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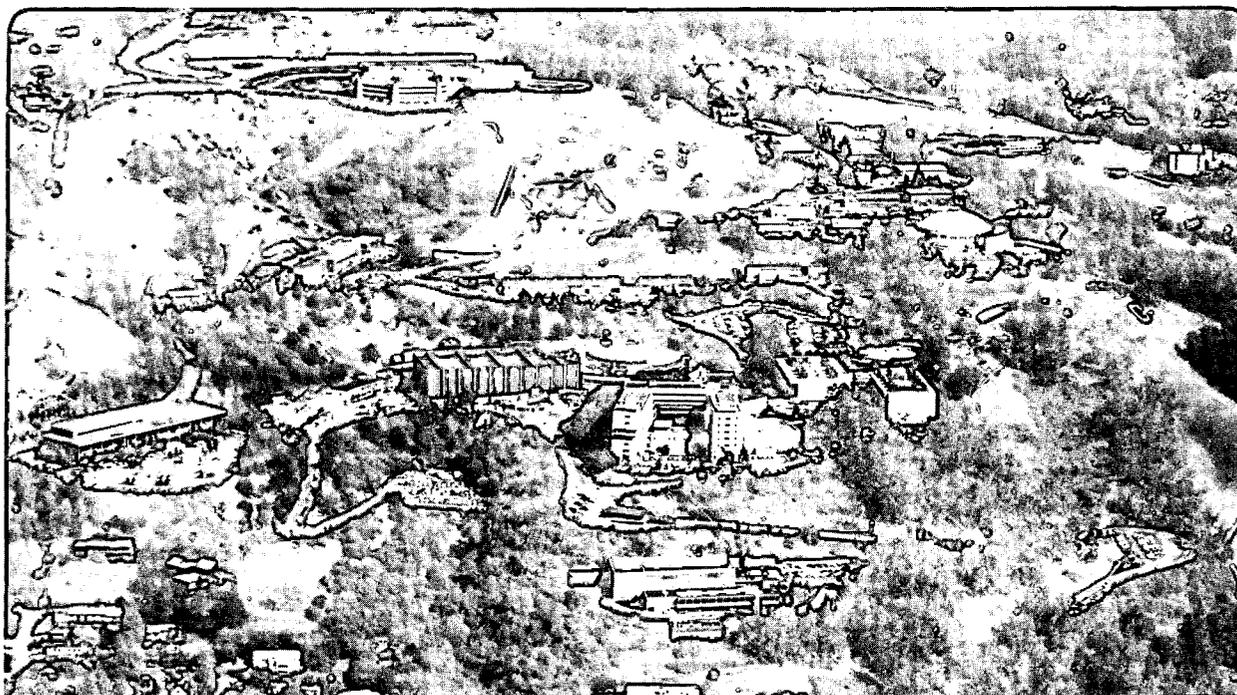
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ENGINEERING NOTE

CODE: BW2007

SERIAL: M4631

PAGE: 1 OF 9

AUTHOR: R. Byrns

DEPARTMENT: Mechanical Engineering

LOCATION: Berkeley

DATE: August 1, 1973

PROGRAM - PROJECT - JOB

BEVATRON VACUUM PUMPING SYSTEM

CRYOGENIC PUMPING

TITLE

HELIUM REFRIGERATOR CROSS-CONNECT STUDY

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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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.

RB/ml

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COST ESTIMATE OPTION I (min. cost)4000 ACCT.ENGR & DESIGN 300 HRS @ \$20⁰⁰ 6000⁰⁰TRANSFER LINE ~ 100^{FT} (DUAL LINE)

PARTS FAB. 160 HRS.

ASSY 160 HRS.

320 HRS @ 17⁵⁰ = 5600 } 6400
MATERIAL 800

AUX. VAC SYSTEMS. 1500

(J.O. 38385 11/72 "CVI" XSPR LINE - \$2000 FOR 35 FT. DUAL)

CONNECTOR BOXES, 2 REQ.

CONTROL, ISOLATION VALVES . . . 600

BAYONET COUPLINGS 400

PARTS FAB 100 HRS @ 17⁵⁰ 1750

MATERIAL 300

ASSY FAB. 1050

2 each @ 4100 8200

INSTALLATION (REQUIRES MACHINE)
* ACCESS TIMEINSTALL 2 BOXES + 100^{FT} XSPR LINE160 HRS @ 17⁵⁰ 2800TOTAL ESTIMATED COST. \$24,900⁰⁰*
(± 10%)* SOME COST REDUCTIONS POSSIBLE IF
OPR. CREW USED (BUT ONLY ~ 15-20%)

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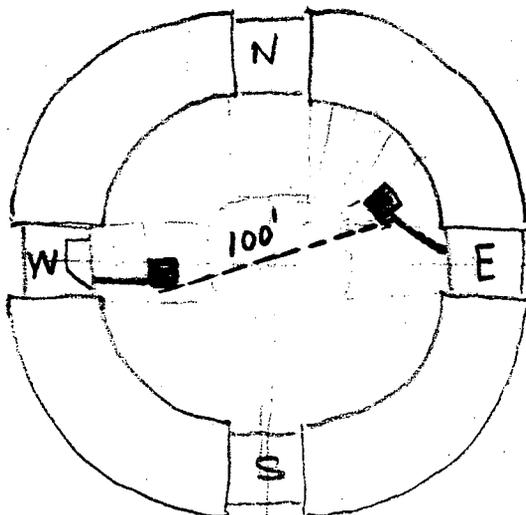
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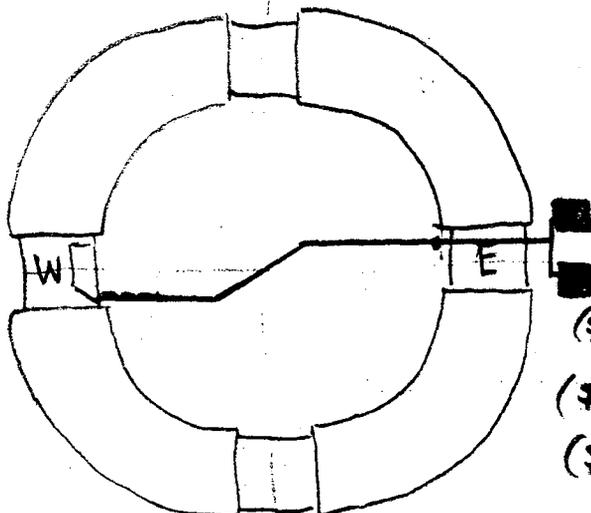
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OPTIONS FOR REFRIGERATOR ARRANGEMENTSI OPTION

Leave cold boxes AS IS.
 Add ~100 FT X'SFR LINE, BAYONETS, VALVES
 No change in compressor supply-returns
 " " " Elec. Wiring & Conduit
 Minimum heat load addition

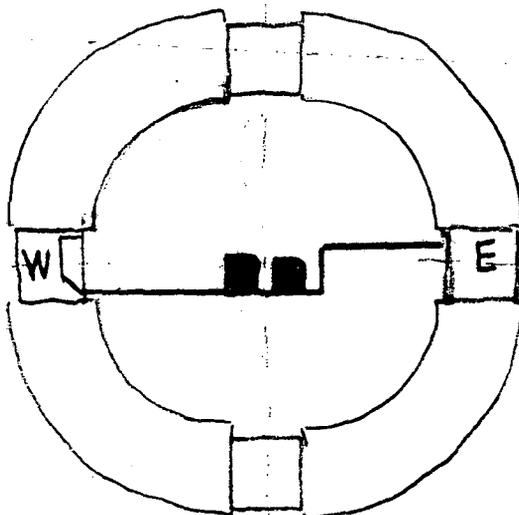
Minimum Cost.

II OPTION

Move cold boxes outside shielding
 to EAST by compressor room.
 Better operating access (full time)

(\$)¹⁵⁰ Adds ~ 200 FT. X'SFR LINE, BAYONETS, VALVES
 (\$)¹⁵⁰ MUCH CHANGE IN COMPRESSOR S+R PIPING
 (\$)¹⁵⁰ " " " 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 X'SFR LINE
 CHANGE COMP. S+R PIPING
 " " ELEC. + CONDUIT
 LARGE COSTS OVER I.

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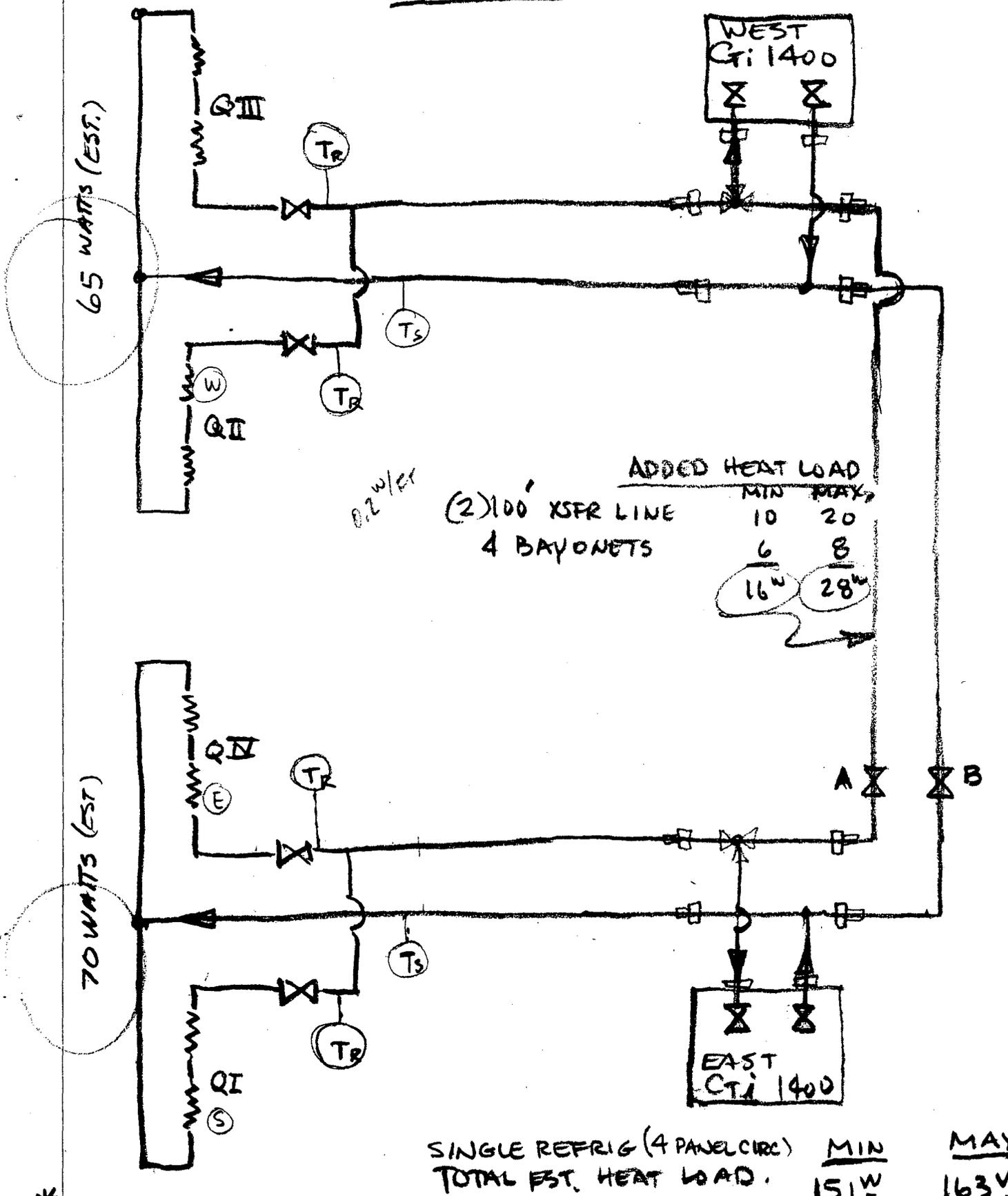
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SCHEMATIC *



SINGLE REFRIG (4 PANEL CIRC) MIN MAX
TOTAL EST. HEAT LOAD. 151W 163W

* (REF. SCHEMATIC LBL DWG 17C8196)

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OPERATIONS.

WITH MINIMUM VALUES & XFR LINE ADDED
 MIN. NEW VALUES REQ'D - (2) A & B - ISOLATION ONLY

MODE I.

WEST REFER TO WEST
 EAST v v EAST
 VALVE A & B CLOSED.

MODE II.

WEST OR EAST REFER TO BOTH
 EAST & WEST. VALVE A + B OPEN.
 2 REFER. ISO. VALVES CLOSED IN
 OFFED REFER.
 ONE (OR TWO) COMPRESSORS ON ACTIVE
 REFER.

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

ADDITION OF VALVES A & B IS MINIMUM POSSIBLE, HENCE CHEAPEST
 * IF BALANCING CIRCUIT IS NECESSARY - OPERATION IS ON
 INSIDE PLATFORM. BALANCING VALVES & TEMP. BULBS
 COULD BE ADDED TO TOPSIDE FOR MORE CONVENIENT
 OPERATION, ON SHIELDING ROOF.
 (VALVE A COULD BECOME 2-3WAY VALVES ON RETURN LINE)

ADDITION OF ~100 FT OF CROSS-OVER XFR LINE + BAYONET
 MEANS ADDED HEAT LOAD OF 16^w min, 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 AP BALANCE

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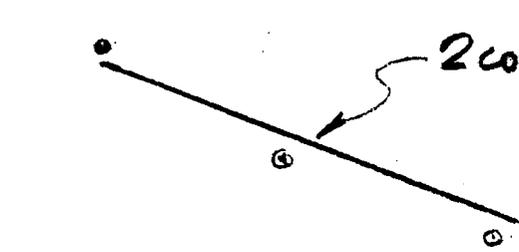
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EFFECT OF ENGINE EXHAUST PRESSURE ON CAPACITY
CTI MODEL 1400 FROM PRD ^{FROM} _{DISCOUNT}
6-9-72

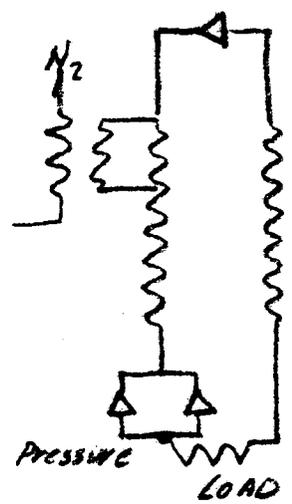
(ALL RETURN TEMPS. @ 20°K
SEE DATA SHEET)

LOAD @ 20°K - WATTS

450
400
350
300
250
200
150
100

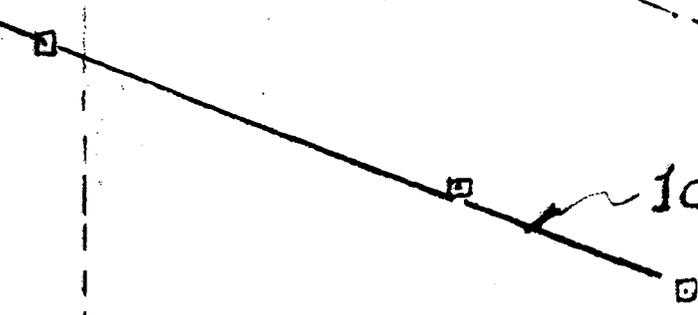
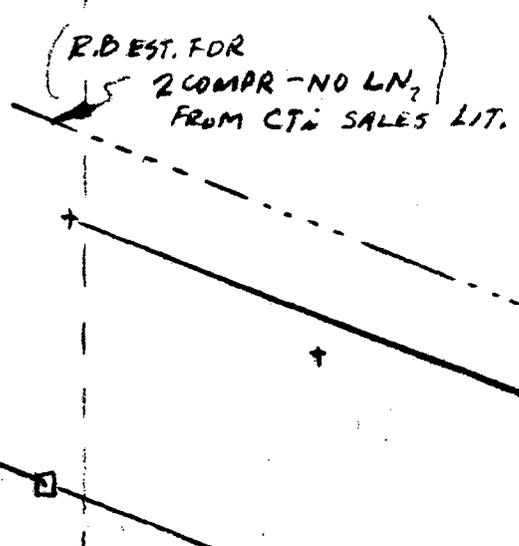


M1400 CONFIGURATION



APPROX. BEVATRON CRYOPANEL OP/R. BACK PRESSURE

(R.D. EST. FOR 2 COMPR - NO LN₂ FROM CTI SALES LIT.)



ENGINE EXHAUST PRESSURE (PSI)

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BEYATRON CTI MODEL 1400 - 20°K - TEST DATA @ BOSTON

LN. USE 2347/HR

LN. USE ~ 17 LINE/HR

MAY JUNE 72

TEST NO	COMPRESSORS	LN	SUPPLY PRESSURE	ENGINE PRESSURE	TEMP °C	ENGINE INLET TEMP °C	ENGINE INLET PRESS.	TEMP SUPPLY	TEMP	TI 2	ENGINE SPEED	MOTOR	START	TITLE
#5	2	YES	213	4.6	-12	27.6	178	13.7	20	278	30	28	432	SWIM
5-23-72	2	YES	221	9.2	-10	23.7	187	13.8	20	278	30	30	402	SWIM
	2	YES	231	14.6	-10	23.9	197	15.0	21	278	30	30	380	SWIM
#1	1	NO	218	3.5	-10	22.4	197	12.2	19.3	104	20	30	238	SWIM
	1	NO	230	16.5	-10.5	23.4	271	13	20	104	20	20	187	SWIM
6-3-72	1	NO	237	29.9	-10.5	23.1	220	14	20.1	104	20	20	161	SWIM
	1	NO	221	9.8	-10.7	23.1	201	13	20	104	20	20	202	SWIM
#2	1	NO	228	2.7	-10.5	27	204	14.7	20	104	20	30	169	SWIM
	1	NO	241	13.5	16.5	27	219	14	20.5	104	20	20	131	SWIM
6-7-72	1	NO	237	19.3	16.5	24.8	219	16.6	20	104	20	20	104	SWIM

20°K HEAT LOAD ESTIMATEEAST REFRIGERATOR

<u>INTERNAL</u>	<u>WATTS</u>	
	<u>LOW</u>	<u>HIGH</u>
5 CRYOPANELS	15	25
TRANSFER LINE - 0.38 DIA x 300 ^{FT.}	15	30
4 FEED THRS.	2	4
EDDY CURRENT	1	2
<u>EXTERNAL</u>		
TRANSFER LINE - 0.75 DIA x 70 ^{FT.}	4	7
4 BAYONET UNIONS	6	8
	<u>43</u>	<u>76</u>

OPERATIONAL SUPPLY TEMP. ~ 12°K
(AUG. 72) RETURN TEMP. ~ 15°K.

$$* Q = mC_p \Delta T = (28)(3^\circ K) = 84 \text{ WATTS}$$

$$(9-20-72) \Delta T = 22 - 20 = 2^\circ K \approx 56 \text{ WATTS.}$$

$$Q_{\text{AV}} \approx 70 \text{ WATTS}$$

$$* C_p \text{ for He gas @ 1-2 atm between } 10^\circ K - 20^\circ K = 5.5 \frac{\text{watt-sec}}{\text{gm} \cdot ^\circ K}$$

The CTi Model 1400 compressor output = 60 SCFM (one compr.)

$$P_{\text{atm.}} = 5.1 \frac{\text{gm}}{\text{ft}^3} \text{ at } 300^\circ K$$

FOR 60 SCFM (COMP.) AND 1° C RISE

$$Q = mC_p \Delta T = 5.1 \frac{\text{gm}}{\text{ft}^3} \cdot 1 \frac{\text{ft}^3}{\text{sec}} \cdot 5.5 \frac{\text{watt-sec}}{\text{gm} \cdot ^\circ K} (1^\circ K) = 28 \text{ WATTS}$$

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