MASTER

Polarized Proton Target - IV

Operations Manual

January 1976

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1. INTRODUCTION

A. General Equipment Descriptions

This manual contains certain standard operating procedures for the Vacuum, Cryogenic, and Electronic Systems of PPT-IV. 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 4.2K 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 4.2K by the He^3 Condenser, which resides in the 1K 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. He^4 pumps (H4HV-P1, P2) and control rack
 - d. Exhaust gas clean-up and flowmeters (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.
 - f. H4 Systems rack
- ## 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 area (H3S)
- c. Auxiliary Pumping System (APS)

At the same time, He^3 gas entering the Cryostat at a pressure of 4100 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 4.2K by the He^3 Condenser, which resides in the 1K 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.

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- c. He^4 pumps (H4HV-P1, P2) and control rack
- d. Exhaust gas clean-up and flowmeters (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.
- f. H4 Systems rack

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- b. He^3 Storage area (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.

4. Microwave System

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

5. Magnet and Power Supply

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

6. Computerized Polarization Monitor

This consists of a PDP-11 computer interfaced to the NMR system.

7. 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. LN_2 Tanker

e. Liquid He^4 Dewar

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, 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. Perhaps 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 PEP, 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 LN₂ 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 A,B monitor 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 cryostat is at or near room temperature, and air is present in all volumes.
2. The He³ is in Storage condition.
3. The cryostat transfer line port is plugged.
4. The Mass. Spec. port is open to air.

B. Preparation

1. Turn on the cooling water for the H3 cart and for pumps H4HV-P1, P2.
2. Put APS mode switch in BLANK-OFF.
3. Turn on all AC switches on the H3 cart, except the LN₂

trap controllers.

4. Turn on all AC power on the H4 rack, except the Shaker and Heater.
5. Verify that the following valves are closed:

H4HV-V2B	H4SV-V3B	H3C-V3(MAN.)	H3S-V2
H4HV-V3	H4EV-V	H3C-V4	H3S-VM1
H4HV-V6	CV-1	H3C-V6	H3XS-V
H4HV-V7	CV-2	H3A-V3	H4XS-V
H4SV-V2	H3C-V2	H3S-V1	H2XS-V

Also, the target insertion unit vacuum jacket valve.

6. Equalize pressure in the regions H3R, H3C-P1, H3IV, as follows:
 - a. Open H3A-V1. This allows the H3C-P1 pressure to be read on H3C-BG1.
 - b. Note the H3R pressure on H3C-BG2B and the H3IV pressure on H3IV-BG1.
 - c. Equalize those three pressures, as necessary, by manipulating valves H3S-VM2, H3A-V2, H3A-V3, H3C-V1B, and/or H3IV-V1. Take care not to exceed the target flask pressure limits of Sec. I.C.
 - d. Finish with H3A-V3 closed and the following valves open:

H3C-V1B	H3A-V1	H3S-VM2
H3IV-V1(MAN.)	H3A-V2	

7. Open the following valves (if closed):

H4HV-V2A(MAN.)	H4SV-V3A	H3C-V6
H4HV-V5	H3C-V1A	H4IV-V1(MAN.)
	H3C-V5	H4IV-local

8. Evacuate H3IV, H4IV, H3D, H3R, and H3C-P1 as follows:
Put APS in ROUGHING Mode. Hold down APS P.S. Cheater until H3C-BG-2B is less than ~400t.
9. When APS -TC1 reaches 200 μ or less, put APS in D.P. Mode.
10. 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.
11. Turn on the pumps H4HV-P1, P2. This evacuates the cryostat H4 spaces.
12. Prepare the liquid He⁴ dewar, as follows:
 - a. De-pressurize the dewar.
 - b. Probe for and log the amount of liquid.

- c. Log the reading of H4HV-GSM, and the end-of-dewar estimate.
 - d. Open the He⁴ gas bottle valve and set the regulator for 5 psig.
 - e. Attach the gas return manifold to the dewar and open the dewar vent and H4SD-V3. Make sure H4SD-V1 is closed.
 - f. Attach the purging head to the transfer line and purge for a few seconds.
 - g. Remove the purging hose (at the quick-disconnect) and slowly insert the transfer line in the dewar.
 - h. Close H4SD-V3.
13. When H4SV-TC reads less than 0.3 t, close H4SV-V3A and back-fill the Separator with He⁴ gas by opening H4SV-V2.
 14. Remove the transfer port plug and verify that there is a small continuous flow of gas from the port.
 15. Remove the purging head and quickly insert the transfer line in the cryostat, bottom it, and tighten the seal.
 16. Close H4SV-V2.
 17. Close H4HV-V5 and open H4HV-V6.
 18. 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.
 19. When H3C-TC2 reads 50 μ or less, backfill H3IV, H3D, H3C-P1, and H3R with N₂ gas, as follows:
 - a. Put H4IV-V1 in MAN., closed and close H3C-V1B.
 - b. Put APS in BLANK-OFF Mode.
 - c. Open the N₂ bottle valve and set the regulator for 5 psig MAX.
 - d. Slowly open N2XS-V to admit N₂ to the system. Never admit gas so fast that H3IV-BG exceeds H3C-BG2B by more than $\sim$ 30t, or the target flask may collapse. When H3C-BG2B reaches $\sim$ 770t, close N2XS-V.
 - e. Close H3A-V2 and put H3IV-V1 in MAN., Closed.
 - f. Put APS in ROUGHING Mode. Hold down APS P.S. cheater

