MICRON SIZE FILTERS IN LIQUID HELIUM TRANSFER LINES

M.L. Mallory, H. Laumer, A. Gavalya, J. Yunker, R. Zarobinski, J.A. Nolen
NSCL, Michigan State Univeristy, East Lansing, Michigan 48824

Introduction

After a planned upgrade of the K500 cyclotron, during July 1985, the startup of the accelerator in August was characterized by an increased rate of occurrence of cryogenic problems. Figure 1 illustrates this, where each tick mark as a function of time shows an accelerator cryogenic problem resulting in a delay of K500 operation. A major effort at understanding

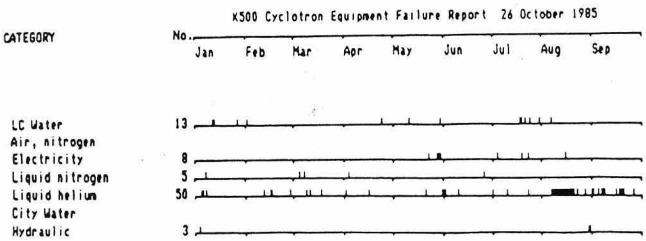

Fig. 1 The equipment failure report of the K500 cyclotron showing the increase in incidents due to problems with the liquid helium distribution system.

this problem was undertaken. A solution has been found that makes a significant improvement in cryogenic reliability. This solution is the addition of a 2μm sintered stainless steel filter in the liquid helium stream. In the following sections, the information obtained concerning this cryogenic reliability problem is described.

Liquid Helium Supply Interruptions

Figure 2 is a schematic drawing of the cryogenic distribution system to the K500 cyclotron. The refrigerators make liquid helium which is stored in a dewar. The storage dewar is pressurized and continuously transfers liquid helium to the K500 cyclotron. In the distribution line are located various control valves that allow metering of the liquid helium to the K500 coil cryostat and to the vacuum cryopanels.

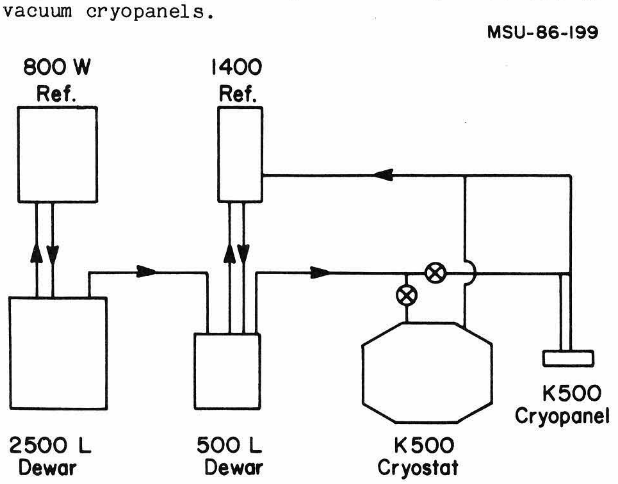

Fig. 2 A schematic drawing of the liquid helium distribution to the K500 cyclotron. The plugging was first located in the valve going to the K500 cryostat.

The first indication of a cryogenic distribution problem was a decline in liquid helium level of the K500 cryostat. This decline in level was diagnosed tobe due to a plug in the cryogenic distribution system. The normal procedure to open a plugged line is to stop the helium distribution, warm up and purge the transfer line. This requires considerable time. After experiencing several of these line plugging episodes, pressure tap points were added along the distribution line and were continuously monitored. The information from the pressure sensors concurred with the line plugging assumption and tended to indicate that one section of the distribution system was the major plugging point. Also in this operational period it was found that the plug could be removed by the simple procedure of just stopping the transfer for one to five minutes. This procedure was christened as "burping" the transfer line. In fig. 3 the pressure drop is shown across a section of transfer line as a function of time. A sample of burping the line is also shown.

