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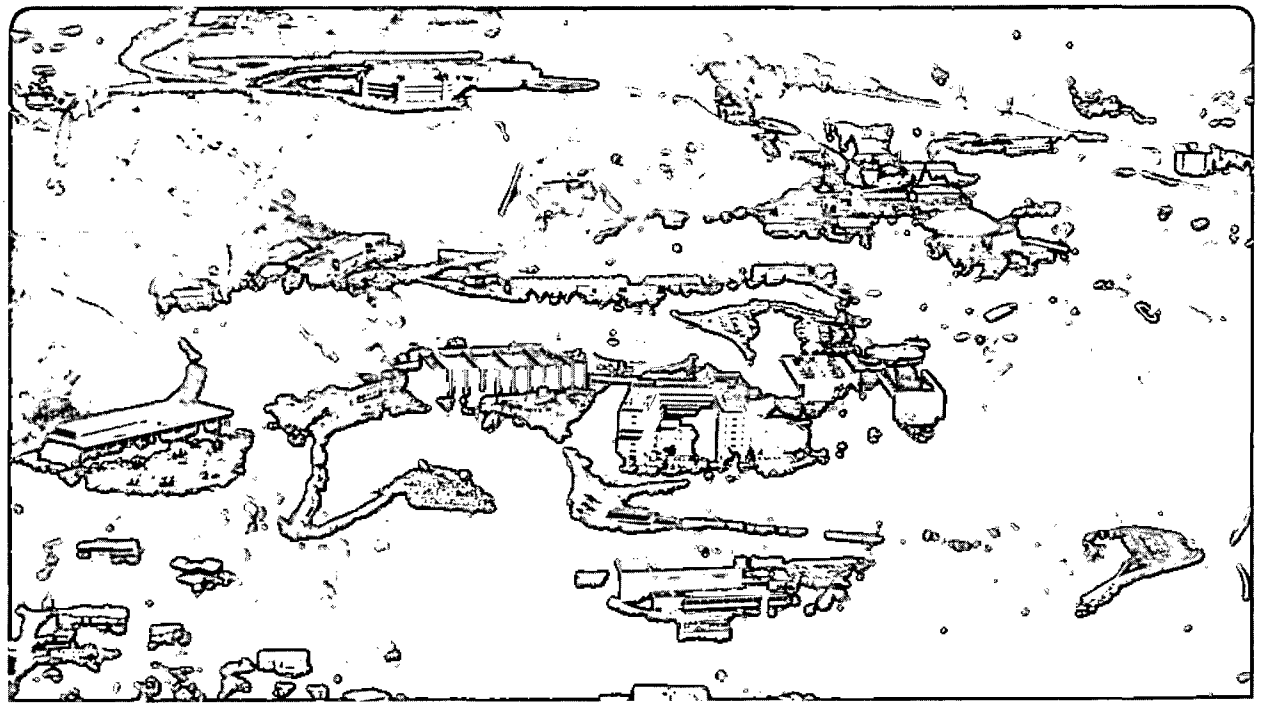

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LAWRENCE RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA
ENGINEERING NOTE

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PROGRAM — PROJECT — JOB
BEVATRON

VACUUM PUMPING SYSTEM

TITLE
CRYOPUMP RELIABILITY

Introduction

During the recent* heavy-ion run at the Bevatron, we have suffered 8 to 12 hours of Helium Refrigerator (20°K) outage, occurring after 12-15 days of operation. This almost seems worse than a year ago when we had operation times approaching 3-4 weeks. The primary fault characteristic is expander valve icing, which occurs gradually until the reefer capacity fades, the cryopanels warm and the beam disappears. Ice on the valves creates leakage, when it builds enough the upstream pressure drops and destroys the reefer yield. Refrigeration capacity is a strong function of pressure expansion ratios, high (225-180 psi) inlet pressure to low (3-5 psi) exhaust pressure. When the valves leak, inlet pressure approaches exhaust pressure and eventually, say 100-120 psi inlet, the reefer yield disappears.

There seems to be some unique idiosyncracy with our 20°K reefers that we have not solved yet. The Hilac 20°K unit has run continuous for 16 weeks, but it has one expander piston and runs at twice our speed. It may be less sensitive to valve icing at the high speed. The Bevatron 4°K unit on the superconducting magnets has run continuous for 10-17 week periods, but it has two expander engines in series at 50°K and 15°K, with associated charcoal traps, plus one at about 8°K.

Many suggestions for cures have been made, in general not inexpensive. The CTi Model 1400 basic unit can deliver continuous service as has been demonstrated by some of the models we have in operation. Were CTi to provide all extras for 99.5% reliability, the price could destroy their market.

Our 20°K reefers are telling us something that we do not completely understand as yet. They run fine for a few weeks and then gradually build ice on the valves. The ice is suspected to be N_2 and O_2 primarily, but may be other gases, as well as H_2O (as much as a spoonful of H_2O has been found in the expansion engines). The contaminant supply can be any one, or combination of a limited number of sources.

I. Supply Gas

The helium supply gas is considered to be very clean. Our other systems take supply gas directly with no trouble. The 20°K cryopump systems only require about 1/3 bottle to charge them, and then theoretically, the closed circuit gas should clean up completely. However, we could be adding small amounts of contaminants from the supply.