- c. Log the reading of H4HV-GSM, and the end-of-dewar estimate.
 - d. Open the He⁴ gas bottle valve and set the regulator for 5 psig.
 - e. Attach the gas return manifold to the dewar and open the dewar vent and H4SD-V3. Make sure H4SD-V1 is closed.
 - f. Attach the purging head to the transfer line and purge for a few seconds.
 - g. Remove the purging hose (at the quick-disconnect) and slowly insert the transfer line in the dewar.
 - h. Close H4SD-V3.
13. When H4SV-TC reads less than 0.3 t, close H4SV-V3A and back-fill the Separator with He⁴ gas by opening H4SV-V2.
 14. Remove the transfer port plug and verify that there is a small continuous flow of gas from the port.
 15. Remove the purging head and quickly insert the transfer line in the cryostat, bottom it, and tighten the seal.
 16. Close H4SV-V2.
 17. Close H4HV-V5 and open H4HV-V6.
 18. 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.
 19. When H3C-TC2 reads 50 μ or less, backfill H3IV, H3D, H3C-P1, and H3R with N₂ gas, as follows:
 - a. Put H4IV-V1 in MAN., closed and close H3C-V1B.
 - b. Put APS in BLANK-OFF Mode.
 - c. Open the N₂ bottle valve and set the regulator for 5 psig MAX.
 - d. Slowly open N2XS-V to admit N₂ to the system. Never admit gas so fast that H3IV-BG exceeds H3C-BG2B by more than ~30t, or the target flask may collapse. When H3C-BG2B reaches ~770t, close N2XS-V.
 - e. Close H3A-V2 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 1000 μ .

- g. When APS-TC1 reaches 200 μ or less, put APS in D.P. Mode.
- h. Put H4IV-V1 in MAN., open.

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 He⁴ gas out the exhaust relief port (H4HV-V4). 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-V3A. (If H4HV-P1 kicks off, turn it back on.)
3. When the cavity temperature reaches 90K, close H4SV-V3A, CV-1, and CV-2.
4. Insert target. See section "TARGET INSERTION".
5. Turn on LN₂ controllers for H3C-NT1 and NT2.
6. Turn on H3C-P1 and P2.
7. Put He⁴ exchange gas in H3IV:
 - a. Close H3A-V2 and H3S-VN2.
 - b. Put H3IV-V1 in MAN., closed.
 - c. Put APS in ROUGHING Mode.
 - d. Purge the He⁴ gas hose by opening H4XS-V completely for ~15 sec., then close it.
 - e. Put APS in Blank-OFF Mode.
 - f. Put H3IV-V1 in MAN., open.
 - g. Carefully crack open H4XS-V watching H3IV-TC. When H3IV-TC reaches ~1000 μ , close H4XS-V.
 - h. Put H3IV-V1 in MAN., Closed.
8. Open H3C-V2.
9. Put APS in D.P. Mode.
10. Put H4IV-V1 in MAN., Open and open local H4IV valve (near cryostat).
11. Open CV-1 to .200 and CV-2 to .050.

12. Open H4SV-V3B completely.
13. Put proper amount of He^3 into circulation, as follows:
 - a. Put H3C-V3 into AUTO, Open.
 - b. Close H3C-V6 and H3C-V1A.
 - c. Slowly crack H3S-V2, while watching H3S-BG.
When H3S-BG reaches the normal operating pressure as logged during the last TE Operation, close H3S-V2.
 - d. WAIT until H3C-TC4 reads less than 100 μ .
 - e. Close valves H3C-V5 and H3A-V1.
 - f. Open H3C-V6 completely.
 - g. WAIT 10 min. for trap H3C-NT2 to stabilize.
 - h. Open H3C-V4 and H3C-V1A. This initiates He^3 circulation.
14. At this time, monitor Bath Level resistor L1. The resistance will rise at an increasing rate.
15. When H4HV-TC2 reaches 10 t, set CV-2 at .025.
16. When H4HV-TC2 reaches 10 t, set CV-2 at .010.
17. When H4HV-TC2 reaches 10 t, close CV-2.
18. The presence of liquid He^4 in the Bath will be indicated by L1 having a steady high resistance around 5000 Ω .
19. Throttle H4SV-V3B to maintain Separator Gas flow H4SV-FM in the range 14-16 liters per minute.
20. When H4HV-TC2 reaches 10 t, set CV-1 at .100.
21. WAIT until H3C-BG1 indicates a pressure less than the HI trip point; i.e., liquid He^3 is collecting in the target flask.
22. As the cryostat comes into equilibrium, to conserve liquid He^4 and maintain the lowest stable Bath temperature, CV-1 should be throttled gradually to its normal setting. Typically, the optimum total gas flow rate is about 40-45 l/m. 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.
23. Put H4IV-V1 in MAN., closed.
24. If TE Mode is desired, see section TO TE MODE FROM NORMAL OPERATION.
25. If Enhanced Mode is desired, put H3IV-V1 in MAN., Open.
Remember to put H3IV-V1 in AUTO, Open, when H3IV-DG alarm clears.

