler mated

Perform several transfer operations

Demate then mate coupling

Perform several more transfer operations

EVA coupler concept



Data/Command System

Approach:

Process control core
- Real time data acquisition

- Real time control
- Manual control
- Pre-packaged routines

- Growth to full automation

Expert system shell
- Fault diagnosis
- Valves, sensors, pumps

- Growth potential to full up expert system with fault work arounds

OAST Technologies

Storage technologies

PODS
Support materials
Design tools and options

Active coolers

Pulse tubes
Sub-kelvin coolers
- He-3
- ADR
- Dilution

2 Kelvin cooler

Passive Orbital Disconnect Struts (PODS)

Variable strength variable thermoconductance Dewar support system

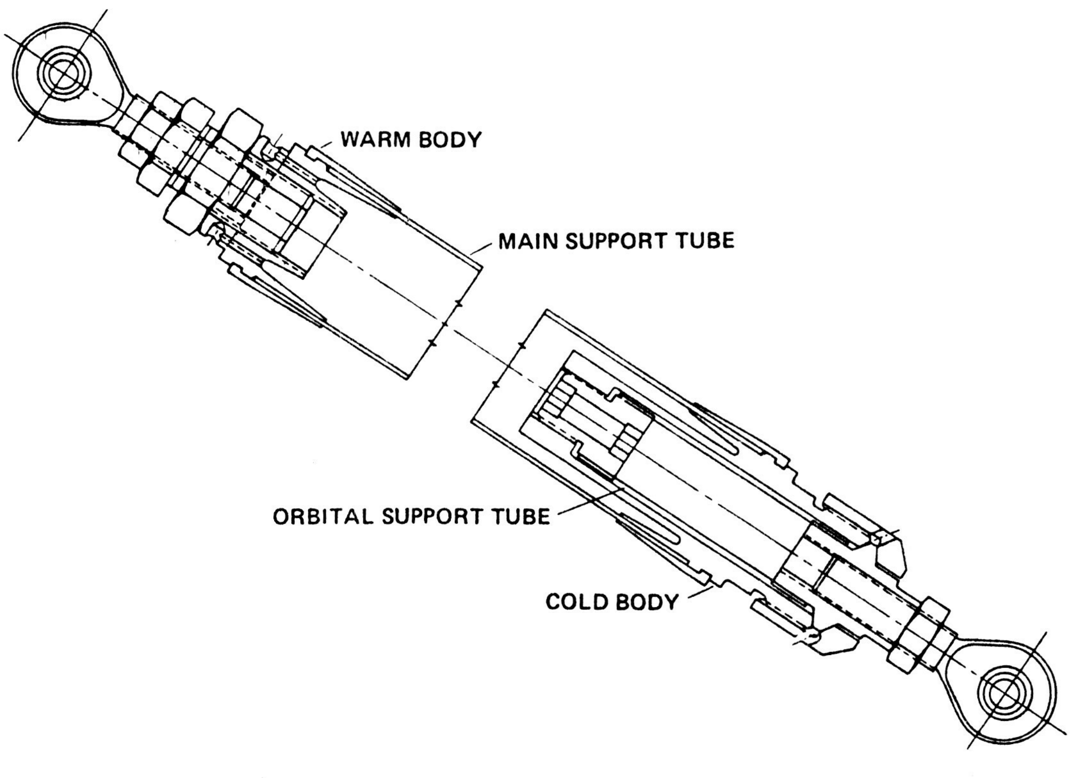
- High strength on launch
- Low conductance on orbit
- Extensive ground testing (flight ready - chosen for GP-B)

Best suited for missions where orbital frequency requirement < launch frequency requirement

Two versions developed

- **PODS-III:** best thermoconductance to strength ratio
- Suited for moderated sized systems
- **PODS-IV:** best side load resistance
- Suited for system with many/heavy shields

DEWAR SUPPORT WITH PASSIVE ORBITAL DISCONNECT (PODS)



PODS III

- HIGH LAUNCH STRENGTH
- LOW ORBITAL CONDUCTANCE
- FLIGHT READY

PODS IV

- INCREASED SIDE LOAD CAPACITY

Support Materials

New materials can improve both strap type and PODS type supports

Want greater strength (ultimate, buckling, fatique, etc.) to conductance ratio

Glass - Epoxy: Used in IRAS and COBE

Graphite - Epoxy: Better below 30 Kelvin (used in PODS)

