ANL-HEP-PR-78-06

POLARIZED PROTON TARGET-III
OPERATIONS MANUAL
REVISION B

January, 1978

D. Hill, A. Moretti, F. Onesto, P. Rynes

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Revision A

Aside from minor additions and corrections, the main changes reflected in this revision are:

1. Simplification of the microwave system. The wavemeters and frequency stabilizing system have been deleted. The matching hardware has also been dispensed with. Section XVII has been modified accordingly.
2. The liquifier operation notes have been altered to be at least slightly more realistic.
3. Section XXVIII.B has been completely re-written for a faster and more convenient clean-up procedure.
4. The "Notes on Alarms" have been expanded.

Revision B

1. Three-compressor operation of the liquifier, with speed control.
2. New microwave power supply.
3. Liquifier decontamination using the CTI adsorber.

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I. INTRODUCTION

A. General Equipment Descriptions

This manual contains certain standard operating procedures for the Vacuum, Cryogenic, and Electronic Systems of PPT-III. In total, these systems comprise the following major divisions:

1. Target Cryostat

   This serves to keep the target cold, typically, near .4K, and consists of the following subsystems:

   a. He^4 Insulating Vacuum (H4IV)

   b. He^3 Insulating Vacuum (H3IV)

   c. He^4 Cooling Stage

   d. He^3 Cooling Stage

   e. Target Flask and Microwave Cavity

   f. NMR Coil

   g. He^4 Transfer Line

   h. Target Insertion/Extraction Unit

In operation, liquid He^4 at $\sim 4.6K$ is transferred continuously from a supply dewar by means of a low loss transfer line to a reservoir, called the Separator, which separates the liquid He^4 from the gas evolved during transfer. The cold gas is pumped from the Separator through the Upper Heat Exchanger, which uses the cooling capacity of the gas to absorb part of the conduction heat leak in the Cryostat walls and to cool a series of thermal radiation baffles which are located between the ambient and the liquid He^4 temperature regions of the Cryostat. The liquid fraction in the Separator passes through a different heat exchanger, called the Lower Heat Exchanger (LHX), on its way to the "1 K Bath", or "Evaporator". This exchanger employs the cooling capacity of the gas evaporated by heat dissipation in the 1 K Bath to precool the liquid flowing into the exchanger. Once through the LHX, the liquid passes through a precision, fine control expansion valve (CV-1), sometimes called the "*Running Valve*", and is delivered to the 1 K Bath. The liquid absorbs the heat load there, evaporates, and is pumped out of the Cryostat, thereby cooling the shell side of the LHX, the Cryostat walls, and the thermal radiation baffles. (A second, coarse, valve (CV-2), sometimes called the "Pre-cool Valve", delivers liquid helium directly to the Cavity from the Separator, and is used mainly for rapid initial cool-down.)

At the same time, He^3 gas entering the Cryostat at a pressure of ~100 t is cooled by the He^3 Heat Exchanger, which is anchored to the thermal radiation baffles. The He^3 gas is then liquified at ~1.3 K by the He^3 Condenser, which resides in the 1 K Bath. It then passes through a "calibrated leak", in effect, a fixed valve, and is delivered to the interior of the target flask, where it cools the target. The He^3 there boils off under the heat load of the polarizing microwaves, and the resultant gas then is pumped out of the Cryostat, cooling some small radiation baffles along the way.

The He^3 flow rate is controlled by the inlet pressure, which can be varied by means of the room-temperature throttling valve, H3C-V6.

The NMR coil is attached to the exterior of the target flask. All materials used in this region (other than the target itself) are hydrogen-free, in order not to contaminate the NMR signal, which is used to measure the degree of target polarization.

2. He^4 Pumping System

   This consists of the following:

   a. He^4 High Vacuum pumping line and instrumentation (H4HV)

   b. He^4 Separator Vacuum pumping line and instrumentation (H4SV)

   c. Stokes pumps (H4HV-P1, P2)

   d. Exhaust gas clean-up and flowmeter (considered to be part of H4HV)

   e. In case the main pumps H4HV-P1, P2 become inoperable, a valve H4EV-V is provided for attaching a small emergency pump, to keep the target cold in the interim.

3. He^3 Pumping System

   This is sometimes called "He^3 Gas Cart" and consists of:

   a. He^3 Circulation loop (H3C)

      This can be subdivided into the low-pressure He^3 Return pumping line and instrumentation (H3R), the Edwards pumps (H3C-P1, P2), the exhaust gas clean-up devices, and the high-pressure Delivery line (H3D).

b. He^3 Storage areas (H3S)

c. Auxiliary Pumping System (APS)

This is used for certain secondary pumping jobs; in particular, for removing air from other systems and for scavenge-pumping on H3IV and/or H4IV, if needed.

d. He^3 Auxiliary pumping lines and instrumentation (H3A)

This is used in connection with APS operations and also to facilitate such things as leak checking and He^3 loading.

e. H3IV and H4IV pumping lines and instrumentation

f. He^4 Storage area (H4S)

This is used to store He^4 gas, mainly for thermal exchange purposes.

4. Remote Monitors and controls

These are located in the PPT trailer and are concerned with the above systems.

5. Microwave System

This consists of a carcinotron microwave source, power supply, and instrumentation.

6. Magnet and Power Supply

The magnet supplies the high, homogeneous field necessary for the target.

7. Computerized Polarization Monitor

This consists of a PDP-11 computer interfaced to the NMR systems and Magnet.

8. He^4 Liquifier and Gas Recovery System

This consists of the following:

a. CTI 1400 Liquifier - Expansion Engine Module plus two compressors

b. Liquid He^4 Delivery Tube

c. Liquid He^4 Storage Dewar

d. He^4 Gas Clean-Up Devices consisting of an oil filter and tandem LN_2 - cooled water and air traps.

e. He^4 Gas Bag - Low Pressure Storage

f. Auxiliary He^4 Compressor-Corken compressor which pumps gas from Low Pressure to High Pressure Storage.

g. He^4 High Pressure Gas Storage Tank

h. Gas Purity Monitor - Gow Mac Thermal Conductivity Gas Analyzer

9. Miscellaneous Auxiliary Equipment

Some of the more important items are:

a. Electrical Power Carts - One of these is dedicated solely to the He^3 Gas Cart.

b. Auxiliary He^3 Pump - Edwards ED500 mechanical pump used to move He^3 into or out of the Gas Cart

c. Cold Funnel and Flask Flusher - items used for Target Insertion and Extraction, respectively.

d. Auxiliary Vacuum Pump for Liquifier System - used for air trap decontamination and purging liquifier components.

e. N_2 Gas Heater - used for rapid warm-up of the air traps.

B. Scope

The instructions contained in this manual are not intended to be comprehensive, in the sense that they cover all facets of the equipment or all possible operational situations. For example, the "care and feeding" of the superconducting magnet is hardly mentioned, since different magnets may be used with PPT-III. (However, cool-down procedures, etc., for the magnet can usually be garnered from the log books.) Other operations, such as loading and unloading He^3 in the Gas Cart, are so infrequent and/or variable in the circumstances under which they occur, that they are not included.

Furthermore, many matters which do appear here are in the nature of "beginners guides"; since the system is a fairly complex one there is often more than one way to proceed, and certain short cuts exist that can, with experience, be used to advantage. In short, there is no substitute for familiarity with the system. Prehaps the greatest use of this manual is simply as a list of reminders.

C. Cautionary Note

The following comments regarding the target flask are put here for emphasis. The flask is made of thin FEP, which is a thermoplastic form of teflon. Owing to its thinness and odd geometry, the flask is easily damaged by too much differential pressure, in favor of either the inside or the outside.

When at room temperature, the maximum recommended internal pressure is 6 psi (300 t) above the external pressure. Higher differentials may rupture the flask. The maximum recommended external pressure is 0.5 psi (25 t) above the internal pressure. Higher differentials may collapse the flask and cause weakening creases to develop. The strength of the flask increases considerably at low temperatures. For example, at LN_2 temperature, it withstands a full atmosphere of internal pressure above external. However, when cold it is more sensitive to cracking due to repeated flexing.

When attached to the cryostat, H3C-BG2 monitors the internal pressure and H3IV-BG the external pressure on the flask.

The fragility of the flask must always be kept in mind during cryostat operations.

II. CRYOSTAT START-UP

A. Initial Conditions

The following conditions are assumed to exist:

1. The liquid helium supply dewar is connected via the transfer line to the cryostat. It contains sufficient helium and is at normal operating pressure.
2. The cryostat Separator has been purged and is free of air.
3. The cryostat is at or near room temperature.
4. The He^3 is in Storage condition.

B. Preparation

1. Turn on the cooling water for the He^3 gas cart and for the Stokes pumps H4HV-P1, P2.
2. Put APS mode switch in BLANK-OFF.
3. Turn on the three AC switches on APS, and turn on the AC Distribution switch.
4. Turn on the AC power for APS-TC2 and APS-TC1.
5. Put H3IV-V1 in MAN., Open.
6. Verify that the following valves are closed:

H4HV-V2	CV-1	H3A-V2A	H3S-V1A
H4HV-V3B	CV-2	H3A-V2B	H3S-V1B
H4HV-V4	H3C-V1	H3A-V4	H3S-V2A
H4HV-V7	H3C-V2	H3XS-V	H3S-V2B
H4SV-V3	H3C-V3(MAN)	H3P-V1	H3S-V2C
H4SV-V4	H3C-V4(MAN)	H4EV-V	

6. Cont'd.

   Also, the valve on the target insertion unit vacuum jacket and the 4" bypass valve for H4HV-OF, FM.

7. Open the following valves (if closed):

H4HV-V3A	H3C-V5	H3S-VM
H4HV-V6	H3C-V6	H3S-VIC
H4SV-V2A	H3A-V1	H4IV-local
H4SV-V2B	H3A-V3	

   Also, the 4" valve below H4HV-OMS and the two valves in series with H4HV-OF, FM.

8. Open H4IV-V1.

Evacuate H3IV, H4IV, H3D, H3R, and H3C-P1; as follows:

9. Put APS in ROUGHING Mode. Hold down APS P.S. Cheater until H3C-BG2 is less than 400 t.

10. When APS-TC1 reaches 500μ or less, open H3A-V2A and then open H3C-V1.

11. When APS-TC1 reaches 200μ or less, put APS in D.P. Mode.

12. If H3C-NT2 has not been decontaminated, do so now, then return to the above status, i.e., pumping in D.P. Mode on H3IV, H4IV, H3D, H3R, and H3C-P1.

13. Turn on the Stokes pumps H4HV-P1, P2, in AUTO. This evacuates the H4 spaces.

14. Purge H4HV as follows:

    a. Open CV-2 to .200.

    b. WAIT for 5 min., then close H4HV-V6 and open H4HV-V7.

    c. Close CV-2.

15. When H3C-TC2 reads 50μ or less, backfill H3IV, H3D, and H3R with N_2 gas, as follows:

a. Close the following valves:

H4IV-V1 H3A-V2A H3C-V1

b. Put APS in BLANK-OFF Mode.

c. Open the N_2 bottle valve and set the regulator for 5 psig MAX.

d. Slowly open H3P-V1 to admit N_2 to the system. Never admit gas so fast that H3IV-BG exceeds H3C-BG2 by more than ∿30t, or the target flask may collapse. When H3C-BG2 reaches ∿770t, close H3P-V1.

e. Close H3A-V3 and put H3IV-V1 in MAN., Closed.

f. Put APS in ROUGHING Mode. Hold down APS P.S. cheater until APS-TC1 is less than 1000μ .

g. When APS-TC1 reaches 200μ or less, put APS in D.P. Mode.

h. Open H4IV-V1.

C. Monitoring and Regulation of Cool-Down

The basic idea is to cool the cryostat as rapidly as the pumping system will allow, without losing large amounts of He^4 gas out the exhaust relief port (H4HV-V5). The following guidelines are conservative. A somewhat faster cool-down can be achieved by "riding" CV-2 down in smaller, more frequent steps. A sample cooling record is included at the end of this section. The exact timing and settings will depend on the previous cooling history (if any).

1. Open CV-1 and CV-2 to .200.
2. Open H4SV-V4, H4SV-V2A, and H4SV-V2B completely.
3. When the cavity temperature reaches 80K, close H4SV-V4, CV-1, and CV-2.
4. Insert target. See section "TARGET INSERTION".
5. Turn on LN_2 controllers for H3C-NT1 and NT2.
6. Turn on H3C-P1 and P2.
7. Open H3C-V2.
8. Put He^4 exchange gas in H3IV:
    a. Close H3A-V3, H3S-VM, and H3S-V1C.
    b. Put APS in BLANK-OFF Mode.
    c. Open H4S-V1.
    d. Carefully crack open H4S-V2, watching H3IV-TC. When H3IV-TC reaches $\sim 1000\mu$, close H4S-V2 and H4S-V1.
    e. Put H3IV-V1 in MAN., Closed.

9. Put APS in D.P. Mode.

10. Open H4IV-V1 and local H4IV valve (near cryostat).

11. Open CV-1 to .200 and CV-2 to .075.

12. Open H4SV-V4, and close H4SV-V2A.

13. Put proper amount of He^3 into circulation, as follows:

    a. Put H3C-V3 in AUTO, Open.

    b. Close H3C-V6.

    c. Open H3S-V2A and H3C-V1.

    d. Slowly crack H3S-V2C, while watching H3S-BG2. When H3S-BG2 reaches the normal operating pressure as logged during the last TE operation, close H3S -V2C.

    e. WAIT until H3C-TC4 reads less than 40 μ.

    f. Close valves H3S-V2A, H3C-V5, and H3A-V1.

    g. Open H3C-V6 completely.

    h. WAIT ∿10 min. for trap H3C-NT2 to stabilize.

    i. Put H3C-V4 in AUTO, Open. This initiates He^3 circulation.

14. At this time, monitor Bath Level resistor L2 and temperature resistor T1. The resistances will rise at an increasing rate.

15. When H4HV-TC2 reaches 20 t, set CV-2 at .050.

16. When H4HV-TC2 again reaches 20 t, set CV-2 at .030.

17. The presence of liquid He^4 in the Bath will be indicated by the following:

    a. L2 will have a steady high resistance around 5000Ω.

    b. Bath Germanium Probe Ge1 will come into range and read around 1.7 K.

18. When T1 reaches 400Ω, set CV-2 to 5 mil open (closure + .005).

19. Throttle H4SV-V2B, to maintain Separator Gas flow H4SV-FM in the range 10-11 liters per minute.

20. WAIT until H3C-BG1 indicates a pressure less than the HI trip point; i.e., liquid He^3 is collecting in the target flask.

21. As the cryostat comes into equilibrium, to conserve liquid He^4 and maintain the lowest stable Bath temperature, CV-2 should be closed and CV-1 throttled gradually to its normal setting. Typically, the optimum total gas flow rate is about 40-45 l/m with a Bath temperature of approx. 1.3 K on Ge1. The exact setting of CV-1 will depend on the supply dewar pressure, thermal history, and other variables. It will also be possible to

gradually turn on microwave power, if desired, and/or to throttle H3C-V6, as appropriate.

22. Close H4IV-V1.
23. If TE Mode is desired, see section TO TE MODE FROM NORMAL OPERATION.
24. If Enhanced Mode is desired, put H3IV-V1 in MAN., Open. Remember to put H3IV-V1 in AUTO, Open, when H3IV-DG alarm clears.

SAMPLE COOLING RECORD

TIME	CV-1*	CV-2	H4HV -FM	H4SV -FM	T1	T2	L2	L3	TC-1	Gel	H3C -FM
1305	closed	closed	0	0	33Ω	33Ω	243Ω	251Ω	+20°C	2.207	0
1315	.200	.200	>50ℓ/m	24ℓ/m	34	34	243	270	-19	2.206	--
1325	"	"	"	26	34	35	253	297	-89	----	--
1335	"	"	"	29	35	37	279	326	-151	2.201	--
1345	"	"	"	33	37	40	340	380	-183	2.199	--
1346	Close CV-1, CV-2, H4SV-V4										
	Insert Target										
1525	closed	closed	0	0	38	38	298	297	-178	--	--
1540	.200	.060	>50	18	38	41	298	360	-180	2.191	--
1600	"	.060	"	20	49	53	700	750	-217	2.182	--
1607	"	.040	"	13	75	106	2000	1600	--	2.182	--
1623	"	.030	45	"	71	99	850	1950	-225	2.186	--
1630	"	"	>50	"	400	225	∿5000	2550	--	∿1.7	--
1636	"	.005	"	13.5	275	220	"	--	--	1.555	6.45 ℓ/m
1640	Close CV-2 and set H4SV-V2B to .130										
1650	.200	closed	>50	11.1	290	170	"	--	--	1.492	7.40
1700	.150	"	45	"	265	185	"	--	--	1.360	0.89
1730	.085	"	40	"	300	190	"	--	--	1.32	∿0.5

*CV-1 = 2° taper needle valve
T1 = LHX outlet temp.
T2 = LHX inlet temp.
L2 = 1K Bath top level
L3 =Separator Tank
TC-1 = Cavity temp.
Gel = 1K Bath temp.

SAMPLE COOLING RECORD (Cont'd)

TIME	H4SV -BG1	H3IV -BG	H3C -BG1	H3C -BG2	H4HV -TC1	H3IV -TC	H4IV -TC	H3C -TC3	Action
1305	+5.2psig	777t	∿775t	771.7t	.01t	---	4.2μ	----	Open H4SV-V4, H4SV-V2A, H4SV-V2B, CV-1, CV-2
1315	-26.5"	771	----	770.9	2.5	---	3.2	----	
1325	-26.3	752	----	770.1	3.5	---	2.7	----	
1335	-26.1	715	----	767.3	5.2	---	2.2	----	
1345	-25.7	530	----	727.	12.	---	1.9	----	
1525	+5.1	---	----	-----	---	---	---	<.1t	Put exchange gas in H3IV
1540	-1	---	----	-----	1.6	1000μ	2.0	----	Start He^3 circulation
1600	0	---	∿450	-----	5.5	900	1.3	----	Close H4SV-V2A; set CV-2.040
1607	+3.3	---	----	-----	∿10	700	1.2	----	Set CV-2 to .030
1623	"	---	----	-----	1.4	450	1.1	----	
1630	---	---	----	-----	>20	---	---	----	Set CV-2 to .005
1636	---	---	282	-----	5.7	92	---	1.7t	
1650	---	---	318	-----	3.4	174	---	2.0	Begin to throttle H3A-V2A to prepare TE(set H3C-V6 at .080)
1700	---	---	365	-----	1.5	200.	---	0.52	Begin to throttle CV-1
1730	---	---	∿300	∿6.2	1.4	∿80	---	∿.2	

III. VALVE STATUS-NORMAL OPERATION

1. In normal operation, CV-1≈ .070 →.100,

   CV-2 is closed and H4SV-V2B ≈140" (at 4 psig dewar press.