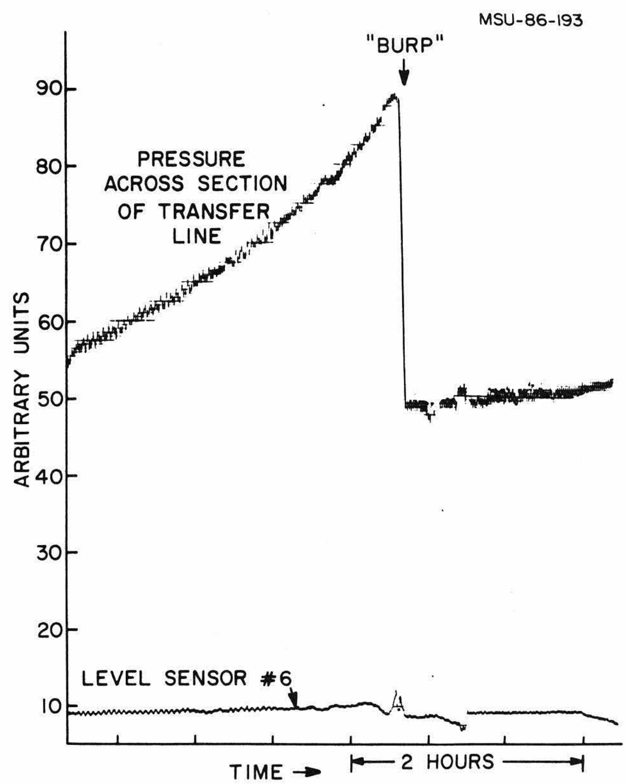

Fig. 3 The pressure across the helium transfer line versus time is shown. The dewar pressure is about 10 psig and the cryostat is ~6 psig. A short closing of the cryostat valve (burp) would restore the transmission of the liquid helium to the cryostat. The liquid helium level in the cryostat is also shown and reflects pressure changes in its level.

This burping procedure allowed cyclotron operations to be interrupted for a shorter time period, varying from

5 minutes to 1 hour. However the intervals between burping the line varied from 3 to 8 hours still resulting in a considerable down time problem.

In an effort to locate the precise plugging point, the valve seat in the control valve of the K500 cryostat transfer line was removed. This stopped the plugging problem in this section of the line, but it then appeared at another location. This result suggested a model of something flowing through the distribution lines that could coalesce at critical locations, for instance at places where the velocity of the fluid changed. The coalesced particles would break loose and plug a small aperture. In an effort to detect such a plug, the K500 cryostat valve seat was reinstalled and upon plugging was rapidly removed (matter of minutes) and examined. All efforts at trying to detect a "solid" blockage failed.

This model also led to the installation of a 200 mesh (~ 100μm spacing) screen on the entrance of the transfer line located in the storage dewar. This screen filter did not alter the line plugging problem.

Helium Refrigerator Operating Mode Experiments

An effort to correlate the plugging with changes in operating modes of the refrigerator system during the July shutdown was attempted but no satisfactory explanation was found. The K500 supply dewar receives liquid helium from the CTI 1400 refrigerator and/or the 800 watt refrigerator and some changes were made in these lines during July. An experiment to supply the K500 dewar only from the 1400 refrigerator resulted in a 13 day period of no line plugging. Before this could be investigated further, the 1400 refrigerator had a heat exchanger failure, necessitating complete dependence on the 800 watt refrigerator, but this strongly suggested a difference in the refrigerators.

An experiment based on the assumption that the helium gas supply had been contaminated was performed. The entire helium gas inventory was replaced. No change in plugging rate was observed. An operational program of recycling the 80 K traps reduced the nitrogen impurities to the 1 ppm level in the ambient gas, but did not stop the plugging.

Filter Experiments

A transfer line section containing a 2 micron filter with a low C_v was built. It seemed to solve the plugging problem but the pressure drop across the filter resulted in problems of maintaining adequate liquid supply to the cyclotron, without making large changes in the dewar pressure. Raising the pressure also creates flashing problems in the K500 cryostat.

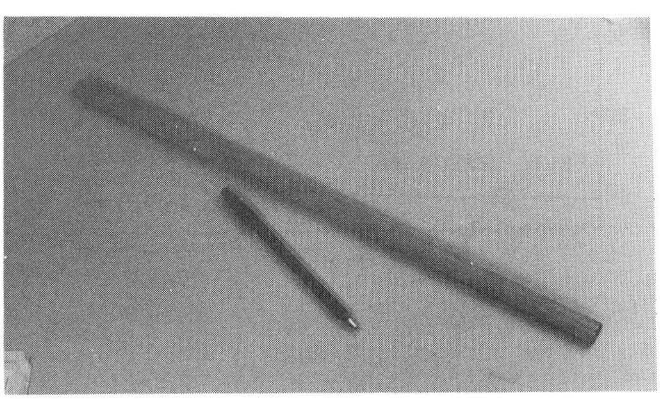

Fig. 4 A photograph of the 2 micron stainless steel filters is shown. It is 18" long and 1/2" in diameter. The liquid helium pressure drop across it is undetected.

Next a 2 micron filter with a large C_v was located[1] and it is shown in fig. 4. This filter could be inserted into the bayonet end of the transfer line connecting the 800 watt refrigerator dewar to the K500 storage dewar and resulted in successful line operation.

A filter box shown schematically in fig. 5 has now been built. It has dual filters and isolation valves. A sample line that connects to an optical spectrometer[2] is provided. This filter box has been installed in the transfer line to the K800 magnet. The K800 line had also shown evidence of plugging. The first attempts at analyzing material trapped in the filter box has indicated an increase in neon and hydrogen content versus samples of the ambient helium gas (Fig 6).

