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PROPOSED HELIUM FOUR REFRIGERATOR FOR HOLDING LARGE CRYOMAGNETS AT 4.224 K

A large cryomagnet might hold 9,000 L of LHe4. Boiloff of He4 to the atmosphere during 60 day operating runs could be considerable. Makeup LHe4 would cost about $2/L. The use of a refrigerator to prevent loss of He4 is easily justified.[1]

The use of a low temperature heat shield at 9K average temperature to essentially eliminate heat leakage by radiation and conduction from the heat shield to the cryomagnet dewar is also easily justified since leakage from a 77 K, LN - heat shield, for instance, would exceed predicted electrical losses.

The rating of a refrigerator designed on the above basis might be 12 W at 4.224 K.[2] It would have the following components:

1) A 40 HP hermetically sealed, motor driven, single stage with RC = 8.0, internally oil mist cooled, helical lobed rotary compressor with cylinder actuated slide gate controller for 100% load modulation, an oil separator and an aftercooler.
2) A separate very high efficiency oil separator.
3) A large warm end, aluminum platefin type heat exchanger.
4) A cold end purifier.
5) A single reciprocating expansion machine.
6) Three small, cold end, aluminum platefin type heat exchangers.
7) Two cold end throttling valves for 8 ATM to 4 ATM and 4 ATM to 1 ATM service.
8) Two flow trim valves to properly split flow at 1 ATM, 7 K between the heat shield and the critical heat exchanger.
9) A heat shield of He4 gas-cooled shadow plates backed by 70 layers of aluminized mylar within a vacuum tank having a valved connection for initial vacuum pumpdown using one of the accelerator startup cryopump sets.

The T-S diagram is shown in Fig. 1.

The schematic one-line diagram is shown in Fig. 2.

The compressor motor drive is oversized for easy startup. Indicated performance is 1660 W/W. Brake horsepower should be close to 25.0. There is little or no justification for increased performance particularly since service would likely be two 75 day runs per year.

Cold end flow would be 0.160 Mols/s while 1.954 Mols/s goes through the expander. Expander discharge flow is split and manually controlled to provide 1.740 Mols/s to the heat shield and 0.214 Mols/s to the cold end return gas inlet of heat exchanger HEX-3. Compressor flow would be 2.114 Mol/s.

The refrigerator could be started prior to rapid filling and gradually lower cryomagnet bulk temperature toward 9K before L He4 is transferred from delivery trucks.