III. VALVE STATUS-NORMAL OPERATION

1. In normal operation, CV-1 $\sim .050 \rightarrow .070$.
CV-2 is closed and H4SV-V3B $\sim .210$ (at ~ 1.5 psig dewar press.).
2. The following valves are normally OPEN:

H4HV-V2A	H3C-V1A	H3C-V4
H4HV-V7	H3C-V2	H3IV-V1 (AUTO)
	H3C-V3 (AUTO.)	H4IV-local

H3C-V6 is open to a degree depending on He³ circulation needs.

3. The following valves are normally CLOSED:

H4HV-V2B	H4SV-V3A	H3A-V2	H3S-VM2
H4HV-V3	H4EV-V	H3A-V3	H3XS-V
H4HV-V5	H3C-V1B	H3S-V1	H4IV-V1 (MAN.)
H4HV-V6	H3C-V5	H3S-V2	H4XS-V
H4SV-V2	H3A-V1	H3S-VM1	N2XS-V

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

4. Normally, H4SV-FM ~ 15 l/m, H4HV-FM = $\sim 40-45$ l/m.

IV. TO PUT He³ GAS INTO STORAGE(Microwaves should be on)

1. Open H3S-V1.
2. Switch valve H3C-V3 to MAN., Closed.
3. Open the following valves:

H3C-V1A (if closed)	H3C-V5	H3A-V1
H3C-V4 (if closed)	H3C-V6	
4. WAIT until H3C-TC4 indicates less than 20 μ .
5. Close the following valves:

H3C-V1A	H3C-V2	H3S-V1
H3C-V1B (if open)	H3C-V4	
6. Turn off (AC off) pumps H3C-P1 and H3C-P2.
7. Turn off microwaves.

IV. TO PUT He³ GAS INTO STORAGE

(Microwaves should be on)

1. Open H3S-V1.
2. Switch valve H3C-V3 to MAN., Closed.
3. Open the following valves:

H3C-V1A(if closed)	H3C-V5	H3A-V1
H3C-V4(if closed)	H3C-V6	
4. WAIT until H3C-TC4 indicates less than 20 μ .
5. Close the following valves:

H3C-V1A	H3C-V2	H3S-V1
H3C-V1B (if open)	H3C-V4	
6. Turn off (AC off) pumps H3C-P1 and H3C-P2.
7. Turn off microwaves.

V. TO He³ STAND-BY FROM NORMAL OPERATION

There are several ways of interrupting the He³ flow through the cryostat and thereby reducing the total heat load on the He⁴ stage. For example, the simplest way is to close H3C-V6 and turn off the microwaves. This is one kind of temporary "He³ stand-by" condition. However, this leaves liquid He³ in the condenser and target flask for an indefinite length of time, and also, with H3C-V1A left open, it leaves the He³ 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 He³.

Therefore, the following procedure, which completely isolates the He³ from the cryostat, is recommended as the "official" He³ STAND-BY condition;

1. Leave microwaves on
2. Close H3C-V4.
3. Open the following valves:

H3C-V1A (if closed)	H3A-V1
H3C-V5	H3C-V6
4. WAIT until H3C-TC4 indicates less than 20 μ .
5. Close H3A-V1 and H3C-V1A.
6. 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 He³ be put into storage.

VI. TO He⁴ STAND-BY FROM NORMAL OPERATION

To put He⁴ stage in STAND-BY (not being used, but keeping target cold):

1. Normally, if the He⁴ stage is to be put into STAND-BY, the He³ stage should first be put into a safe condition. See section "TO He³ STAND-BY FROM NORMAL OPERATION".
2. Close CV-1, CV-2, and H4SV-V3A (if open).
3. Open H4SV-V3B full open.
4. Verify that APS is in D.P. mode, then open H4IV-local (if closed) and put H4IV-V1 and H31V-V1 in MAN., Open.
5. WAIT until Level resistor L1 is less than 4500 Ω .
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 H4HV-V2A panel, switch to AUTO. while holding down the RESET button.
7. H4SV-FM should now read 16-20 l/m.

Note: The above procedure will only keep target cold if there is helium in the supply dewar, dewar pressure is normal, H4 pumps keep running, APS keeps running, etc.

VII. TO NORMAL OPERATION FROM He⁴ OR He³ STAND-BY

A. He⁴ Stage

1. Put H4HV-V2A in MAN., open.
Return the HI and LO set points on H4HV-TC2 to the normal settings.
2. Open CV-1 to .200.
3. Put H4IV-V1 in MAN., closed, and put H3IV-V1 in AUTO., Open.

B. He³ Stage

1. If He³ gas is in storage, perform operation TO He³ STAND-BY FROM He³ STORAGE, WAIT ~ 10 min. for trap H3C-NT2 to stabilize.
2. If He³ stage is in stand-by:
 - a. Open H3C-V1A and H3C-V4. Verify that H3C-V6 is completely open.
 - b. Close H3C-V5, if open.
3. When H4HV-TC2 reaches 10 t, set CV-1 at .100.
4. WAIT until H3C-BG1 indicates a pressure less than the HI trip point; i.e., liquid He³ is collecting in the target flask.
5. As the cryostat comes into equilibrium, it will be possible to gradually turn on the microwave power and throttle CV-1 to its normal setting, while maintaining He⁴ level and H3C-BG1 below the HI trip point.
6. Set H4SV-V3B to maintain H4SV-FM at 14-16 l/m.
7. Throttle H3C-V6, as appropriate.