* Sept. 1973

To eliminate any problem from this, we should add all new gas, and all purge gas through an LN trap, at least for the initial fill. Then make-up gas could go in directly if there are no system leaks. Also, all bottle changing should be done only by manifold pump and purge a minimum of three times.

II. Air Leakage

The main suspect for air leakage is the expander piston seal, a single 3" dia. "O" ring with a 2" stroke. In the seal area, the piston can pump and wipe air into the cylinder. This can be protected with a back-up helium gas atmosphere, preferably supplied by regulator. The valve rods seals are single 1/8" dia. "O" rings, but their pressure is always positive, and the stroke short (~ 1/8").

Another suspect might be compressor suction leaks, but the suction pressure should never be negative because of the low pressure switch (10" H_2O).

III. Residual Contaminant After Purge and Clean-up

Standard purge techniques are multiple vacuum pumps and let ups to pure He gas.

i.e. pump to $760\mu = \frac{1}{1000}$ atm = 10^{-3} air left. Theoretically, 3 pumps = $(10^{-3})^3 = 10^{-9}$ contaminant left. Below 100μ most of the H_2O should be removed. Ideally, many more pump downs can be used, say up to 15 (CTi uses 50+ on charging their gas thermometers). Each successive base pressure should go lower indicating more impurity removal.

High surface absorbants, like charcoal, hold impurities. In general, the amount held is a function of temperature and pressure.

Low T and high P hold impurities. These absorbants also release impurities.

High T and low P release. This release is believed to be our main problem.

Test by R. Schafer, E.N. M4495, on 190 gm of charcoal pellets exposed to air showed:

60°F	- 12 hour pump removed	4.5 gm H_2O
"	- 5 time pump and purge, removed	4.4 gm
150°F	- pump removed additional.	1.3 gm
250°F	- " " "	0.4 gm
350°F	- " " "	0.2 gm

"The test showed it is mandatory to heat to at least 150°F, regardless of whether a long time pump or 5 He gas purges are used for the basic clean-up."

"Further test showed exposure to air for 1 to 2 minutes was enough to absorb almost as much H_2O as exposure for several days." Therefore, our 20°K reefer should not be exposed to air, during expansion engine valve and piston maintenance, unless we can properly reactivate the charcoal.

CTi recommends system clean-up by circulation of pure gas with an external LN charcoal trap for 24 hours.

Items that can hold H_2O in the CTi Model 1400 system are:

1. Linen base phenolic expansion pistons. These should be baked and installed hot (M4495).

2. Linen base phenolic expansion valve assembly (see 1.).

3. About a mile or two of cotton sash cord in the low side heat exchanger.

4. Two large internal charcoal traps. One operates at about 50°K and one at 15°K to 30°K. This latter one may be the culprit. These traps were expected to stop only gas, no H_2O, and have no heating provision other than external gas circulation.

5. One large charcoal external trap on the compressor at ambient. This one we can heat and bake so it should be OK.

6. Compressor oil, it is all prebaked and degassed before use, and during normal operation runs at ~ 80-250°F. Any H_2O release should stop in 5. above, and the oil should be clean in an hour or so of operation.

7. The cryopanel circuits, maybe 200-500 feet of plumbing. This usually runs at 80°K when the LN circuits are cold, and H_2O should all be stopped here.

IV. Operations

We may be able to extend operations by small procedure changes, and this has to do with careful temperature and pressure control of the final charcoal trap. If we start the reefer on itself (SV-3 open) after a clean-up it has no load and soon chugs down to 12-15°K, with a good input pressure (~180 psi). At this T and P, the charcoal grabs N_2 and O_2 and holds it. We then valve onto the Bevatron cryopanels and the heat load goes up. The charcoal T goes up and a little N_2,O_2 release

to the valves; they leak a little and the pressure drops a little. This releases a little more N_2, O_2 and so on. After 2 or 3 weeks, the pressure is at 140 psi and the temperature is at 30°K, and we can't hold the heat load. Experience has shown that the Bevatron vacuum is insensitive up to about 25°K. Desperation measures during the last run were to start the second compressor (expander at the same r.p.m.) and this held through the run. This doubled the thru-put and made the iced valves less sensitive, holding the pressure up.

Proposed cure is to not cool the reefer down all the way to 15°K by itself, but to put the load on with the initial cool-down.

To justify this idea, compare our other reefers. The 4°K magnet system has one charcoal trap at 50°K, one at 15°K and one at 6°K. These traps really hold contaminant gases tightly at their fixed T and P levels, although experience has shown that if we have any outage for ~1/2 hour or more, the traps warm up and the engine valves crud, requiring warm up.

The Hilac 20°K reefer has no isolation valves likes ours (SV-1,2,3). Consequently, they can never cool the reefer down without load, and so the final charcoal trap temperature never goes below its normal operating temperature. Hence, it cannot grab impurity at one temperature for later release at a higher T.

Short-Term Cures

Attempt to correct all items above I through IV as best as possible.

Long-Term Cures

More expensive, when we get into opening up the reefer. Install heaters on the charcoal pots, heaters on the valve bodies. Install dual purifiers for on-line reactivation, dual expansion engines for in-flight changes, pure gas storage system, etc. Approach 100% redundancy for 99% reliability.

RB/ml

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