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Title
HELIUM REFRIGERATOR CROSS-CONNECT STUDY

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SUMMARY

It has been proposed that a cross-connect line be made between the two Helium Refrigerators for the Bevatron cryopump. This would permit single reefer operation and possibly provide more reliability and less outage, particularly during heavy-ion runs. Reliability becomes even more important during future time-sharing operation. Motivation source has been some refrigerator outage during last year heavy-ion runs. However, the record has been good considering the first year learning curve. Recent local refrigerator continuous operation records have been 16.7 weeks (2800 hours) (Hilac) and 9 + weeks (Bev. S.C. magnets). Estimated cross-connect transfer line cost is $25,000 ± 10%.

Recommendation is to leave the system as is, and seek to reduce outage. Scheduled refrigerator maintenance during regular Mondays should help as well as minimizing short on-off periods such as 24 hour PEP tests. Engineering design work could continue as back-up preparation if future reliability is still considered unacceptable.

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Ref. Dwg. 17K4666

Distribution:

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D. Evans K. Lou File (1)
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DISCUSSION

Historically, main sources of cryogenic refrigerator outages have been: 1. Compressors, and 2. Valve icing due to contaminants. Compressor trouble stemmed from poor lubrication with the lighter gases such as helium and hydrogen. The CTi Model 1400 compressor has essentially solved the compressor problem and gives reliable service for 3500-7000 hours continuous operation.

Contamination trouble can occur suddenly or over a long term progression. Contaminant sources are: 1. Supply gas, 2. Leakage during operation, 3. Residual gas due to insufficient purge, including gas left in charcoal traps and filters. Our helium supply gas has proven to be very clean and the vendor (Poxco) is reliable. We have no known history of dirty Poxco bottles (although we have from other vendors). The only logical source of air leakage during operation is the expander piston seal. This, we have protected with a helium back-up can and its pressure only seems to go negative during cool-down. We plan to improve purge procedures, using as many as 12-15 rapid pump and purges with careful pressure decay monitoring. This should delay valve icing and extend operations to 12 weeks or more.

Additionally, we have added a fast valve warm-up circuit which should permit valve de-icing and return to operation in 1 to 3 hours.

The enclosed estimate for the cross-connect transfer line of $25,000 is for the minimum, most economic option. There are some uncertainties in its operation.

1. Heat Load and Mass Flow

With the added lines and valves, the heat load may exceed the capacity of one compressor. Always with refrigeration, it is good to have more capacity than load by 50-100%, because things never get better (2nd Law). It might be necessary to operate with two compressors, or one compressor plus LN.

In any of these modes, balancing the flow to the four cryopanel circuits would be required. Presently, with one compressor (60 scfm) to 2 cryopanel circuits, the balance is automatic. One compressor to 4, may require some valve throttling and trimming. Two compressors to 4 could possibly be self-adjusting.

2. Outage Time

It might take as long to cool down the transfer line and balance the system for one refrigerator as it does to warm-up one sick reefer and de-ice (say 2 hours). However, on a planned change-over one reefer could be taken out of service for a complete warm-up and purge cycle. This would provide more flexibility and hence reliability. Also, emergency repair is more easily handled.
COST ESTIMATE

**Option I (Min. Cost)**

$4000 ACET.

**Engineer & Design**
300 HRS @ $20/hr  = 6000

**Transfer Line ~ 100 ft (Dual Line)**

- **Parts Fab.** 160 HRS
- **Ass'y** 160 HRS
- **320 HRS @ $17.5/hr = 5600**
- **Matl** 800
- **Aux. Vac Systems** 1500
- **Connector Boxes,** 2 req.
  - **Control, Isolation Valves** 600
  - **Bayonet Couplings** 400
  - **Parts Fab 100 HRS @ $17.5/hr = 1750**
  - **Matl** 300
  - **Ass'y Fab.** 1050
  - **2 each @ 4100 = 8200**

**Installation** (Requires Machine)

- **Install 2 Boxes + 100 ft Xfr Line**
  - 160 HRS @ $17.5/hr = 2800

**Total Estimated Cost** $24,900 (± 10%)

*Some cost reductions possible if our crew used (but only ~15-20%)
OPTIONS FOR REFRIGERATOR ARRANGEMENTS

I OPTION
Leave cold boxes as is. Add ~100 ft XSPR LINE, BAYONETS, VALVES. No change in compressor supply-returns. " " " ELEC. WIRING + CONDUIT
Minimum heat load addition
Minimum Cost.

II OPTION
More cold boxes outside shielding to EAST bay compressor room. Better operating access (full time)
($) Adds ~150 ft XSPR LINE, BAYONETS, VALVES
($) MUCH CHANGE in compressor S+R piping
($) " " " ELEC. WIRING + CONDUIT
50% HEAT LOAD INCREASE OVER I
MAXIMUM COSTS.

III OPTION.
Move cold boxes to top center igloo gets out of crane way.
Adds ~120 ft XSPR LINE
CHANGE Compr. S+R PIPING
" " " ELEC. + CONDUIT
LARGE COSTS OVER I.
Author: R. Byrns  
Department: Mechanical Engineering  
Location: Berkeley  
Date: August 1, 1973  

**Schematic**

**6.5 watts (est.)**

**Q1**

**QII**

**QIII**

**QIV**

**T1**

**T2**

**T3**

**West CT: 1400**

**East CT: 1400**

**Added heat load**

\[
\begin{align*}
\text{MIN} & : 10 \\
\text{MAX} & : 20 \\
\end{align*}
\]

(2) 100' KSF line  
4 Bayonets

**Single refriger (4 panel circ)**

**Total est. heat load**

\[
\begin{align*}
\text{MIN} & : 151W \\
\text{MAX} & : 163W \\
\end{align*}
\]

(Ref. Schematic LBL DWG 17C8196)
OPERATIONS

WITH MINIMUM VALUES & XSRF LINE ADDED
MIN, NEW VALUES REQD -(2) A & B - ISOLATION ONLY

MODE I

WEST REFER TO WEST
EAST V V EAST
VALUE A & B CLOSED.