Alumina - Epoxy: Under development by various groups

Conductance similar to glass above 30 K
Conductance similar to graphite below 30 K
Ultimate strength similar to glass
Stiffness similar to graphite

Alumina - PEEK (a polimerized ketone) Ames/NBS program

Promises to be better than epoxy (also less permeable to helium diffusion)

Pulse Tubes

Motivation:

Need for low cost, highly reliable, high efficiency coolers (15-100 K)

Pulse tubes:

One moving part (a room temperature compressor with a room temperature seal)

Uses existing G-M and Stirling cryocooler technology
compressors, regenerator

No cold displacer

Phase shift between pressure and velocity waves is supplied by balast volume and orifice

Heat pumping occurs within empty (except for working gas) tube

Heating/cooling is the result of discontinuity of enthalpy flow at ends of tube

Bread-board single stage:

60K min., 16W @ 100K, 50-90% efficient (tube only)

Overall efficiency approaches that of Stirling cycle

Model:

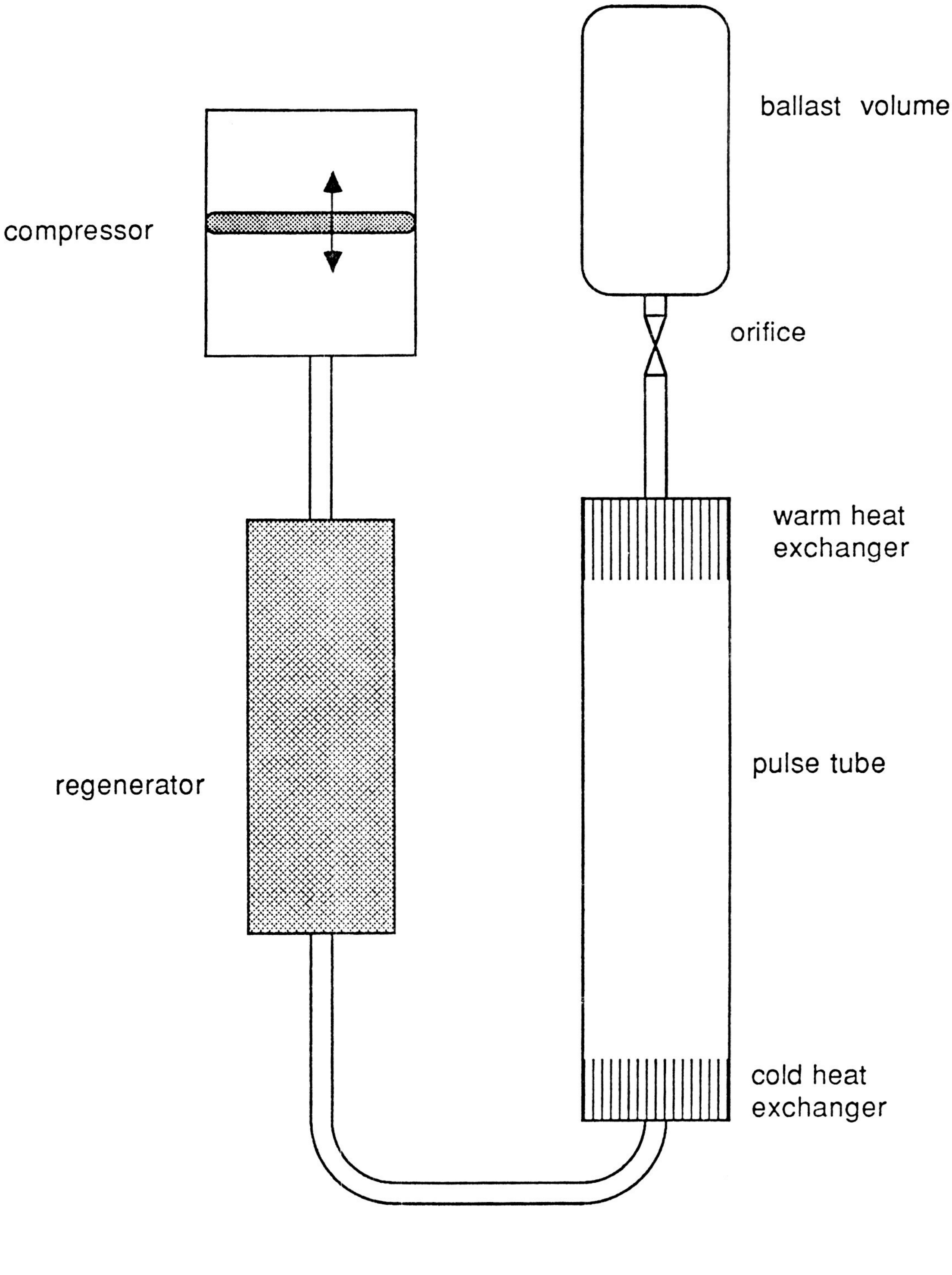
Math model being developed to study optimization of cycle cooling power scales with volume of pulse tube