VIII. TO He³ STAND-BY FROM He³ STORAGE

A. Initial Conditions:

1. It is assumed that the system is charged with a proper amount of He³, that pump H3C-P1 is well evacuated, as well as the plumbing comprising H3D and H3R, and that the He³ traps have been decontaminated.
2. Turn on the LN₂ controllers for H3C-NT1 and H3C-NT2, if these are off.
3. The following valves are closed:

H3C-V1A	H3C-V4	H3S-V1
H3C-V1B	H3A-V2	H3S-V2

B. He³ Stand-By:

1. Turn on pumps H3C-P1 and H3C-P2.
2. Open the following valves:
H3C-V2 H3C-V5 (if closed) H3A-V1 (if closed)
3. Put H3C-V3 in AUTO., Open.
4. Close H3C-V6.
5. Slowly crack valve H3S-V2, while watching H3S-PG.
When H3S-PG reaches the normal operating pressure as logged during the last TE operation, close H3S-V2.
6. WAIT until H3C-TC4 indicates less than 20 μ .
7. Close H3A-V1.
8. Open H3C-V6 completely.

VIII. TO He³ STAND-BY FROM He³ STORAGE

A. Initial Conditions:

1. It is assumed that the system is charged with a proper amount of He³, that pump H3C-P1 is well evacuated, as well as the plumbing comprising H3D and H3R, and that the He³ traps have been decontaminated.
2. Turn on the LN₂ controllers for H3C-NT1 and H3C-NT2, if these are off.
3. The following valves are closed:

H3C-V1A	H3C-V4	H3S-V1
H3C-V1B	H3A-V2	H3S-V2

B. He³ Stand-By:

1. Turn on pumps H3C-P1 and H3C-P2.
2. Open the following valves:
H3C-V2 H3C-V5 (if closed) H3A-V1 (if closed)
3. Put H3C-V3 in AUTO., Open.
4. Close H3C-V6.
5. Slowly crack valve H3S-V2, while watching H3S-BG.
When H3S-BG reaches the normal operating pressure as logged during the last TE operation, close H3S-V2.
6. WAIT until H3C-TC4 indicates less than 20 μ .
7. Close H3A-V1.
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, PSI, 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). 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 (see Sec. V). 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. (APS is in D.P. Mode.)
3. Verify that H3C-V6 is completely open, and H3A-V1 is closed.
4. Close the following valves:

H4HV-V2A(MAN.)	H4SV-V3B	H3S-VM2(if open)
H4HV-V2B(if open)	H3C-V2	H4IV-V1(MAN.) (if open)
H4SV-V3A(if open)		
5. WAIT until H4HV-BG1 indicates "0" (1 atmosphere).
6. Close CV-1 and CV-2.
7. When the cavity temperature reaches 100K, immediately do the following:
 - a. Slowly crack open H4HV-V2B.
 - b. When H4HV-V2B is completely open, close it and open H4HV-V2A.
8. Put H3IV-V1 in MAN., Closed.

B. Pump Out H3D and H3R

During the warm-up the contaminants in H3D will have vaporized and appeared as a pressure indication on H3C-TC1 and H3C-BG1, and, to the extent that they can pass through the "calibrated leak" as a pressure on H3C-TC2.

Hence, pump out H3D and H3R as follows:

1. Put APS in ROUGHING Mode.
2. Verify that H3A-V3, H3XS-V and H3S-VM1 are closed.
3. Open the following valves:
 H3A-V2 H3S-VM2
4. When H3C-TC1 reads less than 1 torr, open H3A-V1 and H3C-V1A.
5. When APS-TC1 reaches 200 μ or less, put APS in D.P. Mode.
6. When APS-TC2 reaches 50 μ or less, put H4IV-V1 in MAN., open.
7. When APS TC-2 reaches 20 μ or less, close the following valves:
 H3C-V5 H3A-V2
 H3A-V1 H3S-VM2

C. Return to Normal Operation

1. Completely open H4SV-V3B.
2. Open CV-1 to .200 and CV-2 to .040.
3. Open H3C-V2 and H3C-V4.
4. When H4HV-TC2 exceeds 10 t, set CV-2 to .015.
5. Put H4IV-V1 in MAN, closed.
6. When H4HV-TC2 again exceeds 10 t, close CV-2.
7. When H4HV-TC2 again exceeds 10t, set CV-1 at .100.
8. WAIT until H3C-BG1 indicates a pressure less than the HI trip point.
9. Put H3IV-V1 in AUTO., Open.
10. As the cryostat comes into equilibrium, it will be possible to gradually turn on microwave power and throttle CV-1 to its normal setting, while maintaining He⁴ level and H3C-BG1 below the HI trip point.
11. Set H4SV-V3B to maintain H4SV-FM at 14-16 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 100 μ or less.
2. The He^3 has been put into storage. H3C-P1, P2 are off.
3. These valves are closed (close, if not):

H3C-V1A	H3C-V4	H3S-V2	H3XS-V
H3C-V1B	H3C-V6	H3S-VM1	H3IV-V1 (MAN.)
H3C-V2	H3A-V1	H3S-VM2	H4IV-V1 (MAN.)
H3C-V3 (MAN.)	H3A-V3		
4. These valves are open (open, if not):

H3C-V5	H3A-V2
--------	--------
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 H3S-VM2 and H3A-V1.
3. When APS-TC1 reaches 200 or less, put APS in D.P. Mode.
4. When H3C-TC3 reads less than 0.1t, close H3S-M2 and H3A-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. Open H3C-V4. The trap pressure is now observed on H3C-BG1, TC1.