2. The following valves are normally OPEN:

H4HV-V3A	H3C-V1	H3C-V4 (AUTO)
H4HV-V7	H3C-V2	H3IV-V1 (AUTO)
H4SV-V4	H3C-V3 (AUTO)	H4IV-local

also, the 4" valve below H4HV-OMS; the two valves in series with H4HV-OF, FM; and H3C-V6 is open to a degree depending on He^3 circulation needs.

3. The following valves are normally CLOSED:

H4HV-V2	H4IV-V1	H4S-V1	H3S-V1C
H4HV-V3B	H3C-V5	H4S-V2	H3S-V2A
H4HV-V4	H3A-V1	H3XS-V	H3S-V2B
H4HV-V6	H3A-V2A	H3S-VM	H3S-V2C
H4SV-V2A	H3A-V2B	H3S-V1A	H3P-V1
H4SV-V3	H3A-V3	H3S-V1B	H3P-V2
H4EV-V	H3A-V4		

also, the 4" by-pass valve for H4HV-OF, FM, and the vacuum jacket valve for the target insertion unit.

4. Normally, H4SV-FM~10 l/m, H4HV-FM= ~45 l/m.

IV. TO PUT He^3 GAS INTO STORAGE

(Microwaves should be on)

1. Open valves H3S-V2A and H3S-V2B.
2. Switch valve H3C-V3 to MAN., Closed.
3. Open the following valves:

H3A-V1	H3C-V6	H3C-V1 (if closed)
H3C-V5	H3A-V2A	H3C-V4 (if closed) (MAN.)
		H3C-V2 (" ")

4. WAIT until H3C-TC4 indicates less than 40μ.
5. Close valves H3A-V1, H3A-V2A, and H3C-V1.
6. Watch H3C-TC1. When it stops rising, open valves H3A-V1, H3A-V2A, and H3C-V1.
7. When H3C-TC4 indicates less than 20μ, Close the following valves:

H3A-V2A	H3C-V2
H3A-V2B (if open)	H3S-V2A
H3C-V1	H3S-V2B

8. Switch valve H3C-V4 to MAN., Closed.
9. Turn off (AC off) pumps H3C-P1 and H3C-P2.
10. Turn off microwaves.
11. Turn off the LN_2 controllers for H3C-NT1 and H3C-NT2.

V. TO He^3 STAND-BY FROM NORMAL OPERATION

There are several ways of interrupting the He^3 flow through the cryostat and thereby reducing the total heat load on the He^4 stage. For example, the simplest way is to close H3C-V6 and turn off the microwaves. This is one kind of temporary "He^3 stand-by" condition. However, this leaves liquid He^3 in the condenser and target flask for an indefinite length of time, and also, with H3C-V1 left open, it leaves the He^3 pumps exposed to the cryostat. Thus, if an accidental warm-up occurs, any cryopumped materials that have built up over the course of prior operation, such as water, air, hydrogen, etc., will be pumped into the He^3.

Therefore, the following procedure, which completely isolates the He^3 from the cryostat, is recommended as the "official" He^3 STAND-BY condition:

1. Leave microwaves on
2. Switch valve H3C-V4 to MAN., Closed.
3. Open the following valves:

H3A-V1	H3A-V2A	H3C-V1(if closed)
H3C-V5	H3C-V6	

4. WAIT until H3C-TC4 indicates less than 40μ.
5. Close valves H3A-V1, H3A-V2A, and H3C-V1.
6. Watch H3C-TC1. When it stops rising, open valves H3A-V1, H3A-V2A, and H3C-V1.
7. When H3C-TC4 indicates less than 20μ, close H3A-V2A, H3A-V1, and H3C-V1.
8. Turn off microwaves, or put into stand-by, depending on the situation.

If the STAND-BY is to be for 24 hours or longer, it is recommended that the He^3 be put into storage.

VI. TO He^4 STAND-BY FROM NORMAL OPERATION

To put He^4 stage in STAND-BY (not being used, but keeping target cold):

1. Normally, if the He^4 stage is to be put into STAND-BY, the He^3 stage should first be put into a safe condition. See section "TO He^3 STAND-BY FROM NORMAL OPERATION".
2. Close CV-1, CV-2, and H4SV-V2A (if open).
3. Open H4SV-V2B full open, and open H4SV-V4 (if closed).
4. Verify that APS is in D. P. mode, then open H4IV-VI, H4IV-local (if closed), and put H3IV-VI in MAN., Open.
5. Turn off the LHe Level alarm.
6. Set the LO set point on H4HV-TC2 full left (less than 0) and the HI set point at 0.3 torr. On the HELIUM VACUUM CONTROL panel, switch to AUTO. while holding down the RESET button.
7. H4SV-FM should now read 12-16 l/m.

NOTE: The above procedure will only keep target cold if there is helium in the supply dewar, dewar pressure is normal, Stokes pumps keep running, APS keeps running, etc.

VII. TO NORMAL OPERATION FROM He^4 OR He^3 STAND-BY

A. He^4 Stage

1. Switch to MAN. on the HELIUM VACUUM CONTROL. Return the HI and LO set points on H4HV-TC2 to the normal settings.
2. Open CV-1 to .200 and CV-2 to .025.
3. Close H4IV-V1, and put H3IV-V1 in AUTO., Open.

B. He^3 Stage

1. If He^3 gas is in storage, perform operation TO He^3 STAND-BY FROM He^3 STORAGE, WAIT ~10 min. for trap H3C-NT2 to stabilize.
2. If He^3 stage is in stand-by:
   a. Open H3C-V1 and put H3C-V4 in AUTO., Open. Verify that H3C-V6 is completely open.
   b. Close H3C-V5, if open.
3. WAIT until H3C-BG1 indicates a pressure less than the HI trip point; i.e., liquid He^3 is collecting in the target flask.
4. Close CV-2. Turn on the LHe Level alarm.
5. As the cryostat comes into equilibrium, it will be possible to gradually turn on microwave power and throttle CV-1 to the normal setting, while maintaining He^4 level and H3C-BG1 below the HI trip point.
6. Set H4SV-V2B to maintain H4SV-FM ~ 10 l/m.
7. Throttle H3C-V6, as appropriate.

VIII. TO He^3 STAND-BY FROM He^3 STORAGE

A. Initial Conditions:

1. It is assumed that the system is charged with a proper amount of He^3, that pump H3C-P1 is well evacuated, as well as the plumbing comprising H3D and H3R, and that the He^3 traps have been decontaminated.

2. Turn on the LN_2 controllers for H3C-NT1 and H3C-NT2, if these are off.

3. Valves H3S-VIC, H3S-VM, and H3A-V3 are closed.

4. Valve H3C-V4 is in MAN., Closed.

B. He^3 Stand-By:

1. Turn on pumps H3C-P1 and H3C-P2.

2. Open the following valves:

   H3C-V1 H3A-V2A H3C-V5 (if closed)

   H3C-V2 H3S-V2A H3A-V1 (if closed)

3. Put H3C-V3 in AUTO., Open.

4. Close H3C-V6.

5. Slowly crack valve H3S-V2C, while watching H3S-BG2. When H3S-BG2 reaches the normal operating pressure as logged during the last TE operation, close H3S-V2C.

6. WAIT until H3C-TC4 indicates less than 40 μ.

7, Close the following valves:

   H3C-V1 H3A-V2A

   H3A-V1 H3S-V2A

8. Open H3C-V6 completely.

IX. He^3 DELIVERY DECONTAMINATION

The He^3 delivery system (H3D), so called because it serves to deliver the cooling He^3 to the target, consists of flowmeter H3C-FM, pressure station H3C-BG1,PS1, and TC1, piping to the cryostat, throttling valve H3C-V6, He^3 heat exchangers, He^3 condenser, and a "calibrated leak". The latter components operate at temperatures down to 1K. Any contaminants (other than He^4) that pass H3C-NT2 will therefore solidify in H3D. In great enough quantity, these will increase the impedance of the system and perhaps block it entirely. The usual symptom of this is a reduced He^3 flow during polarization reversal, assuming other conditions are normal.

The following procedure will clear H3D of most contaminants (exceptions: H_2O, CO_2, hydrocarbons). The procedure is simply to partially warm up the cryostat and pump out H3D. The initial conditions are assumed to be those of normal operation:

A. Partial Warm-Up

1. Put He^3 into Stand-By condition. The He^4 stage should be kept in operation until this step is completed, so that cryopumped materials do not get mixed into the He^3.
2. Put H3IV-V1 in MAN., Open.
3. Verify that H3C-V6 is completely open, and H3A-V1 is closed.
4. Close the following valves:

   H4IV-V1 (if open) H4HV-V3A H4HV-V3B (if open)

   H4SV-V2A (if open) H3S-V1C(if open)
5. Throttle valve H4SV-V2B to .040".
6. Turn off the LHe Level alarm.

C. Return to Normal Operation

1. Completely open H4SV-V2B.
2. Open CV-1 to .200 and CV-2 to .060.
3. Open H3C-V1 and put H3C-V4 in AUTO., Open.
4. When H4HV-TC2 exceeds 20 t, set CV-2 to .040.
5. Close H4IV-V1.
6. When H4HV-TC2 again exceeds 20 t, set CV-2 to .025.
7. WAIT until H3C-BG1 indicates a pressure less than the HI trip point.
8. Put H3IV-V1 in AUTO., Open.
9. Close CV-2. Turn on the LHe Level alarm.
10. As the cryostat comes into equilibrium, it will be possible to gradually turn on microwave power and throttle CV-1 to the normal setting, while maintaining He^4 level and H3C-BG1 below the HI trip point.
11. Set H4SV-V2B to maintain H4SV-FM $\approx$ 10 l/m.
12. Throttle H3C-V6, as appropriate.

X. He^3 TRAP DECONTAMINATION

This operation is ordinarily done only in preparation for Start-Up, but it might also have to be done if, by some accident, air or other contamination got into the circulation loop during operation. Decontamination consists of warming the traps and pumping off the contaminants.

A. Initial Conditions:

1. Volumes H3IV, H3R, and H3D are evacuated to 100μ or less.
2. The He^3 has been put into storage. H3C-P1, P2 are off.
3. These valves are closed (close, if not):

H4IV-V1	H3C-V4(MAN)	H3A-V4	H3S-V2C
H3C-V1	H3C-V6	H3S-V1A	H3P-V1
H3C-V2	H3A-V2A	H3S-V1B	H3XS-V
H3C-V3(MAN)	H3A-V2B		H3IV-V1 (MAN)

4. These valves are open (open, if not):

H3C-V5	H3A-V3	H3S-VM
H3A-V1	H3S-V1C	

5. The LN_2 controllers for H3C-NT1, H3C-NT2 are turned off.
6. Open the gas ballast valve on pump APS-P2.

B. H3C-NT1

Normally, this trap collects only small amounts of water vapor and CO_2 from outgassing, etc. As the trap warms, the plume of cold vapor from the vent will stop and the ice that has formed on the vent will begin to melt.

At this time, the pressure inside the trap will commence to rise as the trapped materials boil off. This pressure rise can be monitored on H3C-TC3, and when it stops rising, we can pump out the contaminants:

1. Put APS in ROUGHING Mode.
2. Open H3A-V2A and H3C-V1.
3. When APS-TC1 reaches 200μ or less, put APS in D.P. Mode.
4. When H3C-TC3 reads less than 0.1t, close H3A-V2A and H3C-V1.

C. H3C-NT2

Normally, this trap collects any N_2, O_2, CO_2, H_2O, etc. present in the He^3 stream. The warm-up can be facilitated by emptying the dewar of any LN_2 and using the heater. It is sufficient to warm the trap up to somewhat above room temperature. The resulting pressure in the trap is most easily observed by doing the following:

1. Close H3A-V1 and H3S-V1C.
2. Put H3C-V4 in MAN., Open. The trap pressure is now observed on H3C-BG1, TC1.
3. Put APS in ROUGHING Mode.
4. Now pump out the trap by opening H3S-V1C.

5. When APS-TC1 reaches 200 µ or less, put APS in D.P. Mode.
6. In general, the trap is sufficiently clean when H3C-TC1 reads less than .1t.
7. Turn off the trap heater.
8. Put H3C-V4 in MAN., Closed.

D. Final Safe Conditions:

1. Open H3A-V1 and H3C-V6.
2. Put H3IV-V1 in MAN., Open.
3. Close the gas ballast valve on APS-P2.

XI. CRYOSTAT SHUT-DOWN AND TARGET WARM-UP

A. Shut-Down

1. The initial conditions are assumed to be those of normal operation.
2. Put He^3 gas into storage (see section so named). The He^4 stage should be kept in operation until this step is completed, so that cryopumped materials do not get mixed into the He^3.
3. Verify that APS is in D.P. mode, then put H3IV-V1 in MAN., Open.
4. Close the following valves:

   H4SV-V4 H4HV-V3A H4HV-V3B (if open)

   H4IV-V1 (if open)
5. WAIT until H4HV-BG1 indicates "O" (1 atmosphere).
6. Close CV-1 and CV-2.
7. If the shut-down is to be long-term, the cooling water and LN_2 flows should be stopped as follows:
   a. Close the He^3 gas cart water supply valve at the water rack.
   b. Turn off H4HV-P1, P2 (Stokes Pumps).
   c. Close the Stokes Pumps cooling water supply valve and the 4" valve below H4HV-OMS.
   d. Turn off the LN_2 controllers for H3C-NT1 and H3C-NT2. If these traps are to be decontaminated, see section "He^3 Trap Decontamination". This is usually not necessary for long-term shut-down.

B. Target Warm-Up

1. The available sources of heat for warming the target are:

   a. Conduction and radiation heating in the cryostat structures.

   b. Conduction and convection in the gasses filling the cryostat spaces.

   c. Electrical heaters for CV-1, CV-2, and He^4 transfer line.

   d. Direct microwave heating of the target.

   The mere fact of He^4 shut-down sets some of these sources into play. However, if the fastest possible warm-up is desired, do the following:

2. Turn on the heater control circuit and set the powerstat for 10 w on CV-1. Then go to position "all".

3. Turn on the microwaves and set the attenuator to .000. If desired, the microwave power can be increased by setting the Anode 2 current to 50 ma.

4. The fastest heating is achieved by breaking H4IV to either N_2 or He^4 gas. However, frost and/or water of condensation will appear on the outer shell unless the H4IV pressure is held to less than 50μ of N_2 or 10μ of He^4, as indicated by H4IV-TC. Such water may be harmful to veto-counters, PWC's etc. near the target. If there

is no such concern, then the H4IV pressure can be raised to 10t of N_2 or 1000μof He^4. In either case, the desired condition of H4IV can be brought about by putting H3IV-V1 into MAN., Closed; putting APS into Blank-Off; and then manipulating valves H4IV-V1, H4S-V1 and H4S-V2 (for He^4); or H3A-V3, H3S-VM, and H3P-V1 (for N_2). If too much gas is transferred to H4IV, use APS to reduce the pressure. Finally, leave H4IV-V1 in a closed condition.

5. When the cavity temperature is above 80 K, the H3 spaces should be filled to atmospheric pressure with N_2 gas:
   a. Put APS in BLANK-OFF Mode.
   b. Open the following valves (if closed):

H3A-V1	H3S-V1C	H3C-V6	H3IV-V1(MAN)
H3C-V5	H3S-VM	H3A-V3	

   c. Check N_2 bottle. High-pressure valve should be open and the regulator set at 5 psig MAX.
   d. Slowly open H3P-V1 to admit N_2 to the system. Never admit gas so fast that H3IV-BG exceeds H3C-BG2 by more than 30t, or the target flask may collapse. When H3C-BG2 reaches 760t, close H3P-V1.

6. Another means of rapid warm-up is to force-flow N_2 gas through the insertion tube, as follows:
   a. The H^3 spaces must first be back-filled with N_2 gas as in item 5 above.

b. Remove the plugs on the H3R local port and insertion tube.

c. Carefully slide the insertion unit in to the mark, after loosening the feed-thru nut. Don't damage the tip. Tighten the feed-thru nut.

d. Attach the N_2 gas hose to the insertion tube.

e. Set the N_2 regulator at 5 psig MAX.

f. Open the N_2 feed valve at the regulator. Check for flow out of the H3R local port.

This flow must be stopped when you are ready to commence target extraction.

7. To remove the old target, see section "Target Extraction". A target should not be left in the warm cryostat for more than ~1 day, because adverse chemical reactions may take place which make the material more difficult to remove.

C. Complete Shut-Down; System Check

Following target extraction, and if the shut-down is to be long-term, complete the system shut-down as follows:

1. Close the following valves (if open):

H4HV-V2	H4SV-V4	H3C-V4 (MAN)	H3P-V2
H4HV-V3A	H4EV-V	H3A-V2A	H3S-V1A
H4HV-V3B	CV-1	H3A-V2B	H3S-V1B
H4HV-V4	CV-2	H3A-V3	H3S-V1C
H4HV-V6	H3C-V1	H3A-V4	H3S-V2A
H4HV-V7	H3C-V2	H3XS-V	H3S-V2B
H4SV-V3	H3C-V3 (MAN)	H3P-V1	H3S-V2C
	H3C-VM	H3IV-V1 (MAN)	H4IV-V1

2. Turn off all AC power switches on the He^3 Gas Cart.

3. Turn off all AC power in the PPT trailer.

4. Close the carcinotron cooling water supply valve.

5. Shut down liquifier (if it is still on).

6. Turn off the Gow-Mac.

D. He^4 Gas Recovery System Shut-Down

1. The recovery system should be kept in operation until all cryogenic systems are empty of liquid helium and fairly warm (the quantities of cold vapor, particularly in the storage dewar, can be considerable, because of the high density of cold vapor). The storage dewar may take weeks to truly empty, depending on the initial amount of liquid.

2. When ready, recovery is shut-down by turning off the Auxiliary Helium Compressor (Corken) at the relay rack, and by closing the valve outside on the H. P. gas storage tank. Turn off the cooling water for all four helium compressors.

3. The AC power to the two "Gas Bag" pressure meters should be left on.

XII. OPERATOR CHECKLIST

1. Log the helium liquifier operation every 3 hours. Keep the blue storage dewar pressure in the posted range. (Turning the brass valve, near the port to which the blue dewar is connected, CW increases the pressure)

2. Check SCM water bucket every day and empty when necessary.

3. The charcoal purifiers should be cycled at the posted intervals.

4. The He^4 water traps should be cycled whenever supply pressure "1" exceeds pressure "2". If this does not help, it means the heat exchanger is probably plugged.

5. The liquifier must be shut down and decontaminated when the helium production falls below 17 l/hr. (on two-compressor operation) as measured at the make-up gas flowmeter.

6. When a commercial dewar of helium has been used and is empty, tag it MT and place outside overhead door. Remove all fixtures that belong to us.

7. He gas supply at rear of Stokes pumps: when bottle in use gets low, valve open the back-up bottle and replace spent bottle, leaving the valve closed on the new back-up bottle. Normally, both bottles should be valved closed, unless external dewar pressurization is necessary.

8. When PPT cryostat is in Stand-By Mode (keeping cold) He^4 Separator Flow (H4SV-FM) should stay

8. (Cont'd)

in the range 12 - 16 l/m. Notify system expert if this condition should fail to exist.