Future work:

Build demonstration unit

Measure performance at lower temperatures (a second stage)

Pulse tube refrigerator



Sub-Kelvin Coolers

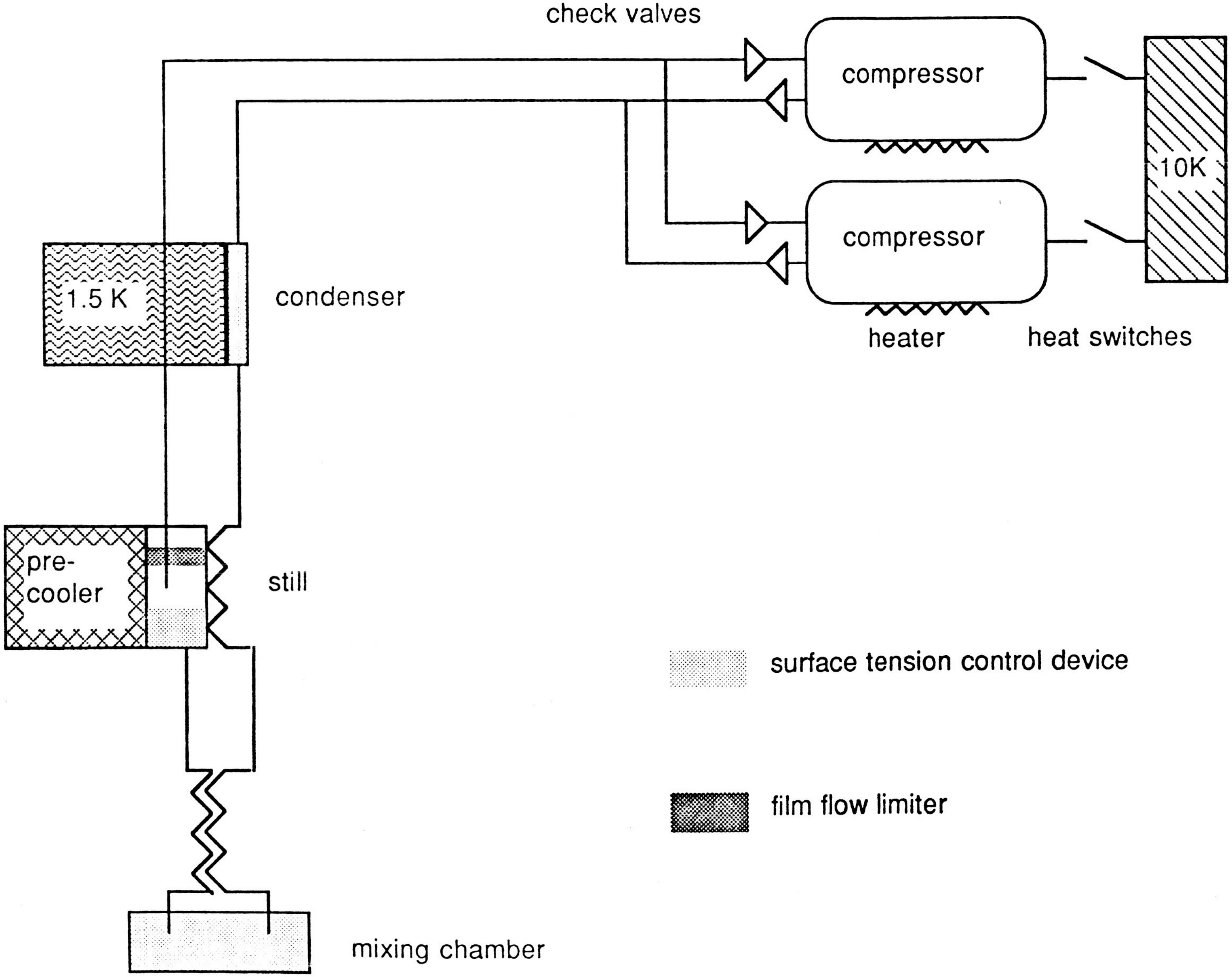
Dilution Refrigeration (300-5 mK)

