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Beam splitter refrigerator/liquifier test summary conducted at the Cosmotron helium test facility

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No. 44

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BEAM SPLITTER REFRIGERATOR/LIQUEFIER TEST SUMMARY CONDUCTED AT THE COSMOTRON HELIUM TEST FACILITY

Purpose of Test

The purpose of this test was two-fold. (1) To have a manufacturer's representative train BNL personnel in the proper operation and maintenance of the machine. (2) To determine the refrigerator/liquefier capability when coupled with the 2' x 10' test dewar which will be employed at the Helium Test Facility for testing the beam splitting magnets and possibly for testing models for the H-10 magnet. The machine was tested and accepted in September 1971 at the manufacturer's facility in Waltham, Massachusetts.

System Description

The helium refrigerator-liquefier is a Cryogenic Technology, Inc.(CTI) Model #1400. It has two main features which are somewhat different than the standard model. First, manual valves have been installed in the cold box to allow proper utilization of the available refrigeration in the low pressure return gas stream. The heat exchangers can be completely by-passed or gas can return to the discharge side of either the first or second expansion engine, and finally the return gas can pass through the Joule-Thompson heat exchanger. The second feature is the transfer lines. Two separate vacuum-jacketed superinsulated transfer lines are used instead of the standard co-axial type of line. These lines are both 20 ft long and have a flexible section to aid in alignment between load and refrigerator. The high pressure line contains the remote-controlled Joule-Thompson valve.

A 2' x 10' vacuum-jacketed, superinsulated LN_2 shielded dewar was used as the liquid test dewar. Contained in the dewar were four different liquid level detectors; one resistor probe, one thermistor probe, and two superconductor probes. The output from the American Magnetic superconductor probe was fed to a chart recorder for permanent record. The remaining elements of the dewar included a heater, liquid withdrawal tubes, safety relief, LN_2 radiation shield, pressure indicator and two vacuum-jacketed bayonets for the helium supply and return lines.

The remaining components in the system included a high pressure gas supply, LN_2 charcoal purifiers and a helium gas recovery system.

System Start-up and Test

The test began on January 17, 1972. First, a number of system checks were conducted along with some component modifications. Late in the afternoon after some preliminary purging of the various systems, the major components were connected and warm helium gas was circulated continuously, without cooling, in a closed cycle which included a LN_2 charcoal purifier for removal of impurities. It was decided to continue this mode of operation until Tuesday morning. From 1700 on Monday the system was left unattended until normal working hours on Tuesday.

Sometime Monday evening the system cut off on high pressure compressor discharge. A plug of impurities had developed in the freeze-out purifier. Tuesday morning it was decided that additional clean-up was necessary. The dewar, refrigerator, and compressors were separated from one another. Clean-up of the system was done by alternately evacuating and filling with helium. The procedure was continued on respective components until mid-afternoon on Tuesday. It was determined at this point that the major source of contaminant was in the liquid dewar. Therefore, it was decided to freeze those impurities in the dewar before reconnecting the dewar to the other components. Liquid nitrogen was first allowed to cool the insulating vacuum nitrogen shield which is also heat stationed on the outside of the dewar's upper neck. This technique was continued until impurities began to freeze out on the inside of the upper portion of the inside dewar. The next step was to cool the dewar entrance radiation shield with LN_2. The dewar gas was again tested by flowing dewar gas past a LN_2 trap that is shielded from the atmosphere. No visible contaminants were observed in the dewar gas at this point.

Again all components were connected and gas was allowed to circulate in a closed cycle without cooling in order to clear the total system of contaminants. The system ran overnight unattended.

Wednesday morning checks were made of the dewar gas, employing techniques previously mentioned, and no visible contaminants appeared. The expansion engines were started and precooling of the helium inlet gas was allowed.

This mode of operation continued with the machine and dewar cooling down all day Wednesday, Thursday and Friday. It seemed to reach a level that indicated that the machine could not liquify into the large 2' x 10' dewar.

On Friday aftternoon, it was decided that the system would run over the weekend again unattended except for morning and evening checks by personnel involved in the test. Prior to leaving Friday evening, a significant change was made in the system operating points. The compressor suction pressure was raised to 100" H_2O, which in liquefier mode causes the discharge to rise. What this means is that the mass flow through the system was increased.

Normal surveillance was provided over the weekend without changing system operating points significantly. On Sunday evening, it was determined that liquid was indeed in the dewar. Approximately 300 liters of liquid helium existed in the dewar at 1900 on Sunday evening. It is difficult to determine accurately just when the system started to liquify, but it is estimated it was sometime Saturday morning.

Prior to leaving the facility Sunday evening, a load of 48 Watts was applied. The system ran 9.5 hours with that load and lost a level of 0.1" which is equivalent to 0.74 liters/9.5 hours or 0.056 W. From these numbers it is reasonable to say that the refrigerator liquefier was capable of delivering 48 W of well-controlled refrigeration to the 2' x 10' dewar.

System Test Results

Several operating modes were tried and are listed in the tables which follow. The outlet of the Joule-Thompson valve and its connection with the liquid dewar was designed to determine the effect on the Joule-Thompson valve performance if the Joule-Thompson outlet is completely submerged with a head of 60" of liquid helium, or the Joule-Thompson outlet discharges above the liquid. The results indicated no apparent effect, and if indeed there is an effect, it must be small.

Operation of the system continued until the morning of January 27, 1972. It is clear from this test, coupled with prior experience, that this system when properly operated can run unattended for long periods and deliver constant refrigeration.

The performance of the four different liquid level systems was satisfactory. It is believed that all of the liquid level detectors would be satisfactory for monitoring and controlling system of the nature tested.

BNL TEST DATA

Operating Mode	Rated Liquefaction Rate liter/hr at Machine	Test Liquefaction Rate at dewar ℓ/hr	Rated Refrigeration Rate Output at machine Watts	Test Load in Watts at dewar	Estimated Load Distribution Watts: Transfer Lines	Estimated Load Distribution Watts: Liquid dewar
2 Compressors LN_2 Precooling	24	17-18	70-80	48-50	10	20
2 Compressors	--		57-70	40	10	20
1 Compressor	--		23-30	20	10	20

ACCEPTANCE TEST DATA
September 10, 1971

Mode Employed	Std. Model 1400 at 4.6^oK	BNL Model 1400 at 4.6^oK	Transfer Line Losses
1 Compressor	23 W	12 W	11 W
1 Compressor & LN_2 precooling	34 W	25 W	9 W
2 Compressors	57 W	45 W	12 W
2 Compressors & LN_2 precooling	70 W	70 W	10 W

Recommended Modification & Repairs

1. The present system configuration requires that the compressors and cold box be close coupled. In the recovery mode, this presents a problem because the cold gas return to the compressors gets very cold. A heat exchanger should be installed in parallel with the main compressor suction with appropriate valves, etc. With this modifcation, the return gas, in recovery mode, is allowed to flow through the heat exchanger, thereby warming adequately prior to reaching compressor suction.

2. A helium leak developed in the insulating vacuum of the 2' x 10' dewar and that vacuum was 2×10^{-4} mm Hg during most of the test. This leak should be repaired. In addition, the size of the insulating vacuum pump-out line should be increased to 4 inches.

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