2. Put APS in ROUGHING Mode.
3. Now pump out the trap by opening H3S-VM2.
4. When APS-TC1 reaches 200u or less, put APS in D.P. Mode.
5. In general, the trap is sufficiently clean when H3C-TC1 reads less than .1t.
6. Turn off the trap heater.
7. Close H3C-V4.

D. Final Safe Conditions:

1. Open H3A-V1, H3C-V1A, and H3C-V6.
2. Put H3IV-V1 in MAN., Open.
3. Close the gas gallast 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-V3A(if open), H4HV-V2A H4HV-V2B(if open) H4SV-V3B, H4IV-V1(if open) (MAN.)
5. WAIT until H4HV-BG1 indicates "0" (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.
 - b. Turn off H4HV-P1, P2.
 - c. Close the H4 Pumps cooling water supply valves.
 - 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 .175.

If desired, the microwave power can be increased by setting the Line 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 50 μ of N_2 or 10 μ 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 1000 μ of 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, and H4XS-V (for He^4); or H4IV-V1 and N2XS-V (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 80K, 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):

H3C-V1A	H3C-V6	H3A-V2	H3IV-V1(MAN.)
H3C-V5	H3A-V1	H3S-VM2	
 - c. Check N_2 bottle. High-pressure valve should be open and the regulator set at 5 psig MAX.
 - d. Slowly open N2XS-V to admit N_2 to the system. Never admit gas so fast that H3IV-BG exceeds H3C-BG2B by more than 30 t, or the target flask may collapse. When H3C-BG2B reaches 760t, close N2XS-V.
6. Another means of rapid warm-up is to force-flow N_2 gas through the insertion tube, as follows:
 - a. The H3 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 into the mark, after loosening the feed-thru nut. Don't damage the tip.
Tighten the feed-thru nut.
- d. Attach the N₂ gas hose to the insertion tube.
- e. Set the N₂ regulator at 5 psig MAX.
- f. Open the N₂ 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 21 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-V2A (MAN.)	H4SV-V3B	H3C-V3 (MAN.)	H3S-VH1
H4HV-V2B	H4EV-V	H3C-V4	H3S-VH2
H4HV-V3	CV-1	H3A-V1	H3XS-V
H4HV-V6	CV-2	H3A-V2	H3IV-V1 (MAN.)
H4HV-V7	H3C-V1A	H3A-V3	H4IV-V1 (MAN.)
H4SV-V2	H3C-V1B	H3S-V1	H4XS-V
H4SV-V3A	H3C-V2	H3S-V2	N2XS-V

2. Turn off all AC power switches on the He³ Gas Cart.
3. Turn off all AC power on the H4 racks.
4. Turn off the carcinotron cooling water supply.

XII. OPERATOR CHECKLIST

1. When PFT cryostat is in Stand-By Mode (keeping cold) He^4 Separator Flow (H4SV-1M) should stay in the range 16 - 20 l/m. Notify system expert if this condition should fail to exist. (In normal running mode, H4SV-1M $\sim$ 15 l/m)
2. About once each week of operation, the excess oil should be drained from H4HV-0F. Notify system expert when red color reaches top of element.
3. Check He and N_2 gas cylinder supply and order gas (4 He and 4 N_2) when inventory is two bottles or less.
4. Check oil levels in the following devices and top up when necessary:
 - a. He^4 pumps H4HV-P1 and H4HV-P2.
 - b. He^3 fore-pump 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)

XIII. TO EXCHANGE He⁴ DEWARs

To avoid interruption of polarization the dewar should be replaced at least 15,000 gl prior to the end-of-dewar estimate, according to H4HV-GSM.

A. Prepare New Dewar and Transfer Line

1. De-pressurize the new dewar.
2. Probe for and record the amount of liquid.
3. Log the reading of H4HV-GSM and the end-of-dewar estimate.
4. Open the He⁴ gas bottle valve and set the regulator for 5 psig.
5. Remove the gas manifold from the old dewar and attach it to the new.
6. Open the new dewar vent and H4SD-V3. Make sure H4SD-V1 is closed.
7. Attach the purging head to the new transfer line and purge for a few seconds.
8. Remove the purging hose (at the quick-disconnect) and slowly insert the new transfer line in the new dewar.
9. Close H4SD-V3.

B. Switch Dewars

1. Close H4SV-V3A,B.
2. Open H4SV-V2.
3. Completely unscrew the feed-thru nut on the cryostat end of the old transfer line.
4. Extract the old dewar and transfer line from the cryostat. Check for gas flow from the open cryostat transfer port.
5. Remove the purging head and quickly insert the new dewar and transfer line, bottom it, and tighten the feed-thru seal.
6. Close H4SV-V2.
7. Open H4SV-V3B to the normal setting.
8. The old dewar should be tagged MT and placed outside the overhead door. Remove any fixtures that belong to us.

