NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA ELECTRONICS MEMORANDUM NO. 106

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To: Distribution

From: D. L. Thacker

Subject: Leaks in Dewars, Pressurized Waveguide, and Helium Refrigerator Lines

Dewars for Cryogenic Front Ends

The cryogenic refrigerator system needs approximately 50 microns Hg (50×10^{-3} Torr) or better vacuum before the refrigerator should be started. 1/ From this point the refrigerator should be able to cryopump to an operating vacuum of 10^{-5} mm Hg (Torr). Gases (with the exception of He) that leak into the dewar are trapped by activated charcoal, which is attached to the cold stage of the refrigerator. When the refrigerator warms up to ambient temperature, the trapped gases are relased causing a rapid increase in pressure.

It is necessary that the amount of gas leaking into the dewar during maximum operating time between scheduled warm-up not saturate the charcoal. For the VLA dewar this implies a leak rate of 2×10^{-2} Std cc/min. At this leak rate the dewar would have to be rough pumped to < 50 microns Hg after every warm up before the refrigerator could be restarted.

$$\text{Leak rate} \leq \frac{10^4 \text{ Std cc}}{1 \text{ yr}}$$

$$\text{Leak rate} \leq .02 \text{ Std cc/min}$$

All NRAO dewars with the exception of those with obvious vacuum problem (TRG 6 cm dewar and the Rice dewar) seem to meet this requirement. Both NRAO constructed dewars have at least an order of magnitude less leak rate. The cooled 21 cm dewar leaks 8×10^{-4} Std cc/min (2 days to leak to 50 microns).

A proposed requirement is for the dewar to maintain 50 microns Hg (50×10^{-3} Torr) vacuum at ambient temperature for a year. This implies a leak rate of 7×10^{-6} Std cc/min. The prime advantage of this low leak rate is that the refrigerator can be restarted after a warm up without rough pumping the dewar. This would be desirable when the antenna is disconnected for a move.

Note that the leak rate (7×10^{-6} Std cc/min) is 2 orders of magnitude less than what we have achieved on the simpler dewars that we have built in the past and is 3 orders of magnitude less leak than that required if rough pumping is allowed after each warm up.

CTI specifies a leak rate of 6×10^{-7} Std cc/min (1×10^{-8} Std cc/sec) for their refrigerator head assembly. It is discouraging that the refrigerator alone is guaranteed to 6×10^{-7} when we need 7×10^{-6} for the entire dewar including all 20 RF lines.

Typical leakage rates for RF lines are:

OSM 208 Feed through	6×10^{-6} Std cc/min
Amphenol Series 48 DC	6×10^{-6} Std cc/min
Amphenol Series 67 DC	6×10^{-5} Std cc/min
Comtech Cold probe	was not purchased to any spec.
NRAO waveguide windows	estimate $<10^{-4}$
NRAO coax lines	estimate $<10^{-4}$

The 50 micron of Hg pressure in a 55 liter dewar implies 3.6 Std cc of gas inside the dewar. This 3.6 Std cc of gas can come not only from leaks but also from outgassing of materials. Indication are that the "O-rings" will out gas over a 100 Std cc of gas over a long period of time. Also there is in the dewar a considerable amount of teflon (beads - dielectric in semi-rigid line) which is notorious for outgassing. The outgassing rates for the ferrites and other materials in the Comtech paramps are unknown, but the fact that Comtech is unable to meet the recool without rough pumping requirement on their systems is discouraging.

In view of the difficulty involved in meeting the proposed requirement of 7×10^{-6} Std cc/min alternate solution should be investigated. Two possible solutions are:

1. Rough pump the dewar after warm-up (like everybody else does). The chief disadvantage is that a mechanical roughing pump must be carried to the vertex room of the antenna. Pumps must be kept horizontal which precludes mounting one permanently in the vertex room unless complicated and expensive gimbols are used. Newer models of roughing pumps are lighter and more portable than the ones we presently use. The pumping operation could lengthen the down time between moves by as much as two hours. Even if the dewars did leak less than the 7×10^{-6} Std cc/min, the portable pump and gauges are needed in the event of a failure.

2. Keep the dewar cold by maintaining power to the refrigerator and compressor during an antenna move. The refrigerator can be turned off for short periods (20-30 minutes) without the temperature rising enough to destroy the vacuum. This would shorten the cool down time after an antenna move to practically zero. If power were kept on all electronics and temperature control systems, so much the better.

Pressurized Waveguide

The TE_{01} waveguide must be pressurized with dry nitorgen with an impurity of less than .02% oxygen (.1% air)[2]. Like everything else the waveguide will leak. With a joint every 5 meters in the pipe, the allowable leak rate per joint is 14 Std cc/time between purges. If the desired time between purges is 6 months, this implies a maximum leak rate of 5×10^{-5} Std cc/min for each joint. For a field assembled joint checked with portable leak testing equipment this may be marginal. The Parker O-ring Handbook claims a helium leak rate of 3×10^{-4} Std cc/min for the size O-ring needed. Admittedly the oxygen leak rate will be less, the 6 months between purges is arbitrary, and the .1% air is subject to some modification; however, it is clear that leaks in the waveguide are a potential problem area.

Two possible techniques to alleviate the leak problem are:

1. weld some or all of the joints in the waveguide

2. continuously purge the waveguide with nitrogen. It would cost approximately $15,000/year to change nitrogen once a day in the waveguide. This would allow a leak rate of 9×10^{-3} Std cc/min/joint which should be easy.

Helium Lines for Cryogenic Refrigerators

Contamination seems to be the persistent problem with our cryogenics systems. For small leaks in helium lines, helium diffuses out and air diffuses in. Note that the high pressure inside of the helium lines does not inhibit the amount of air diffusing into the line. No data is available that I know of on how much contamination is allowable in the refrigerator lines before it causes trouble. One good way of obtaining this data is to keep careful records of how much helium must be added to the present systems to replenish the helium lost through leaks. Correlating this data with failures in our present system would give a good indication of the leak rate necessary for cryogenic lines.

[1] Operator's Manual, CRYODYNE Helium Refrigerator, Model 340LS, April 1966 Arthur D. Little, Inc., Division 500, Cambridge, Massachusetts.

[2] Read Predmore private communication (≈ 1/2 dB loss).