MODE II

WEST OR EAST REFER TO BOTH
EAST & WEST - VALUE A & B OPEN.
(2) REFER ISOL. VALVES CLOSED IN
OFFED REFER.
ONE (OR TWO) COMPRESSORS ON ACTIVE REFER.

(2) VALVES ON DISTRIBUTION BOX NEAREST
* TO ACTIVE REFER. POSSIBLY THROTTLED
FOR TEMP. BALANCE TO CRYOPANELS
(IF ONE COMPRESSOR USED)

ADDITION OF VALUES A & B IS MINIMUM POSSIBLE, HENCE CHEAPER
IF BALANCING CIRCUIT IS NECESSARY - OPERATION IS ON
INSIDE PLATFORM, BALANCING VALVES & TEMPS BULBS
COULD BE ADDED TO TOPSIDE FOR MORE CONVENIENT
OPERATION, ON SHIELDING ROOF.
VALUE A COULD BECOME 2 - 3 WAY VALVES ON RETURN LINE.

ADDITION OF ~100 BTU OF CROSS-OVER XSRF LINE + BAYONET
MEANS ADDED HEAT LOAD OF 16 W, 28 W MAX.

THIS PLUS EXISTING LOAD APPROACH TOTAL ~ 150 - 160 WATTS
& APPROACH MAX. HE REFER OUTPUT FOR ONE COMPRESSOR
SEE GRAPH NEXT PAGE. OUTPUT MAY DECREASE WITH TIME AS VALVES ICE & LEAK
MIGHT HAVE TO USE 2 COMPRESSORS FOR MORE OUTPUT, MORE
MAX FLOW & LESS PANEL AT RISE - BETTER DP BALANCE
EFFECT OF ENGINE EXHAUST PRESSURE ON CAPACITY

CTI MODEL 1400 FROM 6-9-72

2 COMPRESSORS + LN₂ (34 kWh/m³)

APPROX. BEVATRON CRYOPANEL OP/2.
BACK PRESSURE

R.D. EST. FOR 2 COMP - NO LN₂
FROM CTI SALES LIT.

1 COMPRESSOR + LN₂ (-17 kWh/m³)

1 COMPRESSOR - NO LN₂

LOAD @ 20% - Watts

ENGINE EXHAUST PRESSURE (PSI)
## Title

**BEYATRON Cti Model 1400 - 20 kT.**

**TEST DATA @ BOSTON**

### Table

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<th>Date</th>
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<th>V1</th>
<th>V2</th>
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<th>V4</th>
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### Notes

- May: Data not available.
- June: Data not available.
- July: Data not available.
- August: Data not available.
- September: Data not available.
- October: Data not available.
- November: Data not available.
- December: Data not available.
# 20°K Heat Load Estimate

## East Refrigerator

<table>
<thead>
<tr>
<th>Component</th>
<th>Low</th>
<th>High</th>
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<tbody>
<tr>
<td><strong>Internal</strong></td>
<td></td>
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<tr>
<td>5 Cryopanels</td>
<td>15</td>
<td>25</td>
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<tr>
<td>Transfer Line - 0.38 Dia x 300 ft</td>
<td>15</td>
<td>30</td>
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<tr>
<td>4 Feed Thrus.</td>
<td>2</td>
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<tr>
<td>Eddy Current</td>
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<td>2</td>
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<tr>
<td><strong>External</strong></td>
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<tr>
<td>Transfer Line - 0.75 Dia x 70 ft</td>
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<td>7</td>
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<tr>
<td>4 Bayonet Unions</td>
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<td>8</td>
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<tr>
<td><strong>Total</strong></td>
<td>43</td>
<td>76</td>
</tr>
</tbody>
</table>

**Operational**

Supply Temp. ~ 12°K  
(Avg. 72)  
Return Temp. ~ 15°K  

\[ Q = mc_p \Delta T = (28)(3^°K) = 84 \text{ watts} \]

\[ (9-20-72) \Delta T = 22 - 20 = 2^°K \approx 56 \text{ watts} \]

\[ Q_{\Delta T} = 70 \text{ watts} \]

---

* \( m \) for He gas @ 1-2 atm between 10°K - 20°K = 5.5 \( \frac{\text{wt. sec}}{\text{gm} \cdot \text{°K}} \)

The Cryo: Model 1400 compressor output = 605 cfm (one compr.)

\[ P_{\text{lpm}} = 5.1 \text{ gpm} / \text{ft}^3 \\ 800^\circ \text{K} \]

For 605 cfm (lumpa) and 1°C rise

\[ Q = mc_p \Delta T = 5.1 \frac{\text{gpm}}{\text{ft}^3} \cdot 1 \frac{\text{ft}^3}{\text{sec}} \cdot 5.5 \frac{\text{wt. sec}}{\text{gm} \cdot \text{°K}} (1^\circ \text{K}) = 28 \text{ watts} \]
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