C. Trouble

If for some reason the H3 level is lost during the above, recover it as follows:

1. Turn off microwave power.
2. Open CV-1 to .100 until H4 level is normal.
3. Open H3C-V6 completely.
4. When H3 level is normal, slowly throttle CV-1 and H3C-V6 to their normal settings.
5. Restore microwave power.

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. Normally, 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 "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.

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

2. " He^3 LIQUID LEVEL" alarms: These are wired to H3C-PS1 (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 the Anode voltage
to 0.2 kv or by setting attenuator at .000 ".

3. 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 10 μ .

Instead, call system expert as this may mean that target flask is leaking He³.

4. In normal operation, valve H3C-V3 is in AUTO mode interlocked on H3C-NT2. If you get an "H3C-NT2 LIQUID LEVEL LOW" alarm, H3C-V3 will close automatically and He³ flow will drop off. This valve must be RESET manually after the bad NT2 condition is corrected.
5. Pump H3C-P1 is interlocked on "H₂O FLOW H3C-P1" and "H₂O TEMP. H3C-P1". These must be RESET manually after either such alarm (after alarm condition is corrected).
6. 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 "H₂O FLOW H3C-P2" and "H3C-P2 BACK-PRESSURE".
7. "He⁴ LEVEL INDICATOR" alarm: In the absence of any other alarm condition on the He⁴ system, this usually means that CV-1 is set too lean.
8. H4HV-TC2 HI or LO alarms 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-V2A.

XV. UTILITY FAILURES

1. In case of experimental water supply failure, immediately take one of the following steps:
 - a. Shut down the PPT (close CV-1, CV-2, and H4SV-3B; put microwaves into stand-by).
 - b. Put H4IV-V1 and H3IV-V1 in MAN., OPEN.
 - c. Close H3C-V1A and H3C-V6.
 - d. CALL System Expert.
2. Normally, the LN_2 tanker runs at a pressure of 15-35 psig. We are in trouble if the pressure falls below 10 psig.
3. If there is no LN_2 (e.g., tanker runs dry), immediately close H3C-V4.
4. General (building) a.c. power failure:
 - a. close CV-1.
 - b. close H3C-V2
 - c. CALL System Expert.
5. Air Pressure Failure:
 - a. Open H4IV-V2B
 - b. CALL System Expert.

XVI. HOW TO USE "POLXEC", OFF-LINE POLARIZATION ROUTINE

From Load Start:

Load System as described on computer face.

From Crash:

Console Enable-Halt Switch to "Halt"
 Switch Register to 173100
 Load Address
 Switch Register to 177462
 Enable
 Start

Teletype prints "DOS V08-02"

From using another program

Type: Control + C
 .KI
 \$FI

Mount: DECTAPE labelled "POLXEC" on Drive #0.

DECTAPE switches to "WRITE LOCK", and "REMOTE"

TYPE: \$RUN DT:POLXEC(12,15)

COMMANDS UNDERSTOOD BY POLXEC:

POLXEC types a "c" mark when it is ready to receive commands.

All commands begin with a period. Anything else is treated as a comment.

.TE START THERMAL EQUILIBRIUM ROUTINE. SEE DETAILS BELOW.
 .FQ COMPILE A FREQUENCY TABLE.
 .DU DUMP THE CURRENT NMR DISPLAY
 .DF DUMP THE FREQUENCY TABLE
 .R1 READOUT NMR SWEEP ONCE AND STOP
 .RR BEGIN REPEATED NMR READOUTS
 .ST STOP REPEATED READOUTS
 .HV LOAD SECOND DAC WITH OCTAL NUMBER (FOR CARCINOTRON)
 .RF LOAD FIRST DAC WITH OCTAL NUMBER (FOR FREQUENCY)
 .NT CHANGE NUMBER OF SWEEPS FOR EACH T.E. READOUT
 .BK SWEEPS THE WHOLE RANGE OF FIRST DAC, DISPLAYING FREQUENCY
 OR AMPLITUDE RESPONSE, DEPENDING ON SWITCH ON POL. DIGITIZER.

 .SC CHANGE SCALE FOR DISPLAYS
 .SU DIFFERENT WAYS OF AVERAGING T.E. SIGNALS
 .IN INITIALIZE POLARIZATION DIGITIZER AND CAMAC.
 .KI KILL THIS PROGRAM

CAMAC ASSIGNMENTS

CRATE #1 -- BD011 CRATE

Station 10: JORWAY #40 output register

Station 11: JORWAY #60 input register

T.E. Routine

The computer asks the operator a series of questions.

A "YES" answer is made by simply hitting "CR" button.

A "NO" answer is made by typing any character, then "CR".

After a "NO" answer, the computer asks "MORE?"

A "NO" answer to "MORE?" returns control to main polxec program.

"Clear Sums?" Do you wish to clear the running sums that may have accumulated during previous T.E. passes?

"MORE?" answering "NO" returns control to main polxec program.

"GOOD SIGNAL?" is the signal just taken, now displayed on scope, a reasonable NMR resonance signal?

"GO OFF FIELD." answer YES WHEN the "ONE PERCENT LOWER" switch has been thrown, and the field is off resonance.

"GOOD BACKGROUND?" is the signal just taken, now displayed on scope, a reasonable background off-resonance signal?