- Uses a $^{3}He/^{4}He$ mixture
- Has become the refrigerator of choice in most ground based applications

Approach

- Develop ^{3}He circulating type circulating type
  - 20 years of commercial experience to draw upon
  - Requires the control of 3 fluid interfaces
  - Use surface tension devices to control fluid interfaces
  - (JPL is trying electrostatic control)
  - (MSFC is trying ^{4}He circulating type)

Dilution refrigerator



Sub-Kelvin Coolers

Adiabatic demagnetization refrigerator (<0.1 Kelvin)

- Simplest (gravity independent), closest to being flight ready of all sub-kelvin coolers

- Ames has developed two working ADR's with excellent performance
  - 14 μK stability at 100 mK for 12 hr
  - Achieves temperatures down to 50 mK
  - 90% duty cycle

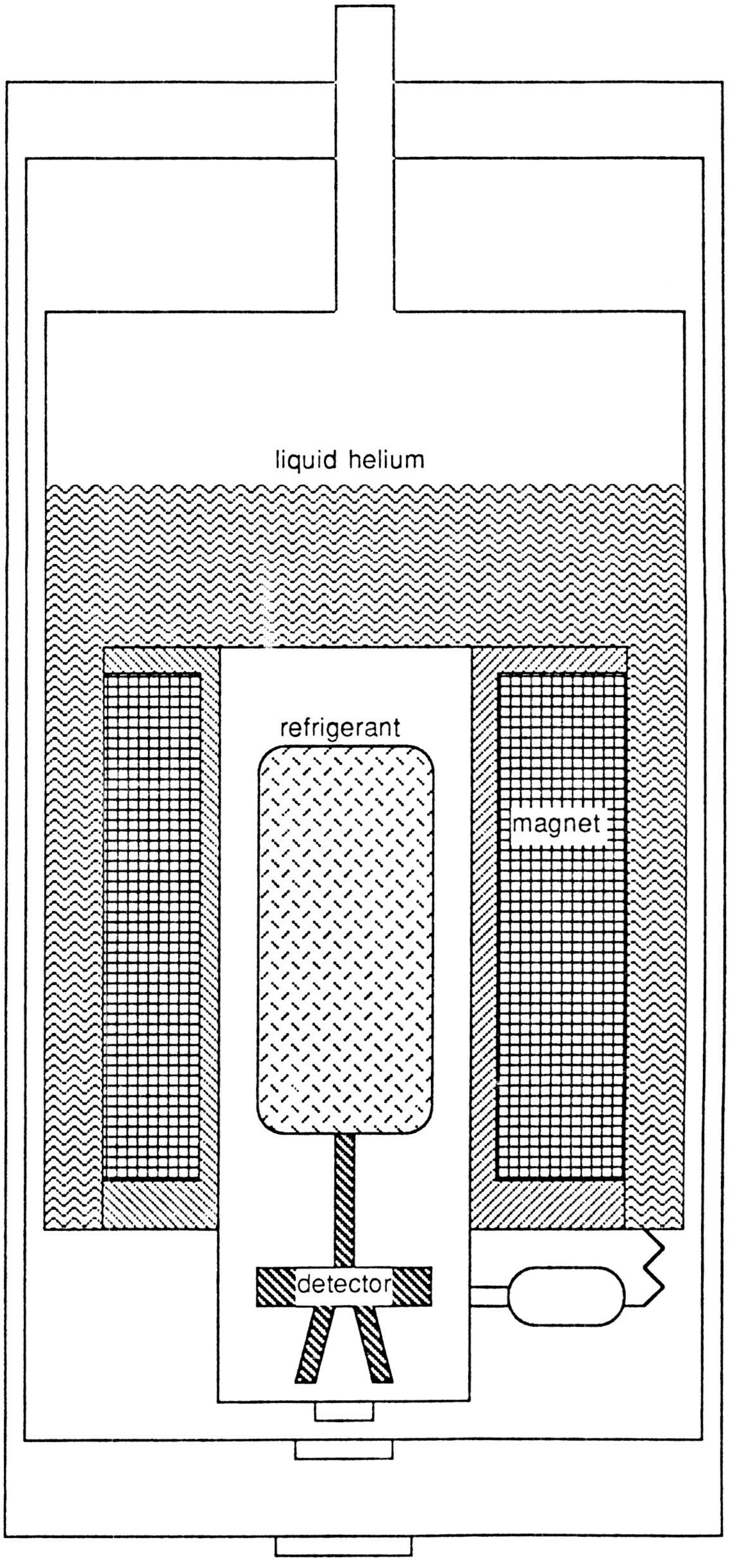
Operating principal:

- Magnetization of paramagnetic material (a solid) at 2 Kelvin with 6 Tesla field
- Adiabatic demagnetization to operating temperature
- Isothermal demagnetization to maintain temperature under feedback control
- Repeat

Current activities:

- Efficiency improvement
- Improved refrigerants (ones without water of hydration)

Adiabatic Demagnetization Cooler



2 Kelvin Cooler

Stored cryogens may not meet requirements of long life (<2 years)

Large heat load (>1 W @ 2 K) missions such as LDR

Goal:

Develop a final stage to work off coolers being developed in other NASA/DOD programs

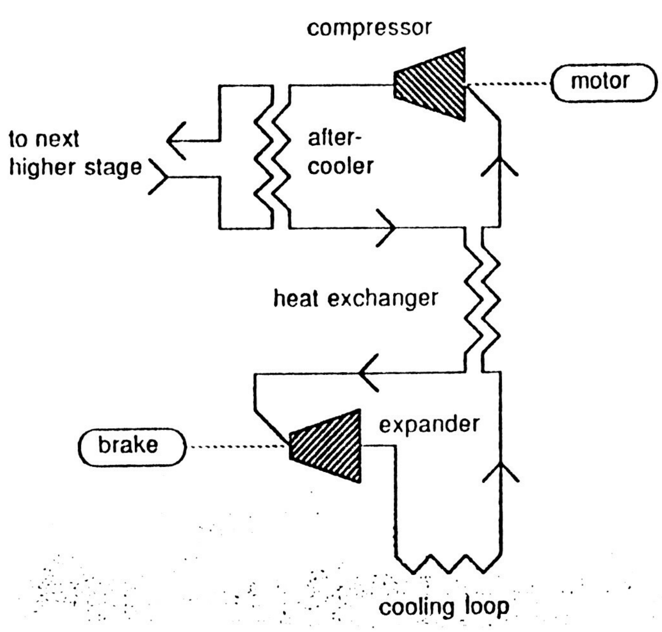
Possible approaches:

Reverse turbo Brayton

Magnetic cycles

Use of ^3He as working fluid

2K Cooling Stage



SPEAKER: PETER KITTEL/AMES RESEARCH CENTER

Mojibul Hasan/Lewis Research Center (Resident Research Associate)

I have a question about your pressure drop. On the straight tube, your pressure drop for helium correlates well with the prediction, however, in the bellows section, the pressure drop was 50 percent greater than predicted. Is this 50 percent over the entire range of flow you tested or only at the higher Reynolds numbers?

Kittel:

We've only made those measurements at the higher Reynolds numbers.

Hasan:

So, you had this inconsistency only at the higher Reynolds numbers; what was the system pressure?

Kittel:

It was near saturation; it was above, but not very much above.