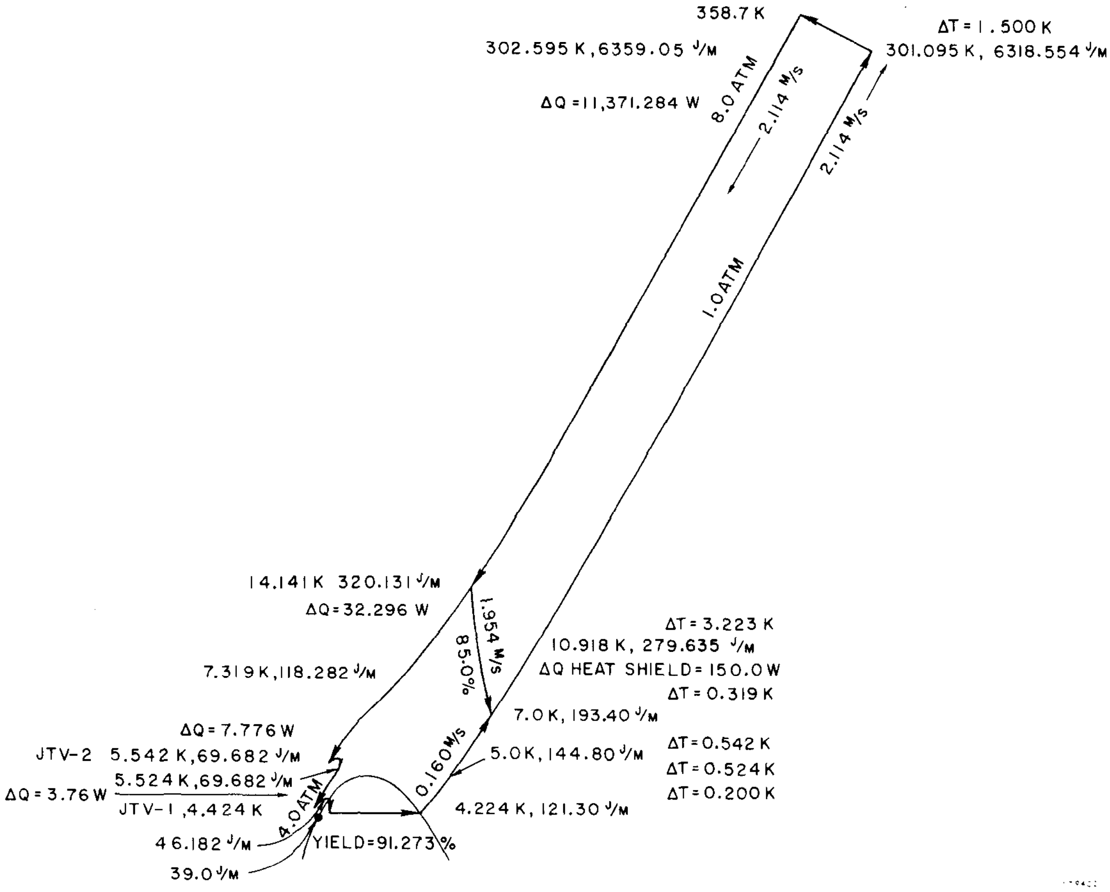
The heat shield load is quite steady at 150.0 W. Cryomagnet electrical losses are assumed to vary from 0.0 W to 12.0 W. When the cryomagnet losses are less than 12.0 W a dummy load within the dewar should be energized to compensate so as to prevent excessive condensation of helium and a rise in liquid level. This is simpler and more accurate than attempting to sense liquid level and control the flows of gas.

Acknowledgement

A thermodynamic system check was made by K. G. Carney, Jr.

References

1. Fred Hall, SUPERSLAC Interim Study No. 17, January 6, 1970.
2. R. D. McCarty, "Provisional thermodynamic functions for helium 4 for temperatures from 2 to 1500 K with pressures to 100 MN/m^2 (1000 atmospheres)," NBS Report 9762.



358.7 K
302.595 K, 6359.05 J/M
ΔQ = 11,371.284 W
8.0 ATM
2.114 M/S
ΔT = 1.500 K
301.095 K, 6318.554 J/M
2.114 M/S
1.0 ATM
14.141 K 320.131 J/M
ΔQ = 32.296 W
1.954 M/S
85.0%
ΔT = 3.223 K
10.918 K, 279.635 J/M
ΔQ HEAT SHIELD = 150.0 W
ΔT = 0.319 K
7.319 K, 118.282 J/M
7.0 K, 193.40 J/M
ΔQ = 7.776 W
JTV-2 5.542 K, 69.682 J/M
5.524 K, 69.682 J/M
ΔQ = 3.76 W
JTV-1, 4.424 K
4.0 ATM
0.160 M/S
5.0 K, 144.80 J/M
ΔT = 0.542 K
ΔT = 0.524 K
ΔT = 0.200 K
4.224 K, 121.30 J/M
46.182 J/M
YIELD = 91.273 %
39.0 J/M