"T.E. POLARIZATION=" answer by typing the thermal equilibrium polarization, in percents, based on temperature reading. Be sure to include decimal point.

"ADD TO SUMS?" is the polarization per unit area of the signal, based on the just completed signal and background, to be used in compiling average T.E. Signal size?

To get a copy of this information.

\$RUN PIP

LP:< DT:INFO(12-15)

XVII. TO CHANGE SIGN OF POLARIZATION

1. Set Line Voltage to proper range (see columns "A").
2. Open CV-1 to .125.
3. Set microwave attenuator to "C". At this time the following two alarms are o.k.

H3C-TC2	HIGH
H4HV-TC2	HIGH
4. Close H3C-V6. As soon as H3C-TC3 begins to drop rapidly, set H3C-V6 at "B".
5. When POL. reaches "D", set microwave attenuator to "E" and set H3C-V6 at "F".
6. Return CV-1 to its normal setting.
7. If, after 10 minutes from step 4, you still have a "He³ Level" or "He³ Flow" alarm, follow section 1 or 2 of "NOTES ON ALARMS."

DATE:

A

13

C

D

E

٤٠

•

—

(VG)

†

95%

!

+

400

(V5)

XVIII. TO ZERO THE POLARIZATION

A. Zeroing

1. Completely close H3C-V6.
2. Set microwave attenuator to .175.
3. When POL becomes less than 2%, set microwave attenuator to .000.
4. Set Anode voltage to $\sim$.2KV.

B. Zero Running

1. Set H3C-V6 $\sim$.045" to maintain He³ level in the normal range as indicated by H3C-DG1.
2. You are now ready for "Zero" running.
3. Note that "He³ Circulation Flow Low" alarm is o.k. in this mode.

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. 130K. This operation requires some experience.

A. Initial Conditions.

1. H3R, H3D, H3C-P1, and H3IV are back-filled with H_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, H4SV-V3A, and H4SV-V3B are closed, but the H4 pumps are on.
4. The following valves are also closed:

H4IV-V2B	H4EV-V	H3A-V2	H3S-VM1
H4IV-V3	H3C-V1B	H3A-V3	H3XS-V
H4IV-V5	H3C-V2	H3S-V1	H3IV-V1 (MAN.)
H4IV-V6	H3C-V3(MAN.)	H3S-V2	H4XS-V
H4SV-V2	H3C-V4		N2XS-V

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

5. The following valves are open:

H4IV-V2A(MAN.)	H3C-V1A	H3S-VM2
H4IV-V7	H3C-V6	H4IV-V1 (MAN.)
H3A-V1	H4IV-local	H3C-V5
6. The following equipment is at hand:
 - a. Cold funnel (clean)
 - b. Pre-measured amount of target material in a small dewar
 - c. Vibrator (electric scribe)
 - d. Flashlight, "tapping" tool, tissue paper.
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 50 μ .

2. Equalize pressures in H3C and H3IV to atmosphere:

- a. Put APS in BLANK-OFF mode.
- b. Put H4IV-V1 in MAN., closed.
- c. Open H3A-V2.
- d. Put H3IV-V1 in MAN., Open.
- e. If H3C-BG2B reads less than 760t, crack N2XS-V until the reading is 760t, then close it.
- f. Open H3A-V3.

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 LN₂ 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 LN₂ 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. 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 for ~ 30 sec, with the magnet on at 2.5T. 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 (~ 93 torr) 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-V3.
2. Put APS in ROUGHING mode and hold down the APS P.S. cheater until H3C-BG2B reads less than 400t.
3. When H3C-BG2A reaches ~ 95 t, put APS in BLANK-OFF mode.
4. If H3C-BG2A pressure grows to exceed 100t, rough down to ~ 95 t again.
5. When the rate of increase of H3C-BG2A becomes less than 0.1t in 5 minutes, put APS in ROUGHING mode.
6. When APS-TC1 reaches 200 μ 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: Line current ~ 50 ma, atten. = .175. 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 1.N₂ REMOVAL RECORD

<u>TIME</u>	<u>H3C-BG2A</u>	<u>ACTION</u>
1320	95 torr	Put APS in BLANK-OFF mode
1322	101.5	ROUGH to 95 torr, then B.O. Mode
1324	97.3	" " " " " "
1326	100.3	" " " " " "
1328	96.5	" " " " " "
1333	97.5	" " " " " "
1343	99.1	" " " " " "
1353	100.1	" " " " " "
1358	96.5	" " " " " "
1403	97.3	" " " " " "
1408	98.0	" " " " " "
1413	98.4	" " " " " "
1418	98.5	" " " " " "
1423	98.5	(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-V2	H3A-V3	H3S-VM1	H4XS-V
H3C-V3 (MAN.)	H3S-V1	H3XS-V	N2XS-V
H3C-V4	H3S-V2	H4IV-V1 (MAN.)	
7. The following valves are open:

H3C-V1A	H3C-V6	H3A-V2	H3IV-V1 (MAN.)
H3C-V5	H3A-V1	H3S-VM2	
8. The following equipment and material is at hand:
 - a. "Flask Flusher"
 - b. Funnel with $\frac{1}{4}$ " 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 250K 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 N₂ bottle valve and set the regulator for 2 psig max. Open the feed valve to the Flask Flusher.
3. When the target material has drained out, put V3 on FILL.
4. WAIT ~15 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 the solvent has passed, put V2 in LOAD, and V1 and V3 on DRAIN.
4. When the solvent has drained into the beaker, put V3 on FILL, and dump the contents of the beaker.
5. WAIT ~15 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 N₂ 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-BG2B 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. He⁴ 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 1000 μ of He⁴ 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 OPERATIONA. 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 .000 and Anode to $\sim 0.2\text{KV}$.
2. Verify that H3C-TC2 reads less than 10μ , then note the reading of H3C-BG2A. This is the true "zero" reading.
3. Close H3C-V1A,B.
4. Open H3C-V6 completely.
5. When H3C-BG2A reads approximately 5 torr above true "zero", close H3C-V6 to .075.
6. Crack open H3C-V1B, until H3C-TC4 reads $\sim 350\mu$.
7. Put He^4 exchange gas in H3IV:
 - a. Put H3IV-V1 and H4IV-V1 in MAN., closed (if open).
 - b. Put APS in ROUGHING Mode.
 - c. Purge the He^4 gas hose by opening H4XS-V completely for ~ 15 sec, then close it.
 - d. Put APS in BLANK-OFF Mode.
 - e. Put H3IV-V1 in MAN., Open.
 - f. Admit He^4 to H3IV in steps by cracking H4XS-V, until H3IV-TC stabilizes at 50-100 μ .
 - g. Put H3IV-V1 in MAN., Closed.
 - h. Put APS in D.P. Mode.
8. By adjusting the setting of H3C-V1B, H3C-BG2A should be set to and held exactly at 5.0 torr above "zero".

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-PS1 LOW

B. Taking the Calibration Signals

1. Follow the TE routine of Sec. XVI.
2. Check the He³ pressure occasionally; trim up if necessary.
3. Log the following information:

H3C-BG1	H3C-TC4
H3C-BG2A true "zero"	H3IV-TC
H3C-BG2A ave. during TE's	H3C-V6
H3S-BG	

XXII. TO NORMAL OPERATION FROM TE MODE

1. Put H4IV-V1 in MAN. Closed, if open.
2. Put APS in D.P. mode.
3. Put H3IV-V1 in MAN., Open.
4. Open H3C-V6 completely.
5. Set CV-1 at .125.
6. Put microwaves in polarization reversal mode, i.e., determine new sign of polarization and set Anode, Line and atten.
7. Open H3C-V1A
8. Close H3C-V1B.
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 SYSTEMA. 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 can produce about 10 watts of microwave power between 68 and 72 GHz. It requires four different dc power supplies for operation. They are: (1) the heater; (2) Anode II, referred to as "line voltage"; (3) Anode I; and (4) grid 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 temperature interlocked. Required flow is 0.2 gpm at 4 psi maximum.
- b. Turn "ON" "CONTROL POWER" switch. If a failure is present, the "Ext" interlock light will be "ON" and none of the voltages will turn "ON".
- c. Turn the "Heater Control" to zero, completely C.C.W. The heater is "OFF ZERO" interlocked and will not turn "ON" if off zero.
- d. Press the "HEATER ON" button and slowly turn the "HEATER CONTROL" C.W. until the operating current is reached. Under no circumstances should the specified heater current be exceeded.
- e. The "Timer Running" interlock light will be "ON" and running. After 5 minutes have elapsed, the "Timer Running" light will go off and the "H.V. Ready" light will turn "ON."

- f. Turn "Line Control Coarse" completely C.C.W. to zero. The "Line Voltage" is off-zero interlocked. Press "Line On" button. Turn knob C.W. until line voltage reaches about 3000 V. At this point, the "Line Under Voltage" interlock should be "OFF." If not, raise voltage slightly until it does. Do not exceed 3600 V.
- g. Turn the grid switch "ON" (if it was off). Wait about 10 seconds. The grid voltage should be about 25 V.
- h. Turn the "Anode Control" to zero and press the anode "ON" button. Raise anode to about 200 V.
- i. Slowly turn "Line Control" to operating "Line Voltage" level. Slowly turn "Anode Control" to its operating level. Never have the anode voltage exceed the line voltage.
- j. Adjust heater current slowly to give operating line current. The anode voltage may also be readjusted to set this final current. Do not exceed 60 ma line current.

2. Turn Off Procedure

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

- a. Turn "Anode Control" to zero.
 - b. Press "ANODE OFF" button.
 - c. Turn "Line Coarse Control" to zero and press "LINE OFF" button.
 - d. Slowly turn "heater Control" to zero and press "HEATER OFF" button.
 - e. Turn "Control Power" switch "OFF."
 - f. Wait about 5 minutes and turn cooling water off.
- ## 3. "Standby" Procedure

The "Standby" procedure is the same as the "TURN ON" procedure except that the anode voltage is only raised to 200 V. If the tube had already been "ON", turn the anode voltage down to 200 V.

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 I, "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 II, "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 ~20mA no power is developed.

In summary, the frequency of operation is related 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.
- c. Isolators transmit power mainly in only one direction. One 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.

XXIV. SCHEMATICS

ENGINEERING NOTE

SUBJECT

NAME

DH

DATE

12-21-75

REV. DATE

FIGURE 1