(In normal running mode, H4SV-FM ~ 10 l/m)

9. Operators should begin to pressurize a commercial dewar of liquid helium into the gas bag shortly after it arrives. This is especially important if Supply Tank pressure "1" falls to 15 psig or less.

Note: This should be done only when no SCM is transferring, and should be stopped at least 15 min. prior to an SCM transfer, to allow the Corken compressor to "catch up".

10. About once each week of operation, the excess oil should be drained from the Stokes oil filter, and from the Stokes exhaust oil sump.

XIII. SPECIAL DAY-SHIFT CHECKLIST

1. Check He and N_2 gas cylinder supply and order gas (6 He and 6 N_2) when inventory is two bottles or less.

2. Check oil levels in the following devices and top up when necessary:

   a. He^4 Stokes pumps H4HV-P1 and H4HV-P2 (use "V-Lube")

   b. He^3 forepump H3C-P2 (this is a special operation; notify system expert if it is necessary)

   c. Mech. pump APS-P2 in gas cart (use Welch Duo-Seal Pump Oil)

   d. SCM IV mech. pumps (under SCM; ") (if on)

   e. Corken oil level (best checked when the compressor is in the off part of its cycle; use 20W non-detergent) (fill to upper mark)

   f. CTI compressors #1 and 2 (this is a special operation) notify system expert (check only when on)

   g. Auxiliary mech. pump used for liquifier and purifier decontamination (use Welch Duo-Seal Oil)

3. Check the total He^4 inventory, gas and liquid, and order helium if the inventory is low. The total inventory is defined as the sum of the following parts:

a. supply tank gas (1 psig = 5 liquid l equivalent)

b. liquid in main He^4 storage dewar ("blue dewar")

c. liquid in the PPT SCM (if used)

d. liquid in the Spin Solenoids (if used)

e. liquid in any other SCM's on line

f. liquid in any other dewars on line (stand-by dewars, extra storage dewars, etc.) or extra gas such as in a tube trailer, etc.

The following information should be determined by a a system expert and posted:

1) contact for ordering helium

2) form of helium to be ordered (gas or liquid)

3) volumetric information on the dewars and SCM vessels on line

4) definition of "low inventory", depending on conditions.

4. When a dewar of ordered helium arrives (or any stand-by liquid exists), see that the boil-off gas gets connected to the gas manifold, unless the liquid is to be used immediately.

5. Check oil filters on Corken and on Stokes Pumps: when red color reaches top, notify system expert.

6. Knock the excess ice off the SCM LN_2 vent ports once per day.

7. Record readings of "He^4 gas summing meters".

8. Record the amount of LN_2 remaining in the outside tanker. Notify R. Mandernack and system expert if the amount is less than 1500 gallons. (Take an average reading over 1 minute of time, if the level is fluctuating).

9. Drain any oil from Corken distance piece, best done when Corken is on.

10. Make a daily check of the purity of the gas in high-pressure storage, as follows:

    a. First, there must be make-up flow, or the gas cannot be sampled easily.

    b. Choose a time when the Corken is not running. If it is running, the gas sampled will be from it and not from the storage tank.

    c. Valve the Gow-Mac to Bypass.

    d. Close the "Purifier Out" valve on the Gow-Mac valve panel, and open the "Water Trap In" valve.

    e. WAIT 15 seconds, to purge the line.

    f. Valve the Gow-Mac to Sample.

    g. When the reading stabilizes, note it.

    h. Close the "Water Trap In" valve, valve to Bypass, open the "Purifier Out" valve, and valve to Sample.

Any unexplained increase in gas contamination should be brought to the attention of a recovery system expert.

11. Check the H3C-P2 shaft-seal oil reservoir. If the oil level has reached the tapered section, note in the log book and re-fill. Use Edwards No. 16 oil.

PPT-III OPERATOR CHECKLIST

DATE	Shift	Oil Levels & Filters	Cycle Air Traps	Cycle Water Traps	Decontaminate Liquifier	He & N_2 Gas Cylinders Ordered	He & N_2 Gas Cylinders Rec'd.	Liquid He Ordered	Liquid He Rec'd	He^4 Summing Meters From 382	He^4 Summing Meters To 382	He^4 Summing Meters From 369	LN_2 Tanker Level	LN_2 Tanker Press	H.P. Gas Purity

XIV. NOTES ON ALARMS

1. "He^3 FLOW" alarms: These are wired to H3C-TC2, which is actually the He^3 gas pressure at the booster pump inlet. (The true He^3 flow is monitored by H3C-FM) Normally, the higher this pressure, the greater is the flow. In the case of a steady indication, the proper operator responses are

"He^3 FLOW LOW"	the microwave power should be increased by reducing the attenuation
"He^3 FLOW HIGH"	the microwave power should be reduced by increasing the attenuation

However, a steady "FLOW HIGH" alarm can be the earliest sign of a booster pump heater failure, so when all else fails, check H3C-P1 control panel for trouble.

An intermediate situation often occurs in which intermittent H3C-TC2 alarms come and go with some regularity. This happens when the microwave power level is appreciably mis-matched to (and less than) the He^3 flow setting of H3C-V6. The target cup then periodically overflows which causes a pressure pulse on H3C-TC2. While this is not particularly harmful to the polarization, the repetitive alarms are annoying.

If there is no He^3 Level alarm, the following cure usually works: Throttle H3C-V6 in 10 mil steps and/or increase the microwave power in 1 db steps until stable conditions are reached.

A "FLOW LOW" condition sometimes occurs when Baseline is being taken. This is o.k. and should go away when Baseline is finished.

XIV. 2. "He^3 LIQUID LEVEL" alarms: These are wired to H3C-BG1 (He^3 gas delivery pressure). We normally operate with a fixed total quantity of He^3, gas and liquid. The idea here is, the more gas (higher pressure on BG1) the less liquid; the less gas (lower pressure on BG1) the more liquid. Normally, the proper operator responses are:

"He^3 LIQUID LEVEL LOW":
Open H3C-V6 in steps of 10 mils until the alarm goes normal, waiting ~5 min. between steps.

"He^3 LIQUID LEVEL HIGH"
close H3C-V6 in steps " " "

If "LEVEL LOW" alarm cannot be corrected by the above, turn microwaves OFF, either by turning Anode 1 voltage to 0.2 kv or by setting attenuator at .200".

Note that the He^3 level and flow indicators are not entirely independent. For example, if H3C-V6 is opened in response to a low level condition, H3C-TC2 must ultimately also respond by rising somewhat as the H3C-BG1 indication falls. Or, if the microwave power is raised in response to a H3C-TC2 low condition, H3C-BG1 must ultimately also respond by rising to meet the higher flow requirement, etc.

To summarize:

Action	Immediate Response	Ultimate Response
open H3C-V6	H3C-BG1 falls	H3C-TC2 rises
throttle H3C-V6	H3C-BG1 rises	H3C-TC 2 falls
increase power	H3C-TC2 rises	H3C-BG1 rises
decrease power	H3C-TC2 falls	H3C-BG1 falls

As pointed out in Note 1 above, the real objective is to achieve a balance between the power level and the flow impedance presented by H3C-V6. Fortunately, there is a certain amount of negative feedback, so that exact settings are not too critical. Also, the polarization is fairly insensitive to small power changes.

XIV.

3. "He^4 DEWAR PRESSURE LOW": usually means something is wrong with liquifier system. Check to see if helium inventory is low or H_2O traps need to be cycled.
4. Valve H3IV-V1 is normally open and set on AUTO. This means that, if there is a H3IV-DG alarm, the valve will close and will not re-open, even if H3IV-DG returns to normal. It should be manually re-opened by pressing RESET (if H3IV-DG is o.k.), or by switching to MAN until H3IV-DG is o.k., then back to AUTO.

   CAUTION: Do not turn to MAN if H3IV-TC reads greater than 10μ. Instead, call system expert as this may mean that target flask is leaking He^3.
5. In normal operating, valves H3C-V3 and H3C-V4 are in AUTO mode running on their interlocks. In particular, each one is interlocked on H3C-NT2. If you get an "H3C-NT2 LIQUID LEVEL LOW" alarm, H3C-V3 and H3C-V4 will close automatically and He^3 flow will drop off. These valves must be RESET manually after the bad NT2 condition is corrected.
6. Valve H3C-V4 (as well as pump H3C-P1, of course)is interlocked on "H_2O FLOW" and "H_2O TEMP. H3C-P1". RESET manually after either such alarm (after alarm condition is corrected).
7. Similar interlocks exist on pump H3C-P1 for the alarm condition "H3C-P1 OVER-TEMP" (not present on Alarm Panel) and pump H3C-P2 for the conditions "H_2O FLOW H3C-P2" and "H3C-P2 BACK-PRESSURE". These only control the pumps, no valves.
8. In the event of a He^4 gas purity alarm, first check and set Gow-Mac zero. If the Gow-Mac Analyzer then shows >100 ppm gas impurity from the charcoal purifier, the liquifier must be shut down and the charcoal purifiers switched. To turn the liquifier back on, see "He^4 Liquifier Operation".

9. "He^4 LEVEL INDICATOR" alarm: In the absence of any other alarm condition on the He^4 system, this usually means that CV-1 is set too lean. Increase the CV-1 setting somewhat. (It may be necessary to bootstrap the He^4 stage back into operation by also momentarily cracking CV-2.)

10. H4HV-TC2 HI or LO alarms on the He^4 Status Panel (buzzer) usually mean that CV-1 and/or CV-2 are improperly set, although other causes are possible, such as loss of H4HV-P1, P2 operation, or loss of air pressure to valve H4HV-V3A.

11. "He^4 GAS BAG" alarm: This indicates abnormally high pressure in the bag, and that He^4 gas is being vented to the outside. The possible causes are many. Check the helium recovery system, all SCM systems, and the liquifier system, for soft insulating vacua, stuck transfer valves, compressor failure, compressor unloader failure, low compressor oil level, etc.

12. SCM LN_2 LOW alarms: If the condition cannot soon be corrected, turn off the SCM in question and turn off its He transfer valve controller.

13. SCM LHeLOW alarms: Turn off the magnet in question until the condition is corrected.

14. In case of the alarm "STS(A) LEAD OVER-TEMP." immediately turn off this magnet.

XV. UTILITY FAILURES

1. In case of domestic water supply failure, immediately take the following steps:

    a. shut down the PPT (close CV-1 (outside), CV-2 (outside), H4HV-V3A and H4SV-V4 (both in trailer).

    b. Open H4IV-V1 and put H3IV-V1 in MAN., OPEN (gas cart).

    c. Close H3C-V1 and H3C-V6.

    d. Shut down liquifier

    e. Turn off all SCM's

    f. Turn off all SCM He valve controllers (outside).

    g. CALL System Expert

2. Normally, the LN_2 tanker runs at a pressure of ~ 30 psig. We are in trouble if the pressure falls below ~ 25 psig. (If you cannot restore the pressure, call EPOG).

3. If there is no LN_2 (e.g., tanker runs dry), immediately take the following steps:

    a. turn off all SCM's.

    b. turn off all SCM He valve controllers (outside).

    c. shut down the liquifier (outside).

    d. contact EPO[redacted]

    e. CALL System Expert

4. General (building) a.c. power failure:

   a. close CV-1 (PPT Cryostat)

   b. close JT's and "brass valves" on liquifier

   c. close H3C-V2 (gas cart)

   d. CALL System Expert

5. Air Pressure Failure:

   a. Put microwaves in Stand-By.

   b. Hook up a bottle of N_2 to the air manifold at the water rack, and set the regulator to 80 psig.

   c. RESET pump H3C-P2 (if off), and valve H3IV-V1.

   d. Contact EPOG.

   e. Bring PPT back into operation by manipulating CV-1, CV-2 and H3C-V6. Restore microwaves.

XVI. COMPUTER OPERATIONS

A. Operating System

Since the NMR program must be run by many people, some of whom are not familiar with computers, the operating system is kept extremely simple. The operating system (also called the monitor) provides time shared multiprogramming and is currently set up with two tasks named foreground and background. The background program is provided primarily as an operator convenience and need never be used as will be seen by its description later in this section.

Basically there are two general categories of operations, data collection and program control. Within each category there are specific jobs to be done: each job providing some service, information, or control function. The monitor simply requests the operator to type in a job number, checks it for validity, and if valid executes the job associated with that value.

Once started the data collection jobs (values 1-9) continue to take data until some fatal error occurs or the operator intervenes to return control to the monitor. The program control jobs (values 100 - 140) are subroutines and the monitor is re-entered at their completion.

Most of the jobs provide special services and flexibility behond the relatively simple needs of the program and it is therefore easy to familiarize oneself with the few jobs necessary to run it. When the foreground program is collecting data it does not expect operator input, it is not under direct monitor control. The operator can "call the monitor" by typing CTRL/C or "Call the background monitor" by typing CTRL/B or use the teletype like a typewriter to log messages.

The background monitor functions in the same way the foreground monitor does except that the jobs it executes cannot conflict in any way with the foreground jobs. To accomplish this, the background monitor does not respond to CTRL/B and will not be entered unless the foreground monitor has initiated a data collection job. Thus the foreground program does not expect any input and all input will be associated with the background program. The jobs available to the background monitor are the same ones available to the foreground monitor (background is therefore not necessary and can be completely avoided) and they have the same associated values. The background monitor will not execute any job that may conflict with an executing foreground job.

B. Control Keys

"CTRL/C" means hold down the CTRL key and depress the C key. There are four control keys used by this program of which only CTRL/C is needed. The others are provided for convenience.

CTRL/C	Call Monitor
CTRL/B	Call background monitor
CTRL/O	Cancel messages enqueued to the teletype
CTRL/A	Abort

C. Input

The computer expects only two kinds of data from the operator: A decimal number followed by a comma or carriage return, or the letter Y (for yes) or the letter N (for no).

D. Monitor Commands - (B) Indicates available from Background

1	Take enhanced signals
2	Take enhanced baselines
3	Take thermal signals
4	Take thermal baselines
5	Take enhanced "V" signals
6	Take thermal "V" signals
7	Take a thermal signal set
8	Take "V" channel signals with no analysis
9	Take "DV" channel signals with no analysis
100	Display data (defined via switch register)
101(B)	Choose idle mode
102(B)	Choose auto mode
103(B)	Choose manual mode
104(B)	Check (update) header values
105(B)	Check (update) calibration constants
106	Check sweep width
107(B)	Check (update) polarization limits
108(B)	Update time
109	Type signal buffer on teletype
110	List signal descriptor variables from dectape signals
111	Copy buffer from core to DT or PP(dectape/papertape)
112	Copy DT to core buffer
113	Zero (erase) a dectape
114	Zero a buffer
115	Zero all buffers (except look-up table)
116	Recalculate signals in core as if they were enhanced sigs.
117	Recalculate signals in core as if they were thermal sigs.
118(B)	Check thermal area "A"
119(B)	Update thermal area "A"
120	Recalculate a set of signals from dectape
121(B)	Choose output unit (dectape/papertape)
122	Reset - Start program over from scratch
123	Reload program from dectape (unit 0)
124(B)	Decide if computer controls magnet
125(B)	Decide if computer controls frequency
126	Start run (SOR)
127	End run (EOR)
128(B)	Check trouble flag word (bits give errors)
129(B)	Rewind dectape (unit 1)
130(B)	Detach background monitor
131	Punch special format paper tapes
132(B)	Decide if true peaks will be found
133	Dectape dump overlay
134	Teletype dump overlay
135	Paper tape loader overlay
136	Reset (spare overlay)
137	Load look-up table from paper tape
138	Punch core dump on paper tape
139(B)	Type last sweep width used
140(B)	Type dispersion correction coefficients

E. Trouble Word Indicator Bits

If any of the troubles occur during normal running (except bit #0) the bell will ring after each signal is processed. If the bell does not ring for a few signals there is probably no trouble (check with option 128)

0	Not in auto mode
1	Polarization out of range
2	Signal peak out of range
3	Real to integer conversion overflow (usually bad data)
4	Dectape error
5	Power fail occurred (clear with reset option 122)
6	Under monitor control (not taking enhanced data)
7	Voltage out of range
8	Not used
9	Frequency out of range
10	Magnet current out of range
11	Out of papertape
12	Not used
13	Not used
14	Not used
15	Polarization overflow (P>204.8%)

Also, the trouble bit is set if no ASI Requests occur within 15 sec.

F. Start of Run

1. Type CTRL/C and wait for computer to type ready.
2. Type in the value 126 (SOR).
3. The run number and enhancement are typed out.
4. If the run and enhancement are both ok, then go to step 9.
5. Type in N (NO).
6. If the run has positive enhancement type in a run number (e.g. 57 or +57 or 57+).
7. If the run has negative enhancement type in a negative run number (e.g. -57 or 57-).
8. Go to step 3.
9. Type Y (for yes) and wait for the computer to type ready.
10. Type in the value 1 (take data) and record in log book .

G. End of Run

1. Type CTRL/C and wait for computer to type ready.
2. Type in the value 127 (EOR).
3. When computer types ready type in the value 1 (Take data).
4. Record in log book.

H. Magnet Correction

When told to do so (option 124) the computer will send a correction voltage to the SCM controller to keep the current at the optimum value. This is done by finding the NMR signal peak and computing the voltage correction from the peak position. If the polarization enhancement is being changed the peak will become very small and a false peak may be found if the flip from one enhancement to the other through zero is not fast enough. If the magnet setting is shifted too far because of this error the magnet setting will be reset. A two minute wait follows to allow the magnet to comply.

I. Baselines

Baselines are taken automatically by the computer, but the magnet current may have drifted far enough to produce an error message. The magnet will be reset to allow the baseline to be taken (followed by a two minute delay) but the next few polarization calculations will not be accurate because the magnet will not be at its optimum setting. The thumbwheel switches on the magnet controller should be set to within one amp of the optimum value to prevent this problem.

J. New Dectape Reel

When the dectape is full (there are 577 blocks) a message will request it be changed. Choose the reel from the rack with the next higher number and mount it on the right hand unit if there is an "R" on the label, or mount it on the left hand unit if there is an "L" on the label. Update the header (option 104) so the dectape block number is 1.

K. Header

Normally the header is not changed except when a new dectape is needed or at the first of the month.

1. Type CTPL/C and wait for the computer to type ready.
2. Type in the value 104 (header).
3. The following 3 values are typed out:

   1 Date
   2 Dectape block number
   3 Run number

4. If all 3 values are o.k. then go to Step 10.
5. Type N (For No).
6. Type in the date as a 4 digit number corresponding to the day and month (e.g. 1124 for Nov. 24, 0109 for Jan. 9).
7. Type in the proper dectape block number which will probably be 1 or the same value typed out in step 3.
8. Type in the proper run number.
9. Go to step 3.
10. Type Y (for yes).

L. Power Fail

When the power for the computer is out of specified limits a power fail condition is raised in the computer hardware. If it was an "AC" power fail the computer will continue to run and a message is typed out. Use option 122 to clear the software trouble bit. A "DC" power fail causes the computer to stop running and all panel lights will be turned off. Restart the program using the front panel as indicated in paragraph O. below.