MSU-86-200

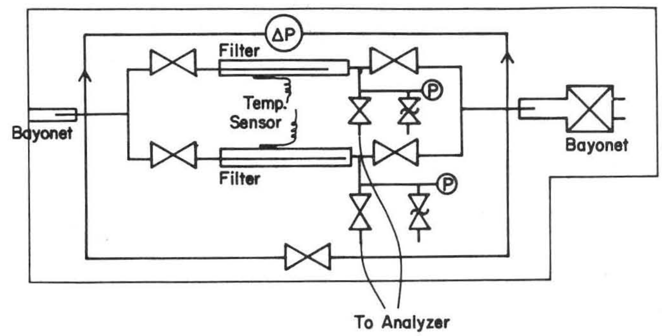

Fig. 5 A schematic drawing of the filter box built to measure what is being trapped in the filters is shown.

Difference in the 800 Watt and 1400 Refrigerator

The successful operation of the line with the 1400 refrigerator has resulted in the comparison of differences in the helium refrigerators and two are noted below. The 1400 has two small filters located in the cooldown stream at very low temperatures. It is assumed that these filters could trap out gasses such as neon and hydrogen. However there is very little evidence of having these filters plug and stop operation of the 1400.

It has also been noted that the 1400 charcoal filters that are installed for trapping of nitrogen and oxygen operate at a temperature below the phase transition to solid nitrogen. In the 800 watt refrigerator the charcoal traps operate slightly above the phase transition to liquid for nitrogen. We have now analyzed the off gas during warmup of the traps and have discovered that the 1400 removes neon, whereas the 800 watt refrigerator does not. We are unable to explain this result but it is consistent with our previous observation of successfully operating the 1400 refrigerator.

Long Term Results with Filter

The cryogenic system has now operated with a filter for a period longer than six months and system plugging problems have been non existent during this period. Continuous monitoring of the neon gas contaminate shows that the system purifies itself. After resupplying the system with new helium gas, the neon contaminate increased to ~ 25 ppm. A verification experiment of the filters removal capability was performed, when they were removed after the new helium gas with large neon contaminate was added to the system. The transfer line plugged after several days. Insertion of the filter slowed down the plugging rate and after 1 week the problem had again completely disappeared. All our present data indicates that the neon gas contaminate in the helium gas is the source of the plugging problem.

Conclusions

We can state with great assurance that these filters in the liquid helium stream have made a significant improvement in cryogenic system reliability. We attribute the plugging problem to the neon gas contaminate in our makeup helium gas. It seems that the neon forms solid clumps at liquid helium temperature, with the size of the clumps larger than 2 microns. The details of how the solid neon moves through the cold end of the liquifier and the storage dewar to the transfer lines are an interesting and unanswered question.

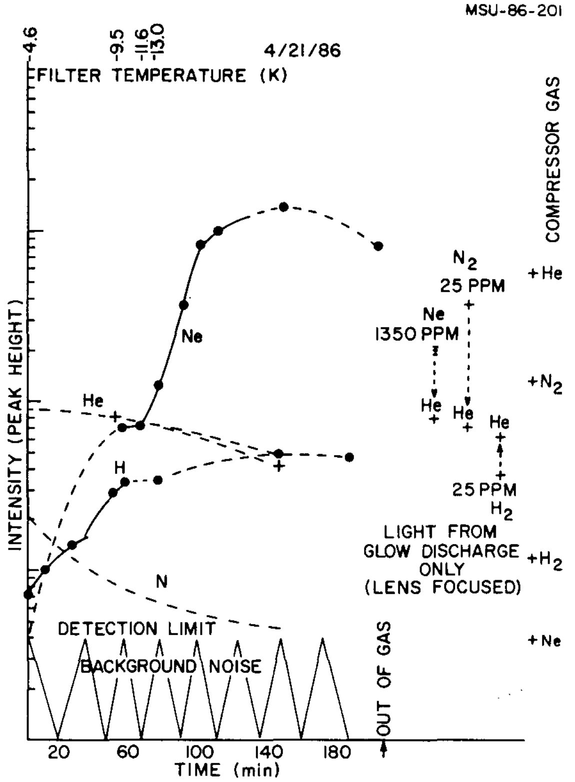

Fig. 6 The relative intensity of the spectrometer lines for material trapped in the 2 μm filter is shown as a function of time after isolating the filters. Also the filter temperature is correlated with time at the top of the graph. The graph indicates that neon is trapped in the filter in large quantities. To the far right is the measured impurities of the compressor gas and next to it various measurements of known calibration gases.

Reference

1. Mott Metallurgical Corporation.
2. R.J. Walker, Cryogenics 26 (1986) 297 and Fermilab Technical Memo TM-742, August 31, 1977.