Fig. 1

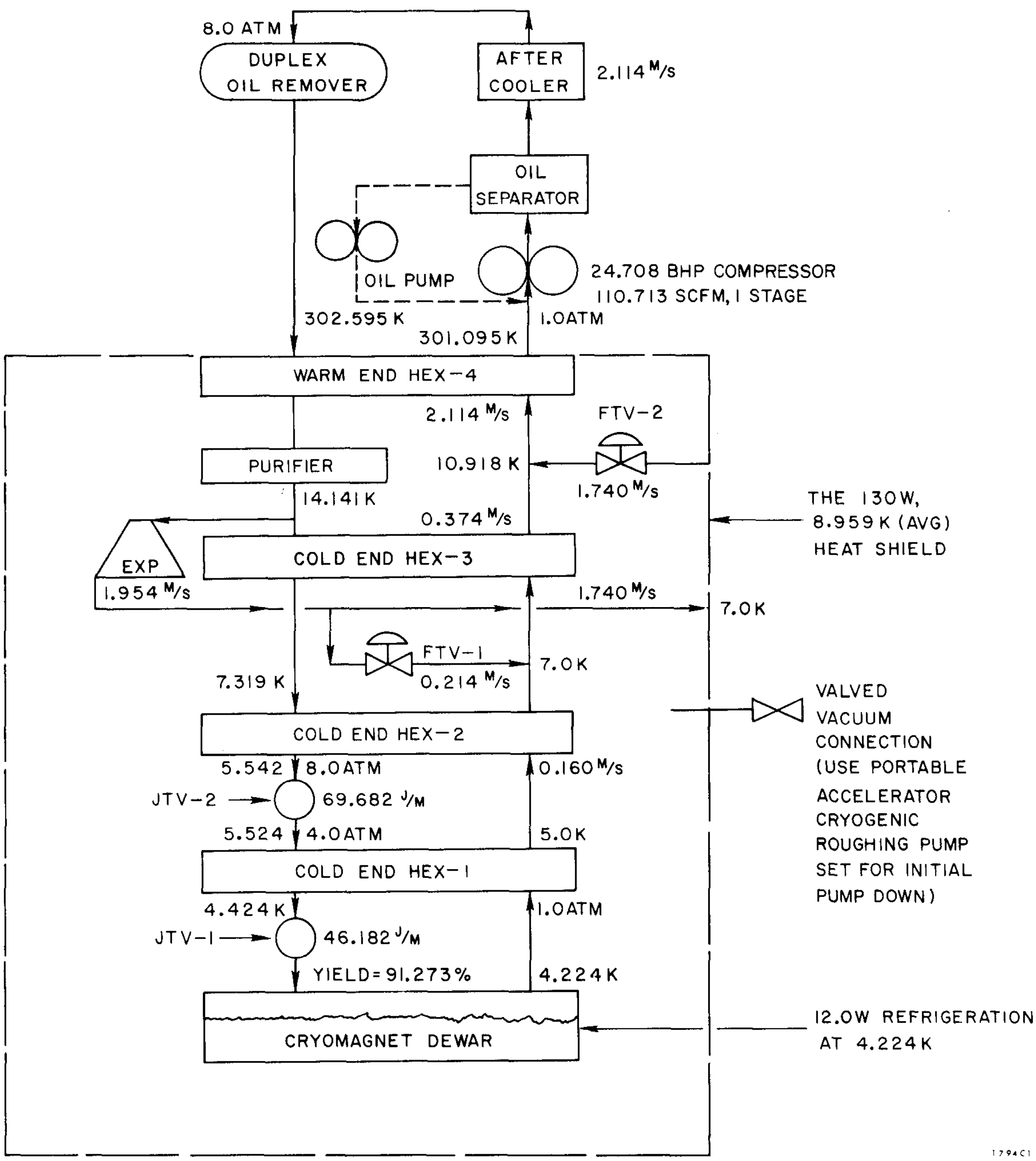

8.0 ATM
DUPLEX
OIL REMOVER
AFTER
COOLER
2.114 M/s
OIL
SEPARATOR
OIL PUMP
24.708 BHP COMPRESSOR
110.713 SCFM, 1 STAGE
302.595 K
1.0ATM
301.095 K
WARM END HEX-4
2.114 M/s
FTV-2
PURIFIER
10.918 K
1.740 M/s
14.141 K
0.374 M/s
THE 130W,
8.959 K (AVG)
HEAT SHIELD
EXP
COLD END HEX-3
1.954 M/s
1.740 M/s
7.0K
FTV-1
7.0K
7.319 K
0.214 M/s
VALVED
VACUUM
CONNECTION
(USE PORTABLE
ACCELERATOR
CRYOGENIC
ROUGHING PUMP
SET FOR INITIAL
PUMP DOWN)
COLD END HEX-2
5.542
8.0ATM
0.160 M/s
JTV-2
69.682 J/M
5.524
4.0ATM
5.0K
COLD END HEX-1
4.424 K
1.0ATM
JTV-1
46.182 J/M
YIELD=91.273%
4.224 K
CRYOMAGNET DEWAR
12.0W REFRIGERATION
AT 4.224K
1794C1

Fig. 2