M. Halt Condition

The computer can stop running because of either hardware or software problems. The run light will not be on. The address and data lights on the front panel may provide some insight to the problem so record their values, then restart the program.

N. Teletype Does Not Respond

If the teletype does not respond to input then it has probably become interrupt disabled. This can be fixed by restarting the program.

O. Restarting the Program from the Front Panel

1. Put power key in the power position.
2. Set all switch register keys down.
3. Press Halt.
4. Lift halt to enable position.
5. Depress load address.
6. Depress start.
7. Put power key in the panel lock position.

P. Reloading the Program from Dectape

1. Put power key in the power position.
2. Set switches as follows:
   15, 14, 13, 12, 10, 9, 6, 5, 4, 3 up -- others down.
3. Press halt.
4. Lift halt to enable position.
5. Depress load address.
6. Put "auto load" dectape on unit 0, write lock, remote.
7. Depress start.
8. The dectape should load and type a period.
9. Type in the three letters NMR (return).
10. When the dectape stops, set switches as follows:
    13, 12, 10 up -- others down.
11. Depress "load address".
12. Depress "start". Program should start. If not, return to step 2.
13. Put power key to panel lock position.

Q. NMR Frequency Correction

When told to do so (option 125) the computer will send a correction voltage to the NMR oscillator to keep the frequency at the optimum value. This is done by measuring the end-of-ramp frequencies and computing the voltage correction from the mean value. The mean value is set to be the operator input value of FREQ, one of the input constants (option 105). For example, FREQ = 8000 sets the mean value at 108.000 MHz, if option 125 is used; and it normally should be.

In general, manual operator intervention is necessary only when the oscillator frequency drifts beyond the capacity of the computer to compensate (±10% of the sweep range). The error message then is "FREQ. OFF BY—, LOWER IF POS, RAISE IF NEG," followed by READY. Manually, reset the oscillator as follows:

1. Using the small screwdriver provided, turn the oscillator tuning screw "f_o" a few degrees in the direction indicated by the error message.
2. Type in option 8.
3. If a new error message is generated, return to step 1. If not, the oscilloscope will display a sweep, i.e., all is normal, and you can hit CTRL/C and continue.

Usually this error can be avoided by occasionally tweaking the "f_o" screw during running, to keep the sweep fairly well centered on the screen. (However, you should verify that the scope horizontal amp. is properly centered, by momentarily grounding the horizontal input and adjusting POSITION.)

XVII. TO CHANGE THE SIGN OF POLARIZATION

1. End run if you have not already done so, then type "1 RETURN".
2. Set Anode 2 Voltage to proper value (see columns "A").
3. Increase CV-1 setting by one turn ccw.
4. Set micrometer valve H3C-V6 at "B".
5. Set microwave attenuator to "C". At this time, the alarms "H3C-TC2 HIGH" and "H4HV-TC2 HIGH" are o.k.*
6. When POL. reaches "D", set microwave attenuator to "E" and set H3C-V6 at "F".
7. Throttle CV-1 by one turn.
8. Notify physicist when POL. reaches 50%. When they say they are going to start the new run, ask for Run number and follow procedure "TO START A RUN".
9. If, after 10 minutes from step 6, you still have a "He^3 Level" alarm, follow section 2 of "NOTES ON ALARMS".

* This is the best time to monitor the operating condition of the He^3 Delivery system. The He^3 flow should be greater than 6000 SCCM. If it is not, the usual cause is foreign material (air, hydrogen, etc.) plugging the He^3 heat exchangers.

	A (Anode 2)		B	C		D	E		F
DATE	+	-	(V6)	+	-	±	+	-	(V6)

XVIII. TO ZERO THE POLARIZATION

A. Zeroing

1. Completely close H3C-V6.
2. Set microwave attenuator to .000.
3. Tell computer to find false peaks (option 132, N) then return to option 1.
4. When POL becomes less than 2%, set microwave attenuator to .200.
5. Set Anode 1 voltage to ~.2KV.

B. Zero Running

1. Set computer polarization limits to LO = 0, HI = 2 (option 107).
2. Set H3C-V6 ~.045" to maintain He^3 level in the *normal* range as indicated by H3C-BG1.
3. You are now ready for "Zero" running.
4. Note that "He^3 Circulation Flow Low" alarm is o.k. in this mode.

Don't forget to reset options 107 and 132 when you start an Enhanced data run.

XIX. TARGET INSERTION

The operation of target insertion will usually be done in the course of "Cryostat Start-Up", although occasionally it might be arrived at via a different sequence of events. The basic requirements are that the target flask be empty, and the cavity is colder than approx. 150K. This operation requires some experience.

A. Initial Conditions

1. H3R, H3D, and H3IV are back-filled with N_2 gas. The pressures will be less than the original back-fill pressure, because the cryostat is cold.
2. APS is pumping on H4IV in D.P. Mode.
3. The He^4 stage is shut down: CV-1, CV-2, and H4SV-V4 are closed, but the Stokes pumps are on.
4. The following valves are closed:

H4HV-V2	H3C-V1	H3A-V2B	H3S-V1B
H4HV-V3B	H3C-V2	H3A-V3	H3S-V2A
H4HV-V4	H3C-V3(MAN)	H3A-V4	H3S-V2B
H4HV-V6	H3C-V4(MAN)	H3XS-V	H3S-V2C
H4SV-V3	H3A-V2A	H3S-V1A	H3P-V1
H4EV-V			H3IV-V1(MAN)

also, the vacuum jacket valve for the target insertion unit.

5. The following valves are open:

H4HV-V3A	H3C-V5	H3S-V1C
H4HV-V7	H3C-V6	H4IV-V1
H4SV-V2A	H3A-V1	H4IV-local
H4SV-V2B	H3S-VM	

6. The following equipment is at hand:
   a. Stepladder (in place in front of the storage dewar)
   b. Cold funnel (clean)
   c. Pre-measured amount of target material in a small dewar
   d. Vibrator (electric scribe)
   e. Flashlight, "tapping" tool, tissue paper, forceps.
7. The "Mass Spec." port on the Gas Cart is open to atmosphere.
8. The N_2 bottle is open and the regulator set at 5 psig MAX.

B. Preparation

1. Pump on insertion unit vacuum jacket:
   a. Close valve H4IV-local.
   b. Open insertion unit vacuum valve.
   c. WAIT until APS-TC2 reads less than 50μ.
2. Equalize pressures in H3C and H3IV to atmosphere:
   a. Put APS in BLANK-OFF mode.
   b. Close H4IV-V1.
   c. Open H3A-V3.
   d. Put H3IV-V1 in MAN, Open.
   e. If H3C-BG2 reads less than 760t, crack H3P-V1 until the reading is 760t, then close H3P-V1.
   f. Open H3A-V4.

C. Insertion

1. Make sure that the insertion tube is pushed all the way in up to the edge of the marking tape.
2. Remove the plug and attach the cold funnel.
3. Attach LN_2 hose to the funnel.
4. Completely open the two pre-cool valves on the funnel and close the feed valve.
5. Slowly open the supply LN_2 valve. When the hose is sufficiently cold, open the supply valve completely.
6. When liquid starts to flow from the second pre-cool valve, open the feed valve by one turn and throttle the first pre-cool to maintain a small flow of liquid. Make sure to wait long enough for stability.
7. Remove the funnel lid, pour in the target (tap the container to be sure it's empty), and replace the lid.
8. Turn on the funnel vibrator and apply the hand vibrator. Be sure to maintain liquid flow, by adjusting first pre-cool valve.
9. After the last material has left the funnel, wait ~30 sec.

10. Close the feed valve and the supply valve.
11. Remove the funnel and replace the plug.
12. Retract the insertion unit 6".
13. Level (shake down) the target. This is done by attaching the NMR coil to the "Super Sugar Shaker" and setting the 60 Hz current at 0.8 amp ("S" or "N" configuration) or 0.5 amp ("L" configuration) for ~30 sec, with the magnet on at 2.5 T. If the magnet cannot be on at this time, the levelling can be done later, but target insertion is not complete without it.

D. LN_2 Removal

All LN_2 remaining in the cryostat must now be removed, particularly from the target flask where it would interfere with operation. This is done by reducing the pressure to just above the freezing point of N_2 and waiting until all indication of boil-off has ceased. He^4 stage cooling must not be resumed until this operation is completed.

A sample record of LN_2 removal is included at the end of this section.

1. Close H3A-V4.
2. Put APS in ROUGHING mode and hold down the APS P.S. cheater until H3C-BG2 reads less than 400t.
3. When H3C-BG2 reaches ~98 t, put APS in BLANK-OFF mode. (The freezing point of N_2 is ~93t.)

4. If H3C-BG2 pressure grows to exceed 110t, rough down to ~98t again.
5. When the rate of increase of H3C-BG2 becomes less than 0.1t in 5 minutes, put APS in ROUGHING mode.
6. When APS-TC1 reaches 200μ or less, put APS in D.P. mode.
7. Close the insulating vacuum valve on the insertion unit.

(Note: If desired, the LN_2 removal above can be slightly hastened by using microwave power: Anode 2 current ~50 ma, atten. = .000. Turn off the microwaves at step 5.)

When Target Insertion is complete, the next step will normally be to continue with "Cryostat Start-Up" as in Sec. II.C.5. Or, one might for some reason choose "He^4 Stand-By". In any case, the cryostat must be provided with cooling to keep the target frozen.

SAMPLE LN_2 REMOVAL RECORD

TIME	H3C-BG2	Action
1432	98 torr	Put APS in BLANK-OFF mode
1433	132	ROUGH to 98 torr, then B.O. Mode
1434	107	
1435	124	" " " " " "
1436	104	
1437	117	" " " " " "
1438	102	
1440	115	" " " " " "
1441	97.9	
1446	106.0	
1451	107.6	
1458	108.7	
1503	109.2	
1508	109.3	
1513	109.3	(Removal is complete)

XX. TARGET EXTRACTION

A target is extracted by melting it, pressurizing it out through a plastic tube threaded down the insertion tube, rinsing the flask with clean solvent, and drying the flask. This operation is normally arrived at in the course of "Cryostat Shut-Down and Target Warm-Up" as is assumed in the following conditions. Extraction should not be attempted without experience.

A. Initial Conditions

1. The He^3 gas is in storage.
2. The He^4 stage is shut down and pressurized to near atmosphere with He^4.
3. The target is warming under the influence of one or more of the following: microwave power, electrical heaters, thermal exchange gas in H4IV, forced N_2 gas flow.
4. H3R, H3D, and H3IV are pressurized with N_2 gas to near atmosphere.
5. APS is in BLANK-OFF mode.
6. The following valves are closed:

H3C-V1	H3A-V2A	H3S-V1B	H3XS-V
H3C-V2	H3A-V2B	H3S-V2A	H3P-V1
H3C-V3 (MAN)	H3A-V4	H3S-V2B	H4S-V2
H3C-V4 (MAN)	H3S-V1A	H3S-V2C	H4IV-V1

7. The following valves are open:

H3C-V5	H3A-V1	H3S-V1C	H3IV-V1 (MAN)
H3C-V6	H3A-V3	H3S-VM	

8. The following equipment and material is at hand:

   a. "Flask Flusher"

   b. Funnel with ¼" Rad-Lab adapter

   c. Graduate

   d. 50-50 water-alcohol solution containing 1% acetic acid (200 ml required)

   e. pure alcohol

   f. bucket

B. Preparation

When the cavity temperature reaches 255K or above, proceed as follows:

1. Remove the plugs from the insertion tube and local H3R port.

2. Carefully slide the insertion unit in to the mark (if this has not already been done), after loosening the feed-thru nut. Don't damage the tip. When in, tighten the feed-thru nut.

3. Attach the funnel and pour in 20 ml of pure alcohol.

4. Attach the Flask Flusher to the local H3R port via the tube "TO H3".

5. Insert the extraction tube and push it in to the mark. If, once beyond the final bend, you meet resistance, don't force it. This means the target is still frozen. Wait for it to melt.

C. Target Removal

In the following, valve numbers refer to valves on the Flask Flusher:

1. Put V1 on DRAIN, V2 on LOAD, and V3 on DRAIN.
2. Open the N_2 bottle valve and set the regulator for 3 psig max. Open the feed valve to the Flask Flusher.
3. When the target material has drained out, put V3 on FILL.
4. WAIT ~10 sec for H3R to de-pressurize, then put V1 on FILL.

D. Rinsing

1. Load 25 ml of water-alcohol.
2. Slowly turn V2 toward FILL. Turn it no farther than is necessary to push across the solvent.
3. When all the solvent has passed, put V2 in LOAD, and V1 and V3 on DRAIN.
4. When all the solvent has drained into the beaker, put V3 on FILL, and dump the contents of the beaker.
5. WAIT ~10 sec, then put V1 on FILL.
6. Repeat steps 1 - 5 until the solvent drains clean. The last couple of loads should be done with 30 ml of water-alcohol. A total of 6 to 8 loads will be needed.
7. Repeat steps 1 - 3 one last time with a load of 30 ml of pure alcohol.

8. When all the alcohol has drained, slowly pull the extraction tube out of the insertion unit, catching excess alcohol with tissue. If there is any evidence of target material in the insertion tube, it should be thoroughly cleaned with the water-alcohol solution.
9. Leave V3 on DRAIN until the insertion tube has blown dry, then close the N_2 bottle and feed valves.
10. Detach the Flask Flusher from the local H3R port and replace this plug and the insertion tube plug.

E. Drying

The flask is dried by pulling a vacuum on it:

1. Open the gas ballast valve on APS-P2.
2. Put APS in ROUGHING mode and depress the APS P.S. cheater until H3C-BG2 reads less than 400t.
3. When H3C-TC1 reads less than 0.1t, the cryostat can be considered dry.
4. Close the gas ballast valve on APS-P2.
5. Turn off the electrical heaters and the microwave power (if on).

F. "Empty Target" Running

In order to run "Empty Target", the cryostat should be cooled so that the target flask is positioned correctly by thermal shrinkage. He^4 stage operation is sufficient. Cool-down is as in "Cryostat Start-Up", except that H3R and H3D should be kept under vacuum and H3IV should be filled with

1000μ of He^4 exchange gas. Also, the insertion unit should be retracted 6".

G. Shut-Down

If the cryostat is being shut down, the H3 spaces should be back-filled to atmosphere as in "Cryostat Shut-Down and Target Warm-Up", part B.5.

XXI. TO TE MODE FROM NORMAL OPERATION

A. Setting the He^3 Temperature

Thermal equilibrium (TE) signals are usually taken with a known target temperature of .889 K, which corresponds to a saturated vapor pressure of 5.0 t. The following procedure sets up this pressure over the He^3 bath. Also exchange gas is introduced to H3IV to make the He^3 boil and prevent thermal stratification.

1. Set microwave attenuator to .200 and Anode I to ~0.2 KV.
2. Verify that H3C-TC2 reads less than 10 μ, then note the reading of H3C-BG2. This is the true "zero" reading.
3. Close H3C-V1, and close H3A-V2A, B (if open).
4. Open H3C-V6 completely.
5. When H3C-BG2 reads approximately 5 torr above true "zero", close H3C-V6 to .075.
6. Crack open H3A-V2A, until H3C-TC4 reads~250μ.
7. Put He^4 exchange gas in H3IV:
   a. Close H4IV-V1 (if open).
   b. Put APS in BLANK-OFF Mode.
   c. Put H3IV-V1 in MAN., Open.
   d. Admit He^4 to H3IV in steps by cracking H4S-V2, until H3IV-TC stabilizes at 50 - 100μ.
   e. Put H3IV-V1 in MAN., Closed.
   f. Put APS in D.P. Mode.

8. By adjusting the setting of H3A-V2A, H3C-BG2 should be set to and held exactly at 5.0 torr above "zero". Valve H3A-V2B can be used for fine tuning.

Before taking actual TE signals, the spins must be allowed to equilibrate at the chosen temperature. Starting from zero polarization, one must wait five relaxation times for the TE signal area to reach within 1% of its final value. This process can be accelerated by judicious use of low-level microwave power (if the correct value is at least roughly known), but even then a wait of at least two or more relaxation times with microwaves fully off is advisable.

The following alarms should be on, and are o.k., during TE-taking:

H3IV-DG   H3C-TC2 HIGH   H3C-BG1 LOW

B. Taking the Calibration Signals

The following instructions refer to computer operations:

1. Go to option 9, gain 1, and, viewing the raw ΔV signal on the oscilloscope, flatten the baseline, if necessary, using the correction pot and/or the curvature adjustments.
2. To take the signals, go to option 7 (TE Sequence). Save Tape? -- Yes, if they are real data; No, if you only want to check the current values of A.
3. Check the He^3 pressure and the baseline occasionally; trim up if necessary.
4. In the computer log book, record the following information:

Dectape reel #	H3S-BG2
TE block #'s	H3C-TC4
VTE block #'s	H3IV-TC
H3C-BG2 true "zero"	H3C-BG1
H3C-BG2 average during TE's	H3C-V6

5. When the estimated level of accuracy appears satisfactory, exit option 7 with CTRL/C.

6. Manually take, and put on tape, a second VTE signal. (An initial VTE is taken automatically in option 7). Option 6, CTRL/C, option 111, buffer 6.

7. Go to option 119 and reset the "A" value in core.

XXII. TO NORMAL OPERATION FROM TE MODE

1. Close H4IV-V1, if open.
2. Put APS in D.P. mode.
3. Put H3IV-V1 in MAN., Open.
4. Open H3C-V6 completely.
5. Put microwaves in polarization reversal mode, i.e., determine new sign of polarization and set Anode 1, Anode 2, and atten.
6. Open H3C-V1.
7. Close H3A-V2A, B.
8. Set correct NMR audio attenuation for enhanced mode. (Usually 400 on H.D.2)
9. Proceed as in "TO CHANGE SIGN OF POLARIZATION."
10. Remember to put H3IV-V1 in AUTO., Open, when H3IV-DG alarm clears.

XXIII. MICROWAVE SYSTEM

A. Description

The block diagram for the microwave system is shown in Fig. 1. The COE40B carcinotron is the rf power source. It is a backward wave oscillator which produces about 10 watts of microwave power between 68 and 72 GHz. It requires four different dc power supply voltages for operation. They are: (1) the heater; (2) Anode II, referred to as "line voltage"; (3) Anode I; and (4) grid (focus) power supplies. The body of the tube, i.e., outside frame and output wave guide, are at ground. All other voltages are floating at the Anode II or "line voltage" which could be as large as 6000 V negative.

B. Operating Procedures for Carcinotron and Power Supply

The carcinotron is a water-cooled tube requiring 0.2 gpm of water flow at a maximum pressure of 4 psi. Under no circumstances should any voltage be applied to the tube without cooling water flow. This could result in permanent damage to the tube.

1. The Turn "ON" Procedure

a. The first step in operating the tube is to turn on the cooling water and adjust for adequate flow. The power supply is both flow and tube temperature interlocked. Required flow is 12 gph at 4 psigmaximum.

b. Turn "ON" CONTROL POWER switch. If a failure is present, the WATER FLOW AND THRML. interlock light will be "ON" and none of the voltages will turn "ON". If so, check thermometer reset and flow switch for closure.

c. Turn the heater control to zero, completely C. C. W.

d. Push HEATER ON button and slowly turn the HEATER control C. W. in .1V steps until the HEATER current reaches the posted operating level. Under no circumstances should the specified heater current be exceeded. Take approximately 2 minutes to get to operating level.

e. Put GRID power switch in the ON position.

f. After 5 min. have elapsed, the GRID and the HV READY light will turn "ON".

g. Turn ANODE II COARSE completely C. C. W. to zero. This voltage is off-zero interlocked. Turn the ANODE I control to zero. Push ANODE II ON button.

h. Raise ANODE II to about 3200 V.

i. Push ANODE I ON button.

j. Slowly turn ANODE II COARSE to operating "ANODE II VOLTAGE" level. Slowly turn ANODE I control to its operating level, to give operating ANODE II current. The HEATER may also be slightly re-adjusted to set this final current. Do not exceed 60 ma anode II current. Fine set ANODE II voltage using ANODE II FINE.

2. Turn "OFF" Procedure

   The turn off procedure is the reverse of the turn on procedure.

   a. Turn ANODE I control to zero and push ANODE I OFF.

   b. Turn ANODE II COARSE to zero and push ANODE II OFF.

   c. Slowly turn HEATER control to zero, then push HEATER OFF.

   d. Turn CONTROL POWER switch "OFF".

   e. Wait about 5 minutes, then turn cooling water off.

3. "Standby" Procedure

   The "Standby" procedure is the same as the "Turn ON" procedure except that the Anode I control is left full C. C. W. If the tube had already been "ON", turn the Anode I control full C. C. W.

C. Carcinotron Theory

A carcinotron is a backwave oscillator which develops microwave power by the interaction of a beam of high potential electrons with a copper microwave structure, the interaction structure. It consists of five main parts:

1. The electron gun structure, cathode which develops the electron beam.
2. Grid which focusses the beam through the interaction structure.
3. Anode 1, "Anode", which controls the amount of beam passing through the interaction structure and, therefore, the power output.

4. Interaction structure, which is a copper cylinder with a beam passage hole and slots to interact with the beam.
5. Anode 2, "Line Voltage," which collects the beam and determines the frequency of operation.

In order to develop output power, a "Starting Current" of about 20 mA is required. Below 20 mA no power is developed.

In summary, the frequency of operation is directly proportional to the "Line Voltage," the output power is proportional to the "Line Current" squared.

D. Theory and Operation of Microwave System

Figure 1 shows the block diagram for the microwave system. In order to understand how it works one should consider that a beam of microwaves acts exactly like a beam of light. The inner walls of the waveguide act as light pipes for the microwaves. If the waveguide is not perfectly matched, there will be a reflected beam of microwaves; therefore, in the waveguide there are two waves except for a perfect match. One is the forward wave, and the other is the reflected wave.

1. Properties of Microwave Components

   a. Directional couplers have the property that they sample a small amount of the microwave power going down the guide only in one direction. In the circuit of Fig. 1, the directional coupler samples in the reflected or backward direction.

b. Attenuators absorb microwave power flowing down the guide and are used to control the amount of power flow. Attenuator 1 controls power going into target cavity. Attenuator 2 controls power going into the crystal detector.

c. Circulators are three-port devices which have the property that microwave power entering port No. 1 goes out port No. 2; microwave power entering port No. 2 goes out port No. 3, etc. It is used to isolate the carcinotron from reflected power.

d. E-H tuner is a matching device. By adjusting the E and H arms, the microwave circuit can be matched for maximum power flow into target cavity.

e. Crystal detectors are microwave diodes used to detect the level of the microwave power.

ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE

SUBJECT: PPT-III MICROWAVE SYSTEM

NAME: DH

DATE: 4-19-76

REV. DATE:

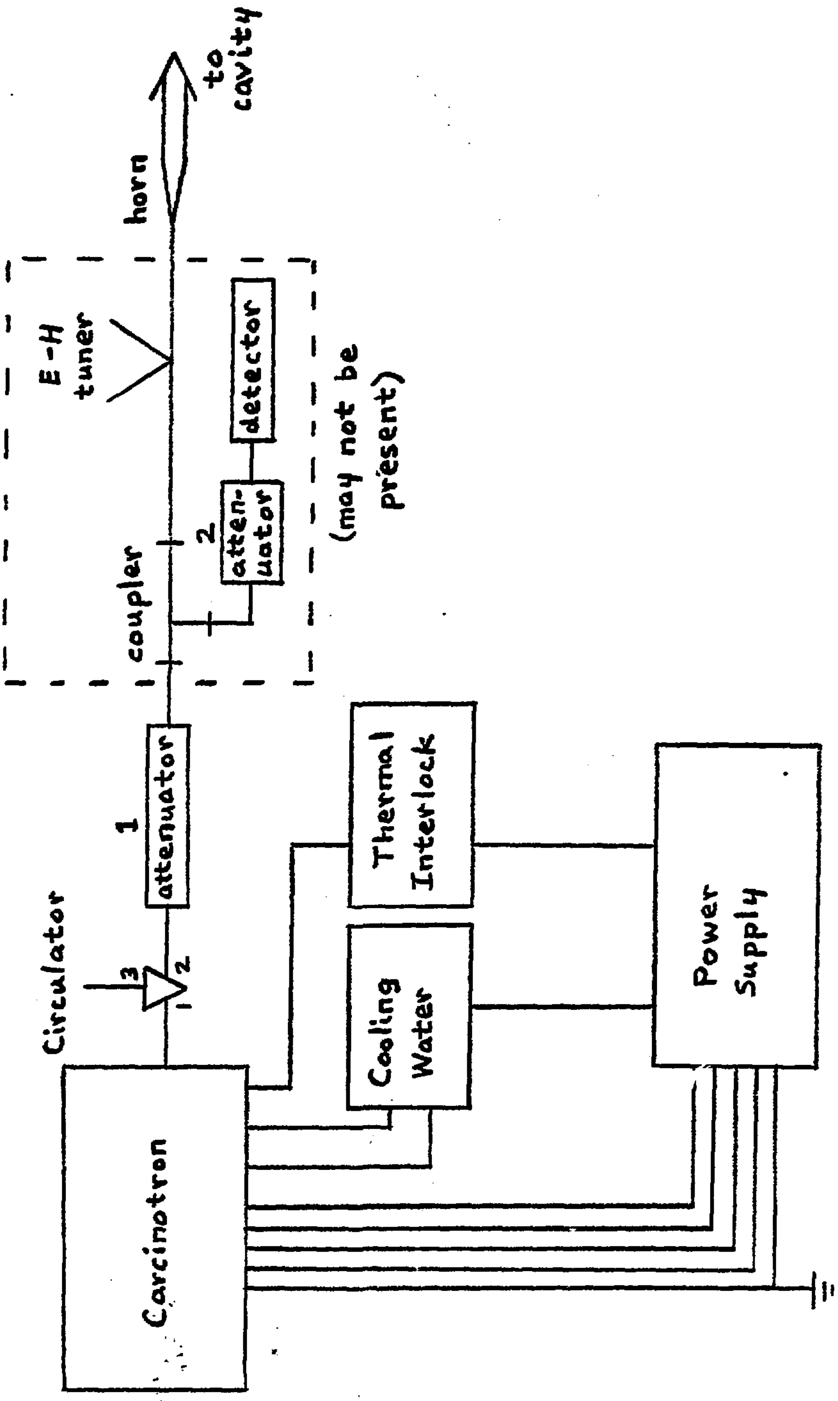


FIGURE 1

XXIV. He^4 LIQUIFIER OPERATION

The following are some brief notes concerning routine liquifier operation. For system details, checks, and maintenance, see the CTI 1400 Manual.

A. Normal Start-Up

1. Initial conditions:
   a. The compressors and engine module are charged with clean helium.
   b. The compressors are supplied with cooling water.
   c. A water and air trap are on-line.
   d. The storage dewar is cold. (If not, see part B.)
   e. The liquifier insulating vacuum is pumped out to better than 100 μ as read by VI-44. If not, start the vacuum pump and open V336.
2. Verify that both JT valves and return valves are closed.
3. Turn on compressor No. 3. Momentarily depress the START button on the speed control, and set the speed at ~ 250 RPM.
4. Open the LN_2 supply valve, and open V806 completely.
5. As the liquifier cools, keep TI-81 in the range 0 to -10° by throttling V806, and the speed in the range 200-250 RPM.
6. When TI-33 reaches 50 psia, close V336 and turn off the insulating vacuum pump.

7. When PI-33 falls to 225 psig or less, turn on compressor No. 2.

8. When PI-33 again falls to 225 psig, turn on compressor No. 1, if 3-compressor operation is desired.

9. In what follows, hold PI-33 to a minimum of 220 psig, by reducing the speed as necessary. Do not exceed 250 RPM, in any event.

10. Begin cracking the JT valve (that feeds the dewar in question) in steps of 5 mils, about 3 minutes per step. At the same time, hold the dewar pressure below 6 psig by cracking the dewar vent valve. Do not open the JT valve any wider than its normal setting. Do not exceed the Corken capacity.

11. If the delivery tube frosts up, and does not melt after ~ 20 min. with the JT at the normal setting, the delivery tube vacuum jacket should be pumped out.

12. When TI-33 starts to rise above 4 psia, start opening the return valve in very small increments, such that TI-33 stays in the range 3-5 psia. At the same time, maintain dewar pressure above 4 psig by closing down the dewar vent valve.

13. The approach to stable operation will be signaled by the following:

a. TI-33 will stabilize in the range 3-7 psia, with the dewar vent valve closed.

b. The JT pressure will drop to its normal value relative to PI-33.

14. If the other JT valve is also to be used, follow steps 10-12. Be sure to finish with an appropriate balance of production into each dewar, and with the return valves set to give nominal dewar pressures.

15. The optimal speeds are:

1 - compressor 45 RPM

2 - compressors 125 RPM

3 - compressors 250 RPM

B. Start-Up with a Warm Dewar

The procedure is the same as above through step A. 5, then as follows:

1. Open the JT valve to near its normal setting. The return valve is kept closed until the dewar is cold. The dewar must be vented as it cools, either by opening the dewar vent valve and/or the SCM transfer valve (if the SCM is to be cooled from room temperature). In either case, as the liquifier cools, the JT valve must be throttled if the Corken capacity is exceeded.

2. Follow steps A. 6 - A. 9.

3. If the delivery tube frosts up, the jacket should be pumped out.

4. When the dewar is cold, as indicated by the dewar level needle coming up to near 0 and by the formation of liquid air on the dewar vent, proceed as in A. 12-15.

C. Rapid Cool-Down

If liquid under pressure is avilable in the dewar, it can be used to speed the liquifier cool-down and attain stable operation more quickly. This should not be attempted without some experience. It involves opening the return valve and cracking the "recovery" valve, with the purifier OUT valve closed.

D. Lowering Production

On occasion it may be desirable to cut back on liquid production, if the top rate is not needed. This is best done by either turning off one compressor or throttling V806, which conserves liquid nitrogen. The speed and/or the JT settings should be changed accordingly.

E. Gas Purity and Purifier Life

The useful life of an air trap (charcoal purifier) depends on three factors:

1. The liquid production rate, i.e., how much gas is flowing through the trap.
2. The degree of purity of the stored gas in the high-pressure storage tank.
3. The fraction of time that the Corken is running, and the purity level of its gas.

For example, if the system has been in operation for several days or more, the high pressure stored gas and the Corken gas will usually have about the same level of impurity, so that the air trap life will depend only on factor 1 above. On the other hand, if the system has been shut down for a long time, the Corken gas may be noticeably more pure than the old gas in storage. Or, if "foreign" gas is being brought in, for example, from D-369/382, the Corken gas may be less pure than the storage gas. In any case, what counts is the average purity of the gas entering the purifier. The higher the purity, the longer the trap will last.

Conservatively, an air trap will last about five days under normal operating conditions (average production of 17 liquid liters helium/hour) at an air contamination level of 100 ppm.

XXV. TO CYCLE (SWITCH) He^4 PURIFIERS (AIR TRAPS)

1. Close access valve "TOP" on new trap and open "IN" valve on new trap.
2. Close LN_2 drain valve on new trap and energize (AC on) LN_2 controller for new trap.
3. Turn off in-tank heater for new trap, and put lid on new trap section.
4. WAIT until "BOTTOM" light on new trap LN_2 controller comes on (takes ~1 hour).
5. Open "OUT" valve on new trap and close "IN" and "OUT" valves on old trap.
6. Log trap change in Liquifier Log Book, on Liquifier Data Sheet and on checklist.
7. Open LN_2 drain valve on old trap and turn off LN_2 FILL CONTROL on old trap.
8. SLOWLY open "TOP" access valve on old trap, to de-pressurize the trap. Leave open.
9. Turn on old trap in-tank heater, and remove lid from old trap section.

(Note: Steps 10-15 should be omitted if the old trap will not be needed again within 8 hours. Go to step 16.)

10. Open access valve "BOT" on old trap.
11. Partially open boil-off gas valve from the tanker trailer, to set a pressure of approx. 10 psig.
12. Plug in gas heater.
13. When frost on "TOP" port of old trap disappears (takes 3 to 4 hours), close boil-off gas valve from the tanker.

14. UNPLUG gas heater from electrical cart.
15. Close "BOT" valve on old trap.
16. Valve off vacuum pump, and connect vacuum hose to old trap "TOP" access port.
17. Valve open the vacuum pump.

XXVI. TO CYCLE (SWITCH) H_2O TRAPS

1. Close "OUT" valve on old trap and open "OUT" valve on new trap.
2. Break ice with hammer. Don't let large pieces of ice fall into the cold box.
3. Lift out the old trap and rest it on the floor until it is sufficiently warm for all ice inside it to have melted (approx. 1-1/2 hours.)
4. Blow out the water in the trap into a suitable container and log the amount and trap number.
5. Replace trap in cold box.

Note: Leave both "IN" valves open at all times. (There are no relief valves on these water traps.)

XXVII. TO SHUT DOWN LIQUIFIER

1. Turn off all but one compressor.
2. Valve to recovery.
3. Put "recovery" switch up.
4. Turn off the last compressor.
5. Wait until flywheel stops.
6. put "recovery" switch down.
7. valve to normal.
8. close JT valve (903 and/or 307).
9. close return valve (902 and/or 308) ("brass valve").
10. furnish the dewars with external pressurizing gas, if necessary.
11. close LN_2 supply valve to liquifier.

(Do the following two steps for complete shut-down only).

12. Turn off water trap LN_2 controller.
13. On the air trap in use:
    a. Turn off LN_2 controller.
    b. Close "IN" and "OUT" valves.
    c. Vent the trap using the "TOP" access valve.

XXVIII. TO DECONTAMINATE LIQUIFIER

When the liquifier becomes contaminated with frozen air or other gas, as indicated by a low production rate and/or abnormal mechanical noise, it must be decontaminated. This is done by warming the liquifier to above the melting point of ice and circulating the dirty gas through the adsorber. It is assumed that the adsorber is clean.

The fastest way to warm up is to push warm gas through the heat exchangers in an unbalanced condition:

1. Shut down the liquifier.
2. Install the four valve jacks.
3. Open V806 completely.
4. Start one compressor.
5. Open the heater-adsorber valves and close the bypass.
6. Set the heater to 175° F.
7. Open the adsorber LN valve. Close when full.
8. Remove the Gardner dewar delivery tube. Open this JT to closure plus .025 and crack V339 to purge the hose.
9. Connect the hose from V339 to the delivery port, then open V339 completely.
10. Open the same JT to closure plus .200 and open the return valve four turns.
11. WAIT until the ice melts on the delivery port.
12. Monitor the "CTI inlet" gas purity. It should be less than 50 ppm.
13. Turn off the compressor, and the heater.
14. Close the heater-adsorber valves and open the bypass.
15. Close the JT, the return valve, and V339.
16. Remove the four valve jacks.
17. Restore the Gardner dewar delivery tube.
18. De-pressurize the adsorber.

To resume liquifier operation, see Normal Start-Up under "He^4 LIQUIFIER OPERATION".

XXIX. SCHEMATICS

ARGONNE NATIONAL LABORATORY

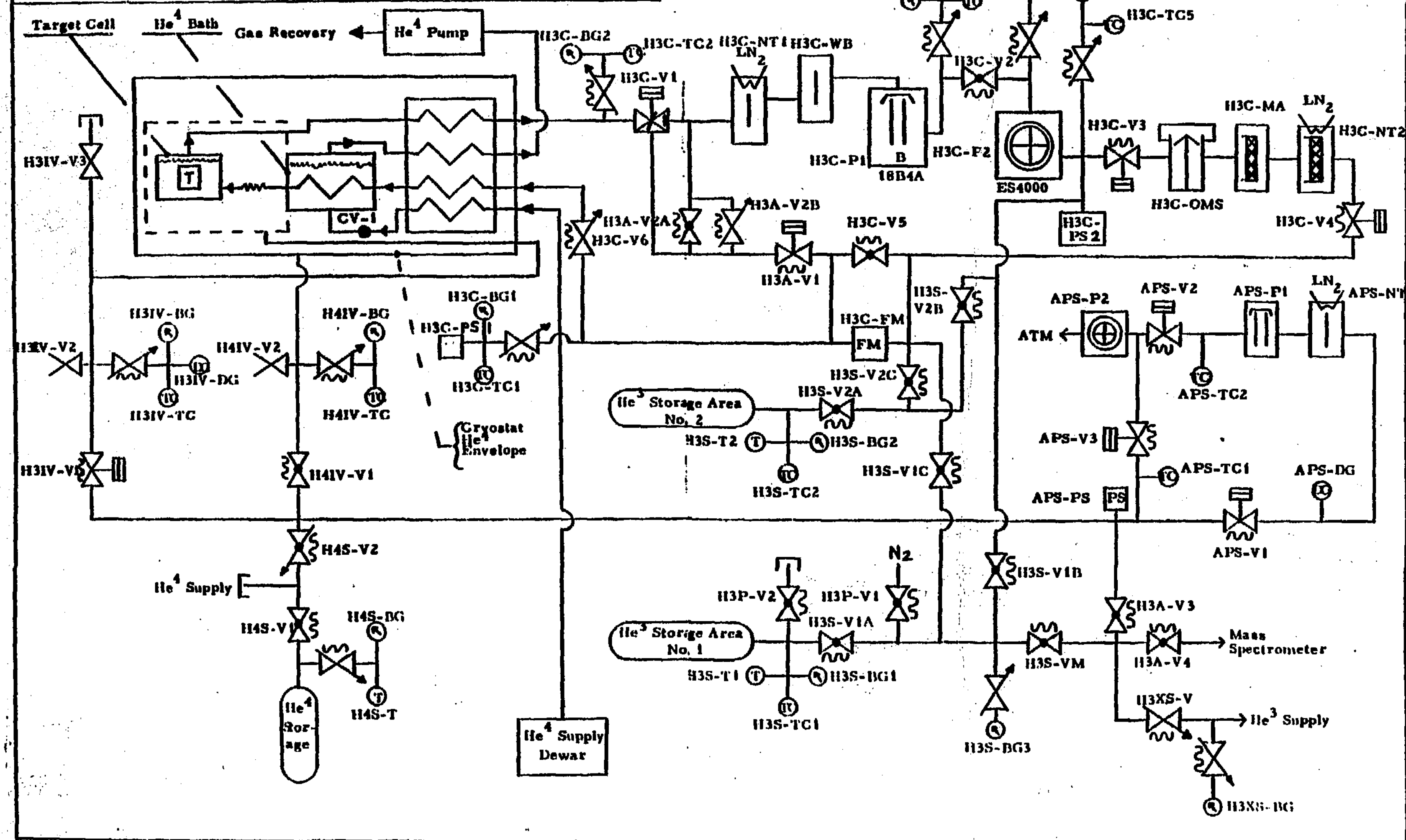
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT		

SUBJECT: PPT-III H3 GAS SYSTEMS - REVISION C

NAME: DH

DATE: 2-18-75



ANL-1488 (2-69)

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ARGONNE NATIONAL LABORATORY

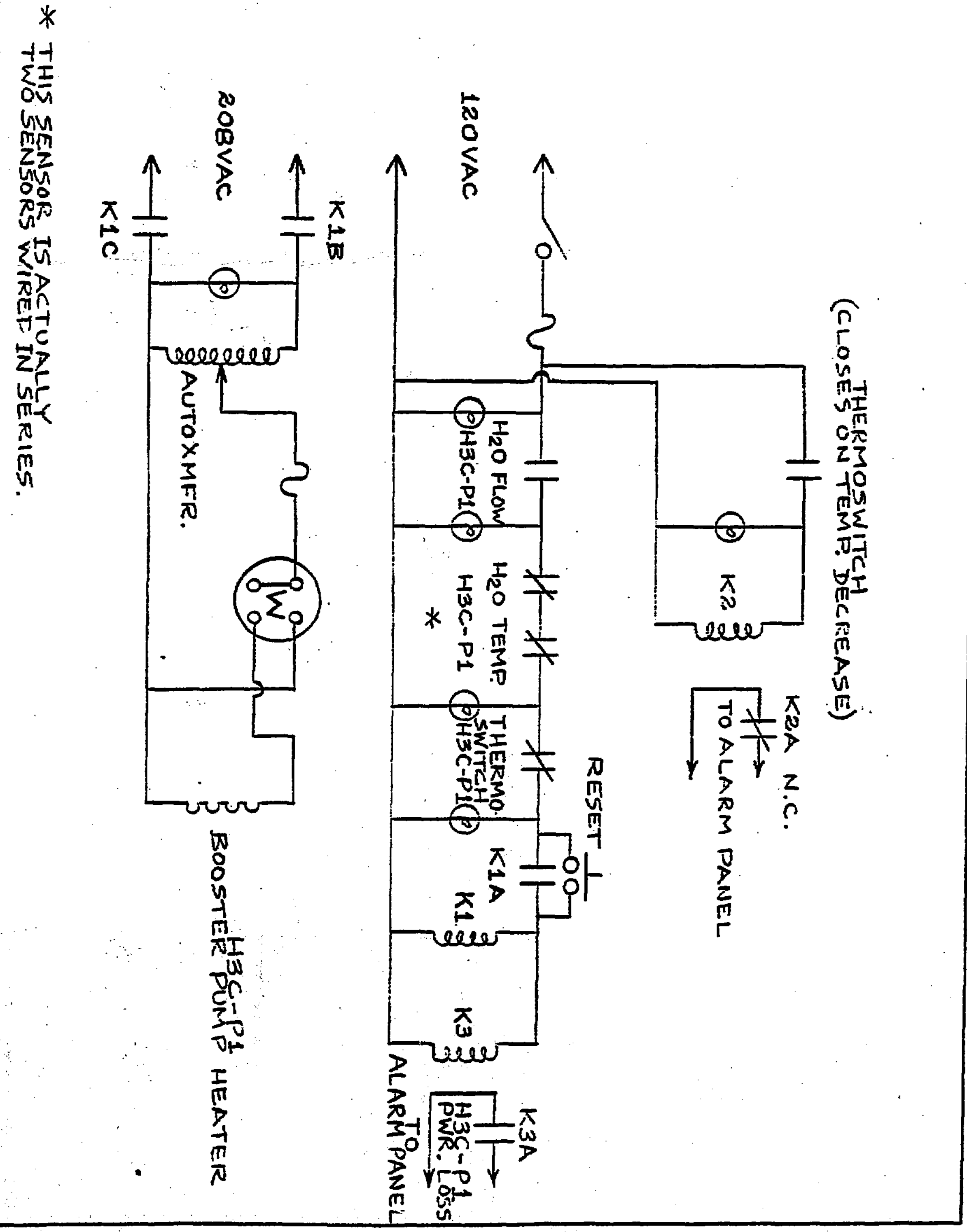
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III		

SUBJECT: PPT-III H3C-P1 CONTROL CKT.

NAME: F. ONESTO

DATE: 7-29-74 REV. DATE:



ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

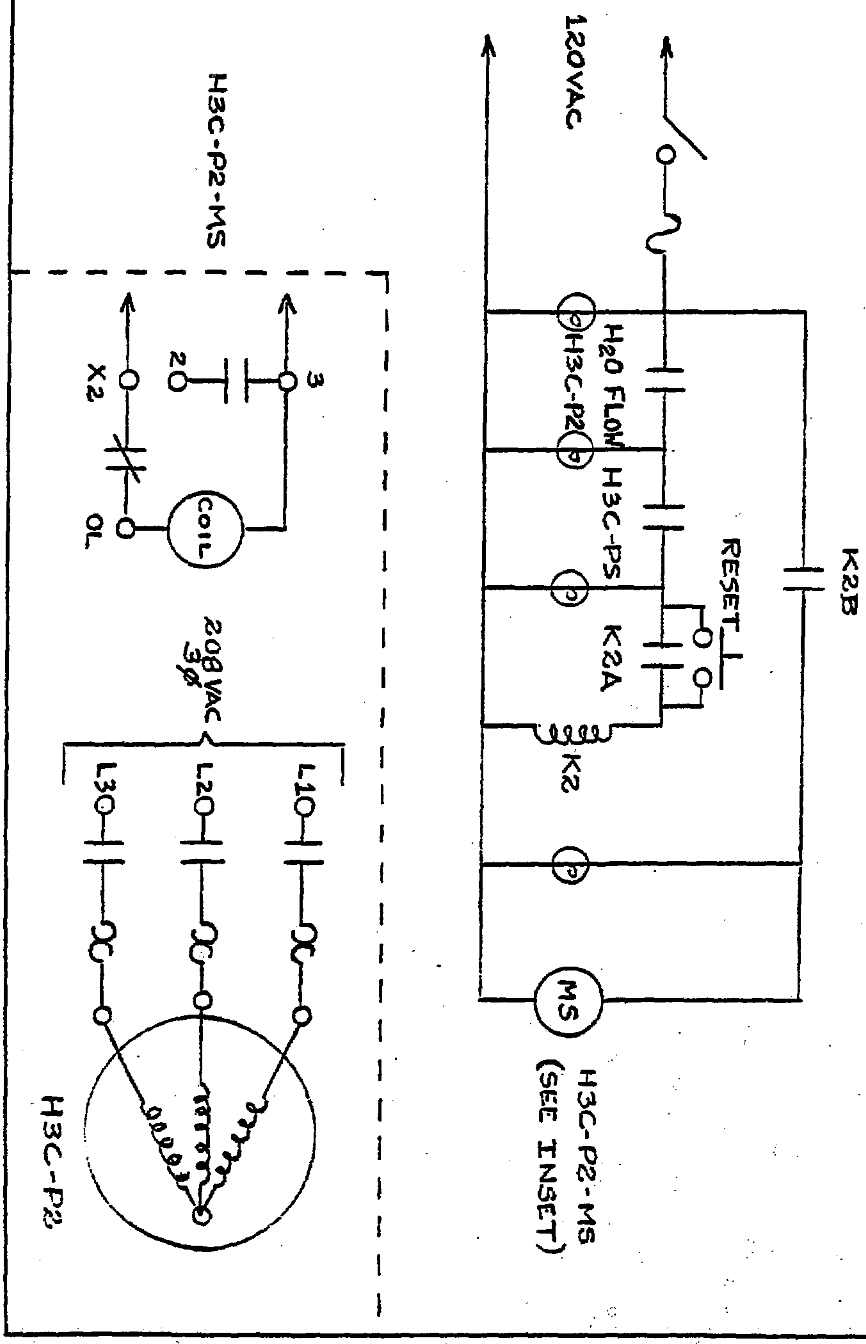
DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III		

SUBJECT: PPT-III H3C-P2 CONTROL CKT.

NAME: F. ONESTO

DATE: 7-29-74

REV. DATE:



ARGONNE NATIONAL LABORATORY

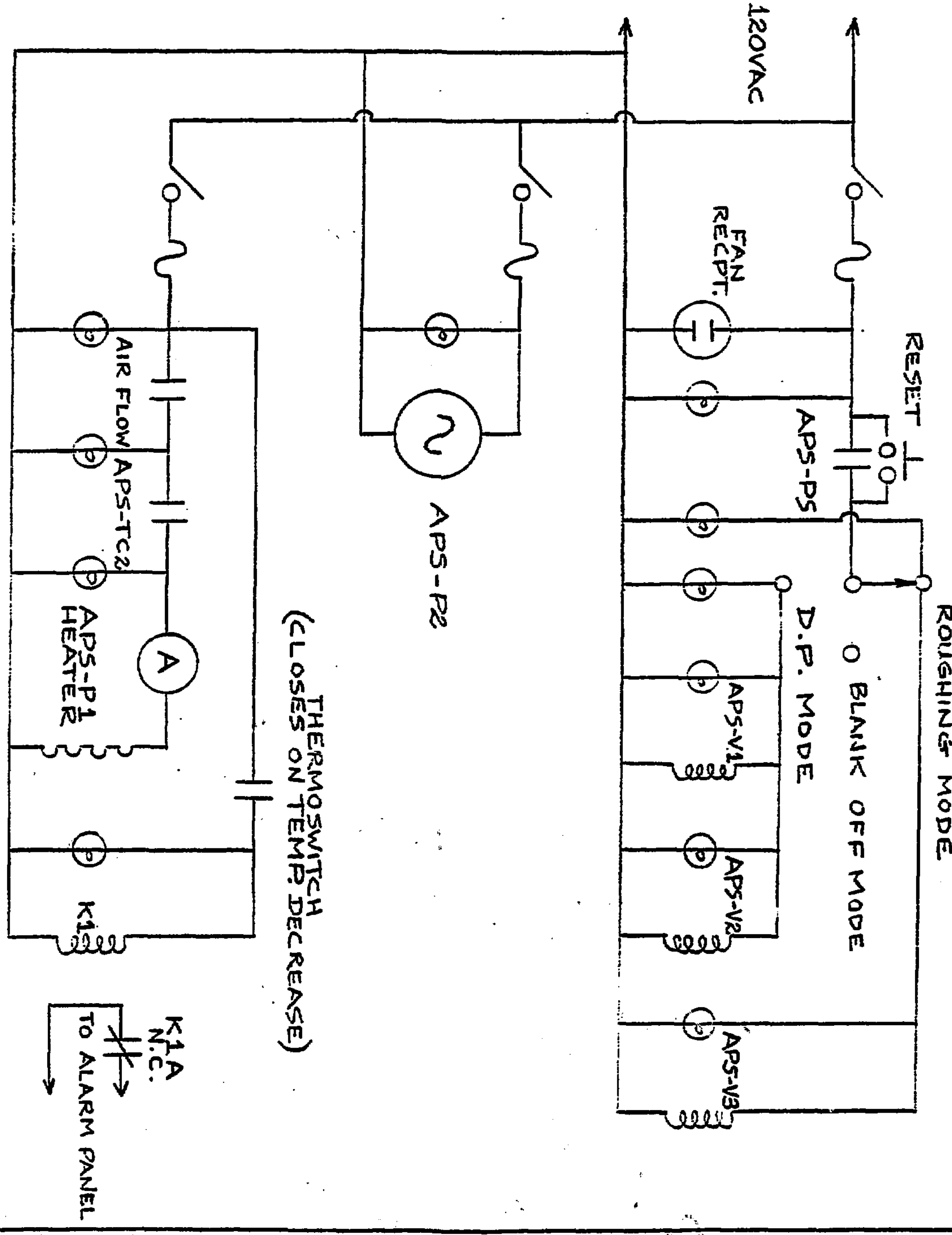
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III PPT-IV		

SUBJECT: PPT-III & PPT-IV AUXILIARY PUMPING SYSTEM CONTROL CKT.

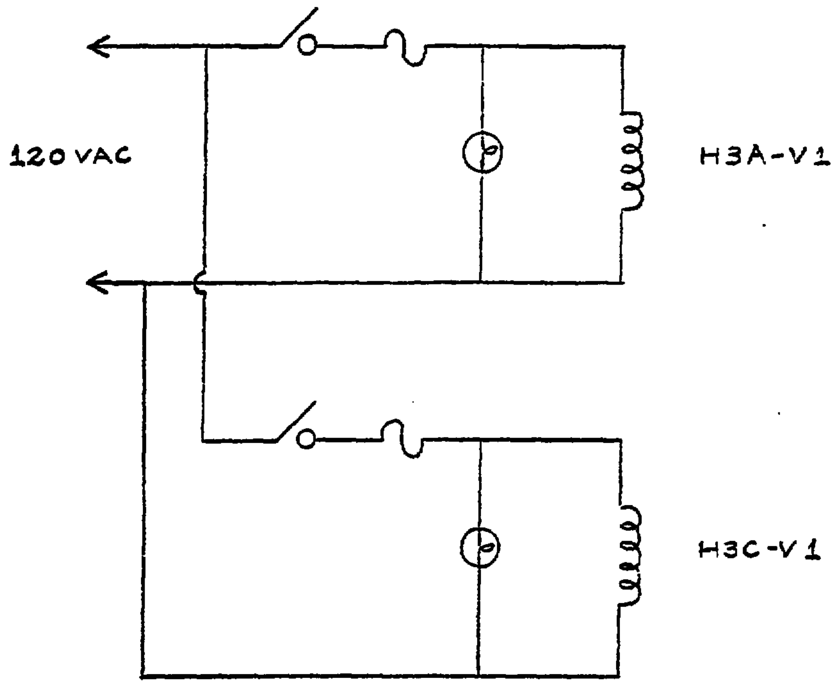
NAME: F. ONESTO

DATE: 7-26-74 **REV. DATE:**



ARGONNE NATIONAL LABORATORY ENGINEERING NOTE	DIVISION	PROJECT	FILE NO.	PAGE
	HEP	PPT-III		

SUBJECT	NAME	
PPT-III H3A-V1 & H3C-V1 CONTROL CKT.	F. ONESTO	
	DATE 7-29-74	REV. DATE



ARGONNE NATIONAL LABORATORY

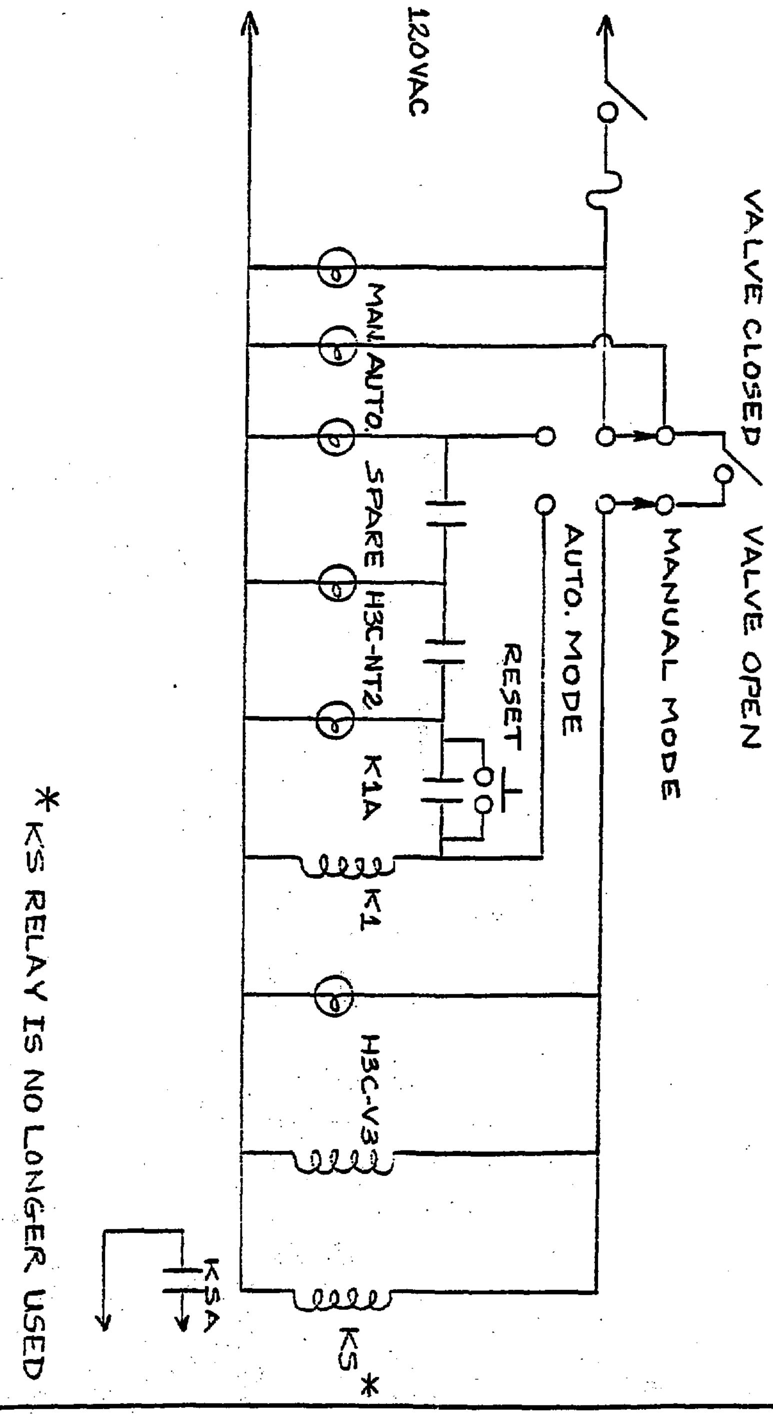
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III		

SUBJECT: PPT-III H3C-V3 CONTROL CKT.

NAME: F. ONESTO

DATE: 7-29-74 **REV. DATE:**



ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

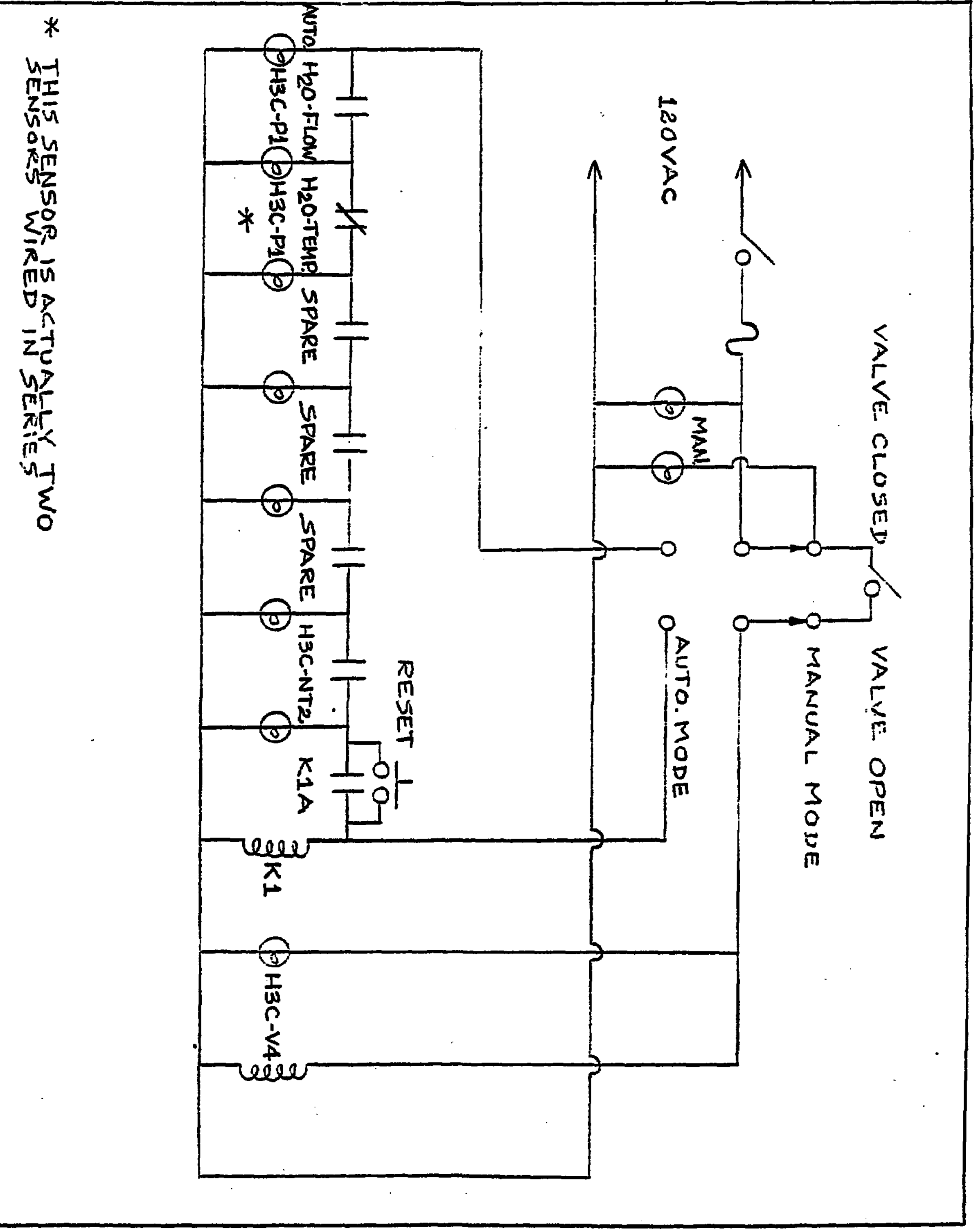
DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III		

SUBJECT: PPT-III H3C-V4 CONTROL CKT.

NAME: F. ONESTO

DATE: 7-29-74

REV. DATE:



ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

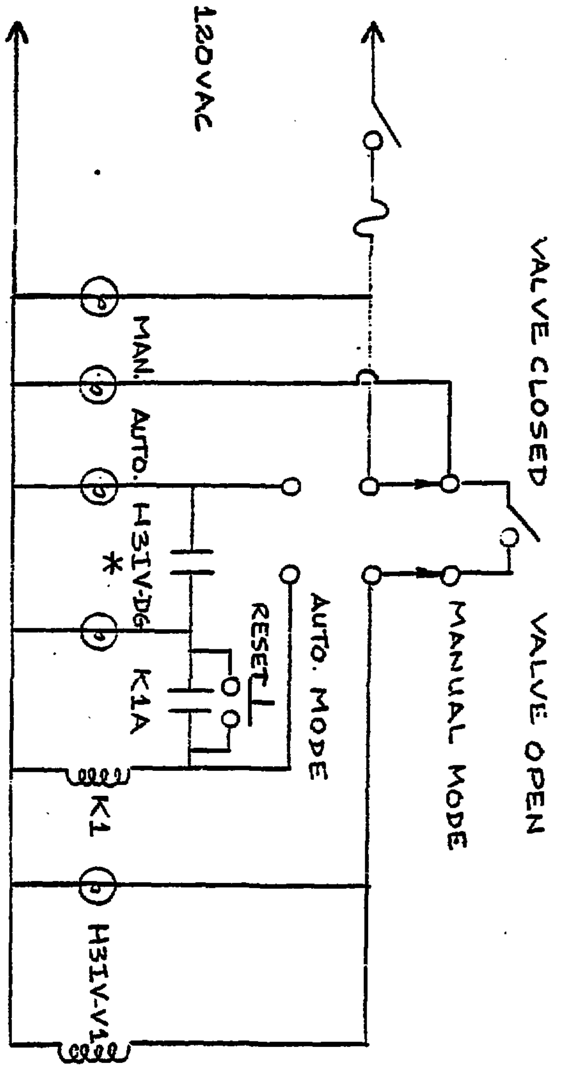
DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT III PPT IV		

SUBJECT: PPT-III H3IV / PPT IV H3IV & H4IV INSULATING VACUUM CONTROL CKT.

NAME: E. ONESTO

DATE: 7-26-74

REV. DATE:



* SENSOR IS H3IV-DG IN PPT-III.
IN PPT-IV THERE ARE TWO CKTS.
AND TWO SENSORS — H3IV-DG & H4IV-DG.

ANL-145 (5-66)

ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

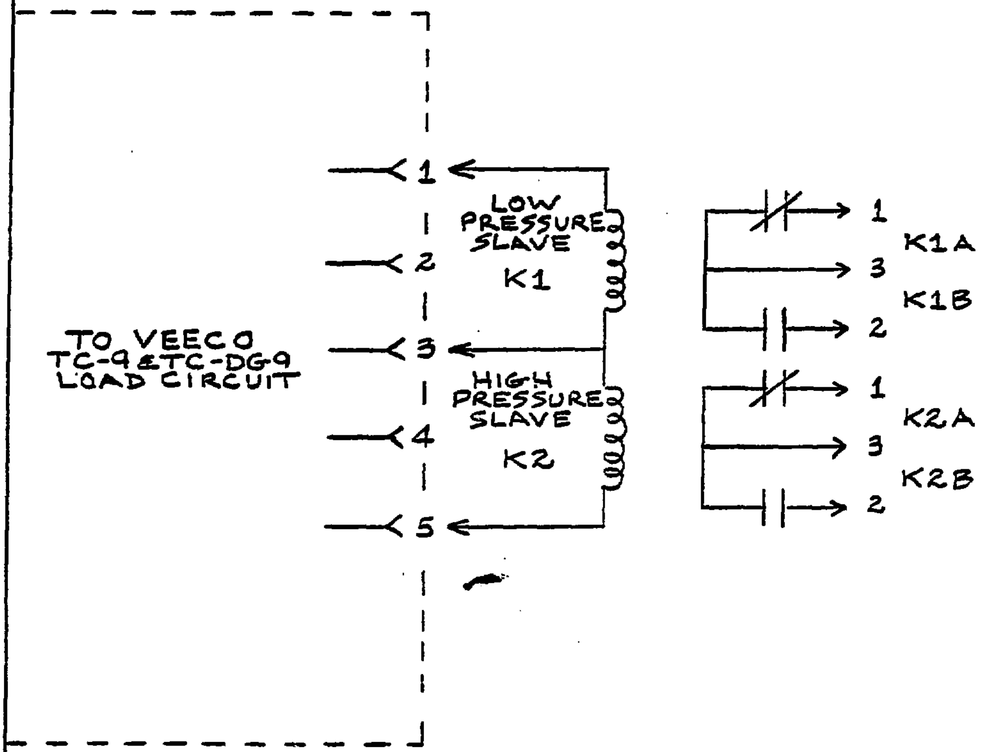
DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT III PPT IV		

SUBJECT: PPT III & PPT IV SLAVE CKT.

NAME: E. ONESTO

DATE: 8-15-74

REV. DATE:

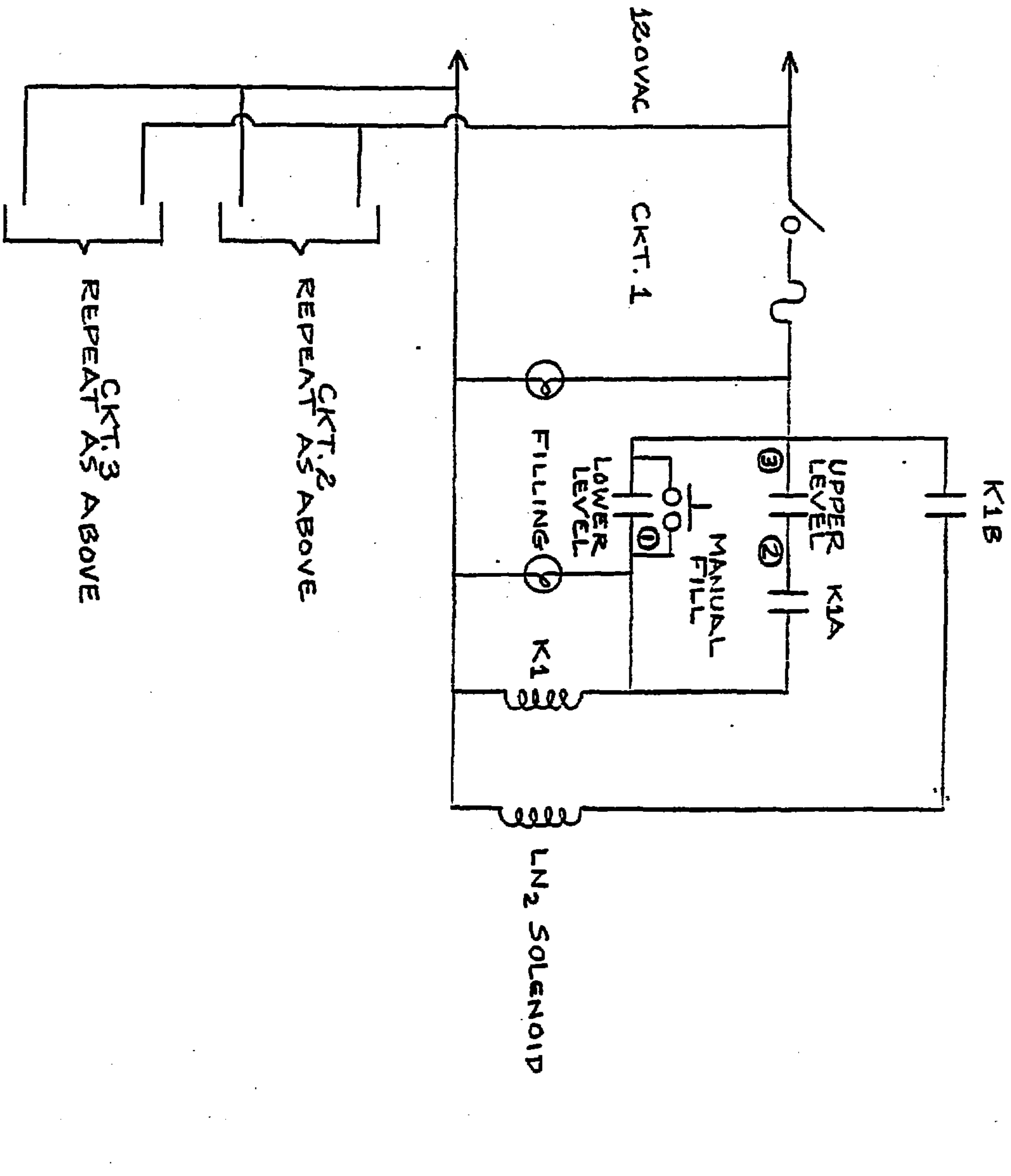


ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III PPT-IV		

SUBJECT	NAME
PPT-III & PPT IV LN_2 AUTO. FILL CKT.	E. ONESTO
	DATE: 7-29-74 / REV. DATE:



ARGONNE NATIONAL LABORATORY

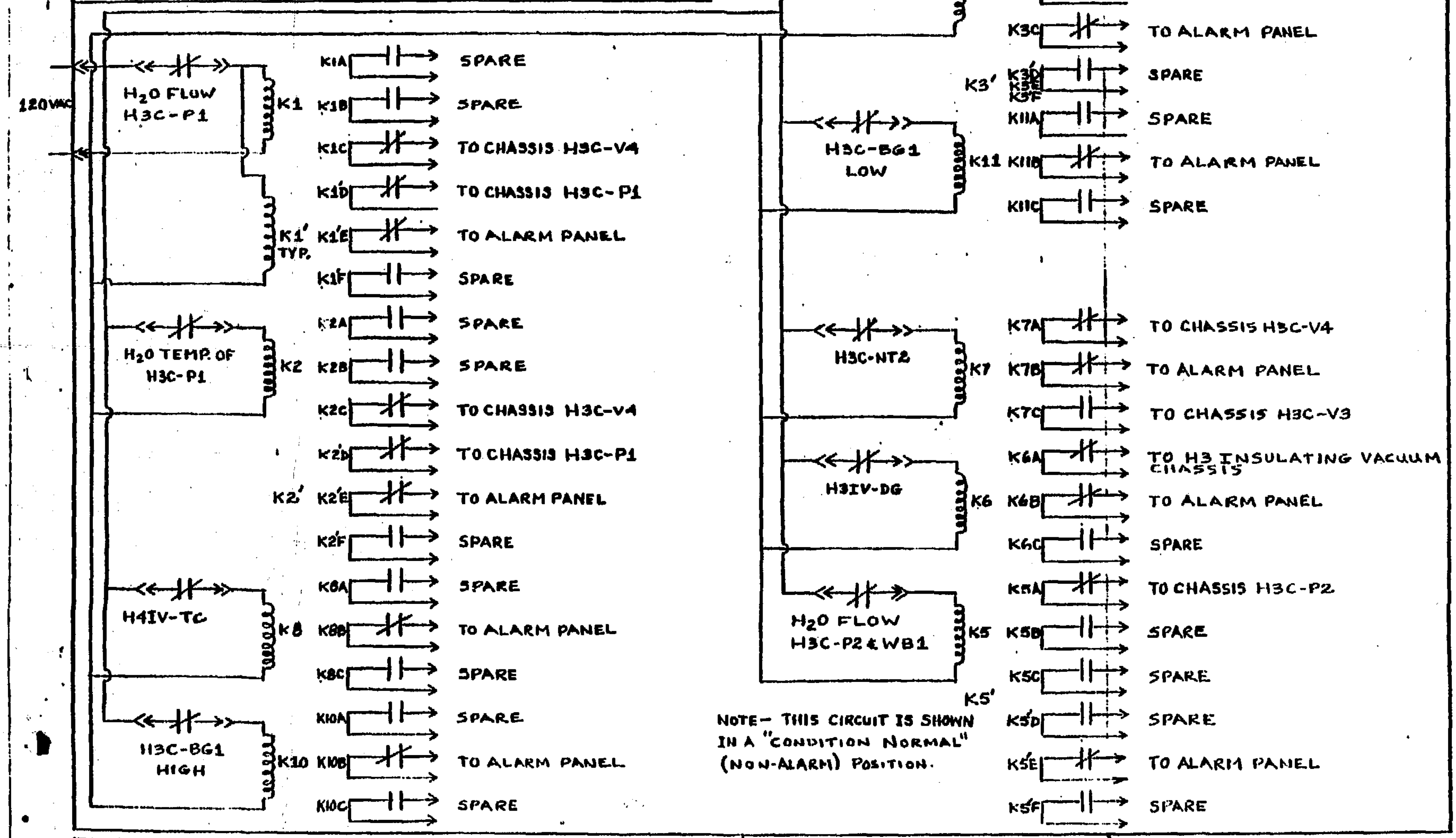
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III		

SUBJECT: MASTER RELAY CIRCUIT PPT-III

NAME: F. ONESTO

DATE: 2-24-70



NOTE – THIS CIRCUIT IS SHOWN IN A "CONDITION NORMAL" (NON-ALARM) POSITION.

ANL-145A (8-66) FOLD

ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

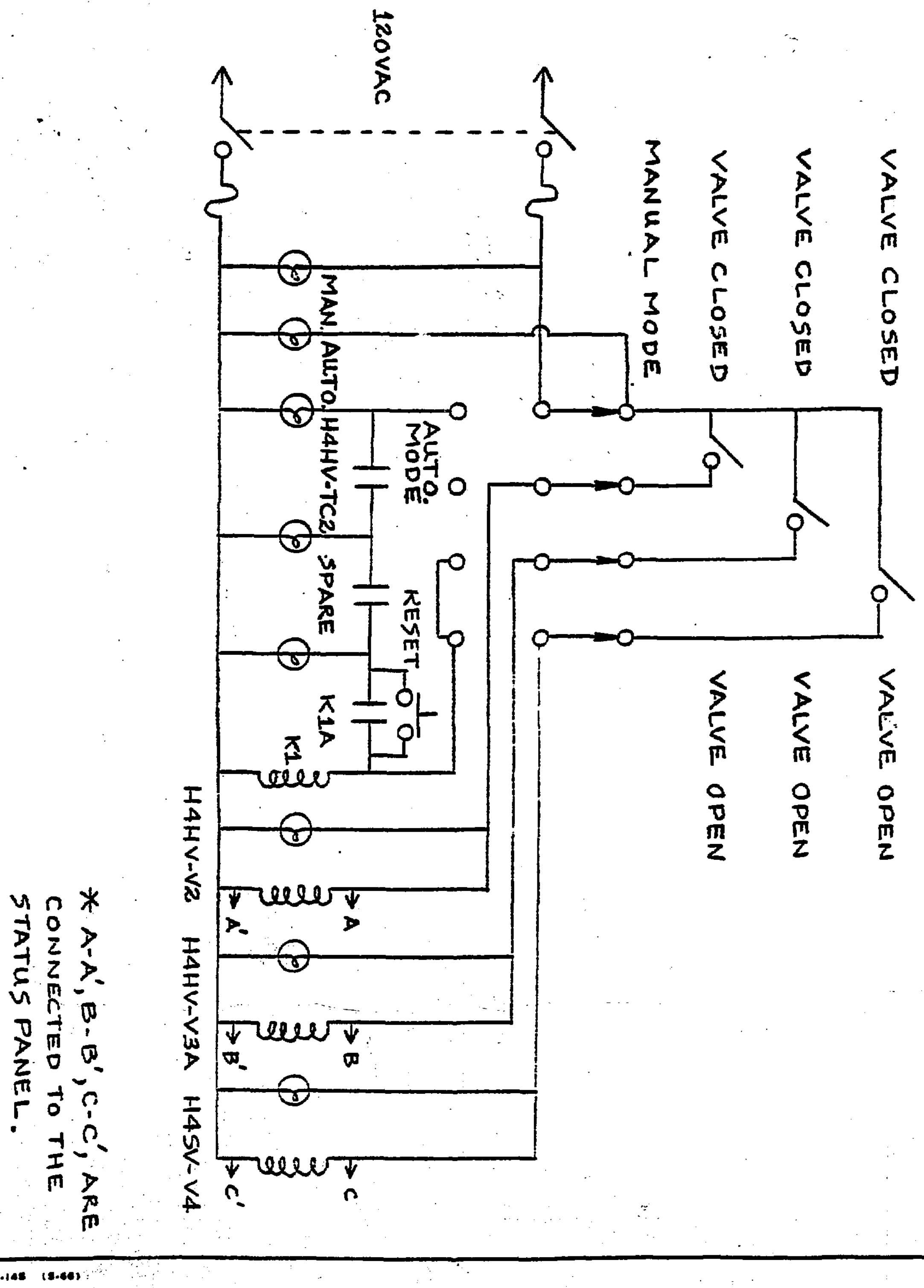
DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT III		

SUBJECT: PPT III He^4 VACUUM CONTROL CKT.

NAME: F. ONESTO

DATE: 3-27-75

REV. DATE:



ARGONNE NATIONAL LABORATORY

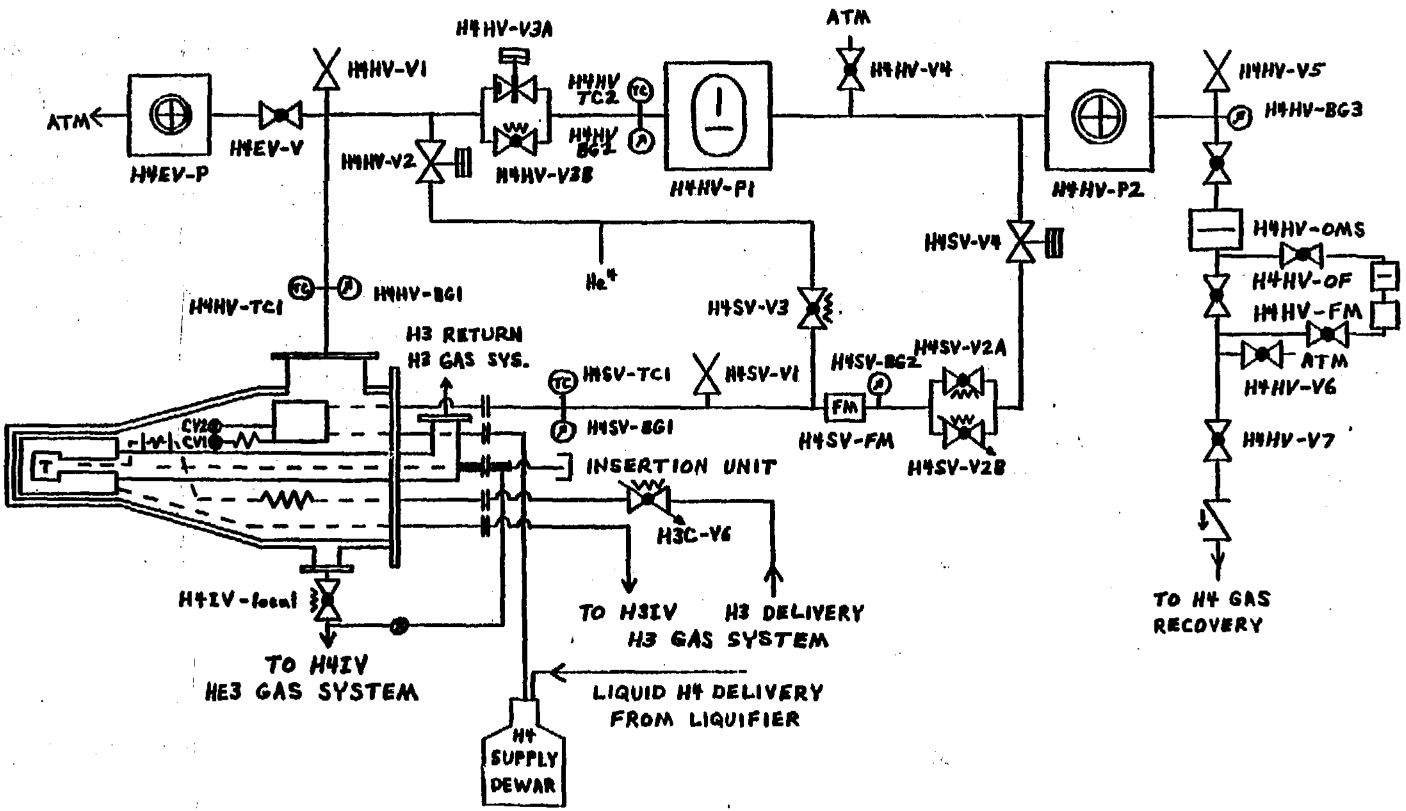
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE

SUBJECT: PPT-III TARGET H4 GAS SYSTEMS - REVISION A

NAME: DH

DATE: 2-18-75



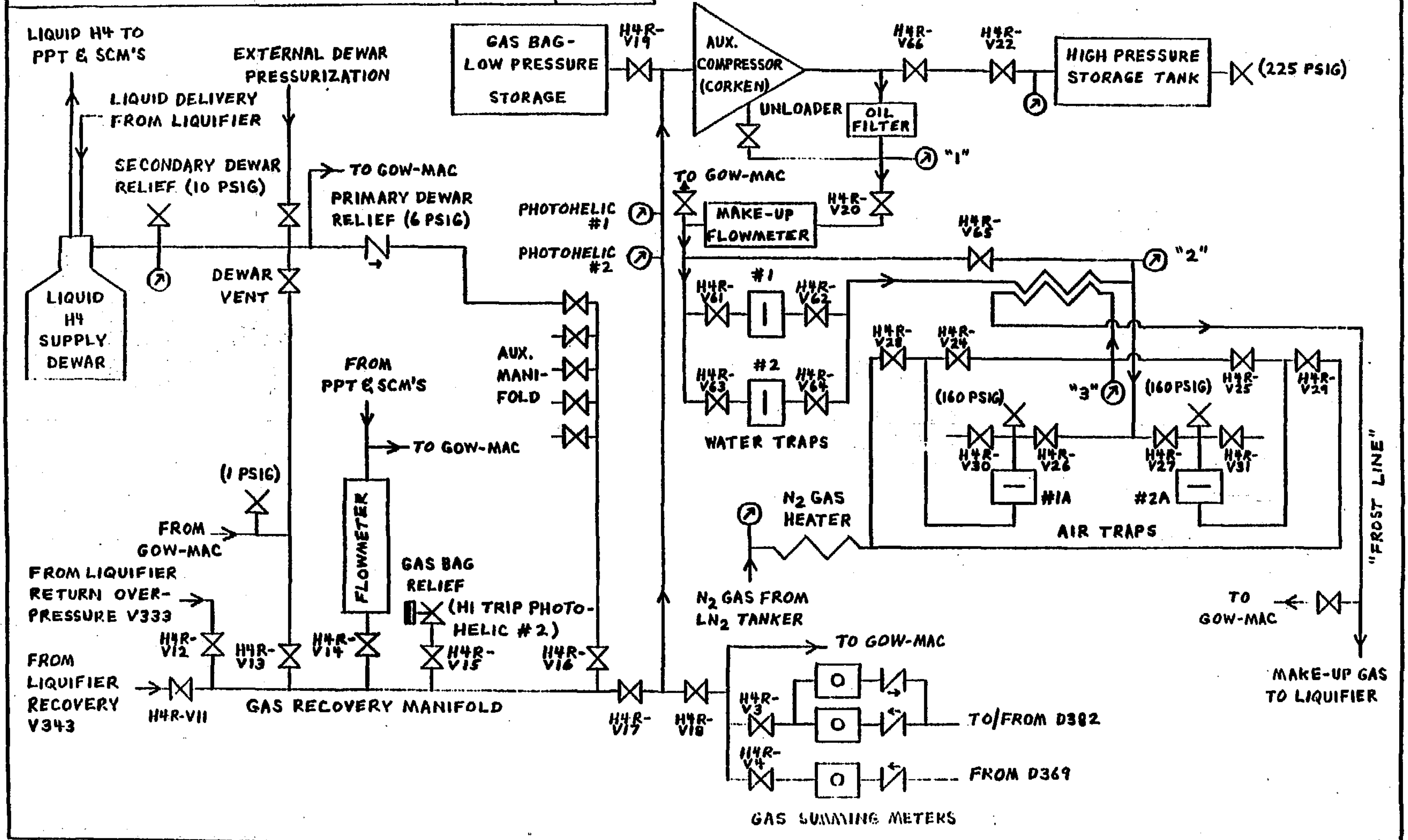
ARGONNE NATIONAL LABORATORY
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE

SUBJECT: H4 RECOVERY AND PURIFICATION SYSTEMS

NAME: DH

DATE: 2-19-75



ANL-140A (6-66)

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ARGONNE NATIONAL LABORATORY

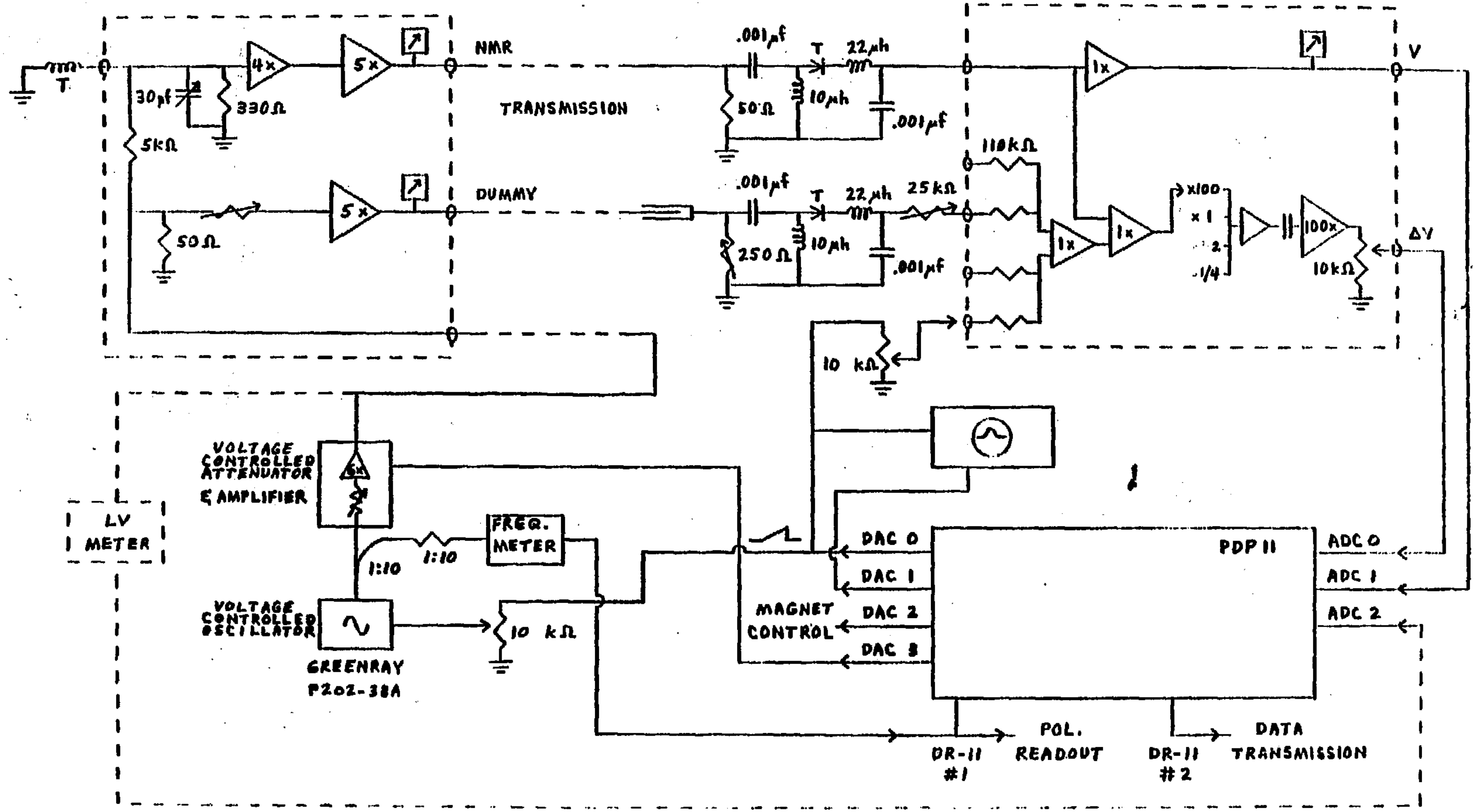
ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE

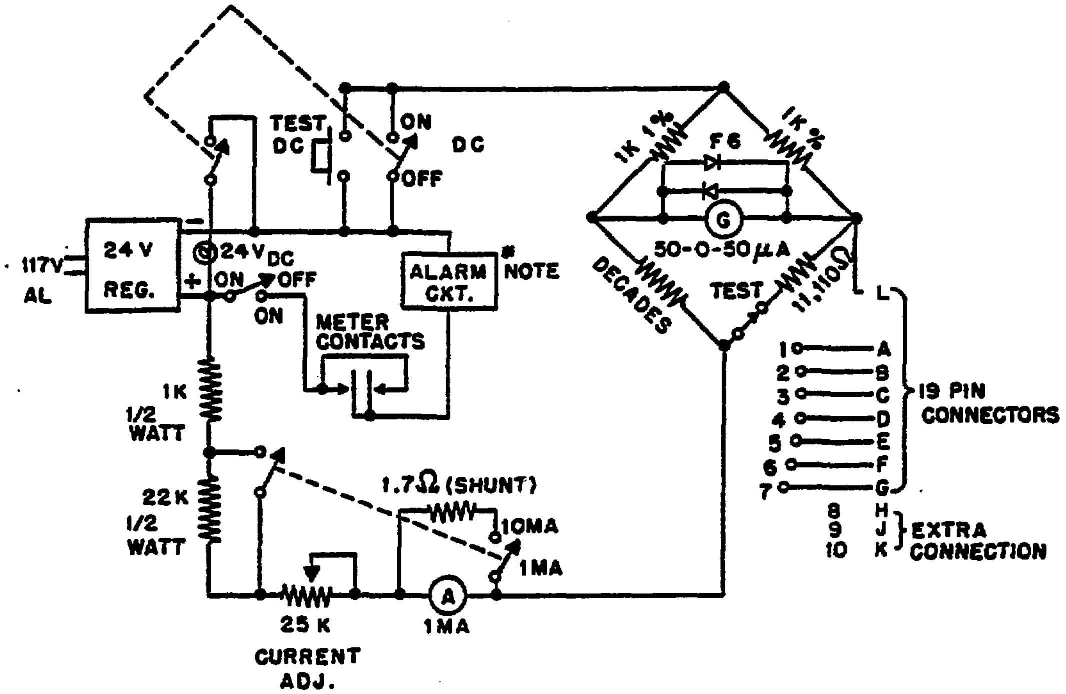
SUBJECT: PPT-III 108 MHz NMR SYSTEM

NAME: DH

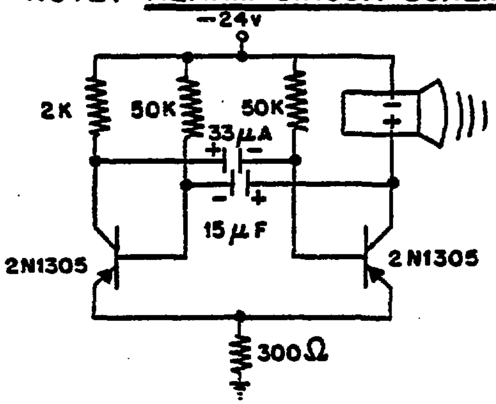
DATE: 3-2-75



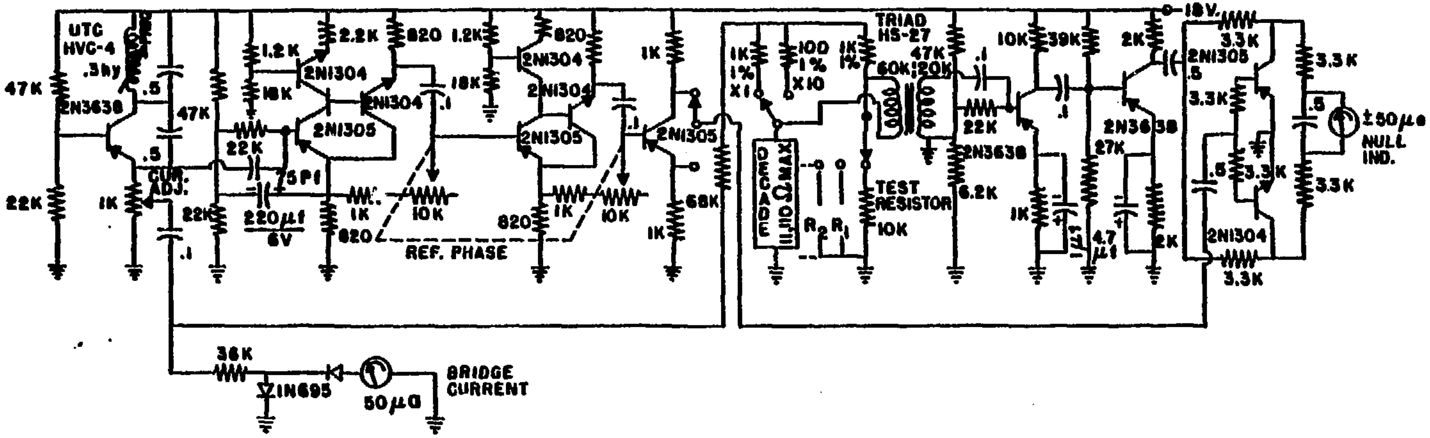
HELIUM LEVEL INDICATOR



*NOTE: ALARM CIRCUIT SCHEMATIC



HELIUM TEMPERATURE INDICATOR



NOTE:

*A.C. BRIDGE FOR HELIUM TEMP. MEASUREMENT

RANGE: 0Ω TO 11K ON x1 POSITION

0Ω TO 111K ON x10 POSITION

BRIDGE CURRENT: ADJUSTABLE 0-50 µA AC

OSC. FREQ: 1000 CPS ± 1%

ARGONNE NATIONAL LABORATORY

ENGINEERING NOTE

DIVISION	PROJECT	FILE NO.	PAGE
HEP	PPT-III		

SUBJECT: PPT-III HEATER CONTROL

NAME: D. HILL

DATE: 1-5-78

REV. DATE: