E158 Liquid Hydrogen Target Operating Procedures

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Contents

1 Training of target operators

Any person authorized to operate the E158 LH_2 target must pass a training course taught by R. Carr of Caltech, who designed the gas handling system for all of the liquid hydrogen targets built by the target group at Caltech and has done the training for the SAMPLE target operators at Bates. There are two levels of operators: Level I (black belt) and Level II (brown belt). Level I operators are trained in all aspects of the operation of the target, including filling the ballast tank and cryoloop with hydrogen, liquefying the hydrogen in the cryoloop and purging hydrogen from any part of the system. They must know the cryoloop hardware and electronics and the interlock system, in addition to being able to operate the software monitor/control program. Level II operators are expected to know how to operate the target software, be familiar with the hardware, and be able to monitor the target's operation, knowing the normal operating parameters.

In addition to the experimentalists who will be qualified as target operators, all of the cryogenic technicians at SLAC will be qualified to at least Level II. At least one member of the cryogenic group will be qualified to Level I.

2 Preparations for liquefying hydrogen

The following target checklist will be filled out, initialed and put in the target logbook before liquefying hydrogen in the target.

Pre-fill Checklist

Date: ____________________

Initials	TASK
_______	1. Notify experimenters and refrigerator group of plan to liquefy.
	2. Check vacuum
_______	upstream beamline (______ torr)
_______	downstream beamline (______ torr)
	3. Connect nitrogen-purged hydrogen vent line to main gas panel
_______	hydrogen cell relief valves
_______	hydrogen cell rupture disk
_______	helium cell relief valve
	4. Connect nitrogen-purged vacuum exhaust line to pumps
_______	scattering chamber
_______	hydrogen lines (VP1 on main gas panel)

Initials	TASK
	5. Visually check integrity of vent lines
______	hydrogen vent line
______	vacuum exhaust line
______	bottle vent line
______	ballast vent line
	6. UPS operational
______	main gas panel
______	counting house computer
	7. Required gases available
______	H_2
______	He
	8. Fast-acting gate valves working
______	upstream valve
______	downstream valve
______	9. Scattering chamber vacuum OK (______ torr)
	10. Open gate valves
______	upstream valve
______	downstream valve
______	11. Verify that all target interlocks are enabled
______	12. Camera view of main gas panel OK
______	13. Operational check of HYDROGEN IN TARGET light
______	14. Warning signs available at entrance to ESA
	15. HADs on and operational
______	Gas Panel (alarm set level:______)
______	Alcove (alarm set level:______)
______	Upstream (alarm set level:______)
______	Chamber alarm set level:______
______	16. Phones and beepers distributed
______	17. Crane red-tagged
	18. Re-check vacuum
______	upstream beamline
______	scattering chamber
______	downstream beamline

3 Target operations

A Manpower

All shifts for E158 will include at least one target operator trained to Level II or above whenever beam will be on the cryotarget during the shift and whenever liquid hydrogen is in the cryotarget, independent of beam delivery to the hall. At all times during runs or when liquid hydrogen is in the target, a Level I target operator will be designated as "on call," carry a pager, and stay within 1 hour of the lab. At these times, R. Carr of Caltech will carry a pager and be available to call in to the lab. The pager numbers and the names of the Level I and Level II operators will be posted in the counting house.

Any operation requiring access to the main gas panel, i.e., cooling the target, filling it with any gas, and purging the target, requires access to ESA. When liquefying hydrogen in the target, two target operators, at least one of which must be a Level I operator, will be in ESA until the fill is completed.

B Documentation

A target logbook will be maintained in which the Pre-fill Checklist and the checklists for gas handling operations (See section 5 on Standard Operating Procedures) are stored. This logbook will also include notes by the target operators during shifts and notes regarding any changes or repairs made to the target system between runs.

C Access to End Station A

When operating without hydrogen in the target or the gas lines, access to the end station will have no additional restrictions beyond those usually applied. A sign stating that there is hydrogen in the target will be placed at the entrance to the hall and a light at the entrance will be turned on by the target operator as part of the standard operating procedures.

When hydrogen is in the target, access to ESA will not be restricted beyond normal requirements in areas outside the shielding tunnel or the alcove. Before a person enters the alcove or the shielding tunnel around the beamline, the gate valves immediately upstream and downstream of the scattering chamber must be closed. If work is done around the detectors, a cover will be put on the downstream beam window. If any of the HADs alarm limits are reached, an alarm will sound and all people in the end station must immediately leave the hall.

4 Procedure for overriding interlocks

A beam interlock box handles a number of hardware and software interlocks,[1] sending a fast shutdown signal for the beam if the target parameters go out of their acceptable ranges or if

[1] *"E158 Liquid Hydrogen Target Preliminary Design,"* R. Carr, J. Gao, C. E. Jones, R. McKeown, R. Boyce and J. G. Weisend II, SLAC Internal Report E158-101, March 2000.

the state of the target becomes unknown. At times, particularly when filling or purging the cryotarget, it is necessary to override an interlock. This is done with a set of toggle switches located on the front panel of the beam interlock box. These switches are covered with a bar to prevent accidentally changing their state. Lights on the front panel of the interlock box show the state of an interlock (OK/tripped) and whether it is enabled or disabled.

When someone enables or disables an interlock, a note will be made in the target logbook. In addition, signals showing whether each interlock is enabled or disabled, okay or tripped, are send to the target monitor program, displayed on the main screen of the target computer, and sent over ethernet to the BridgeVIEW control system for the CTI 4000.

5 Standard operating procedures for the target gas handling system

The following sections contain the detailed instructions for all of the procedures involving the E158 target gas handling system, including the initial and final state checklists to be filled out, signed and dated by the target operators performing the procedure. A copy of the completed checklists will be put into the target logbook.

Figure 1 shows the target gas handling system referred to in the operating procedures.

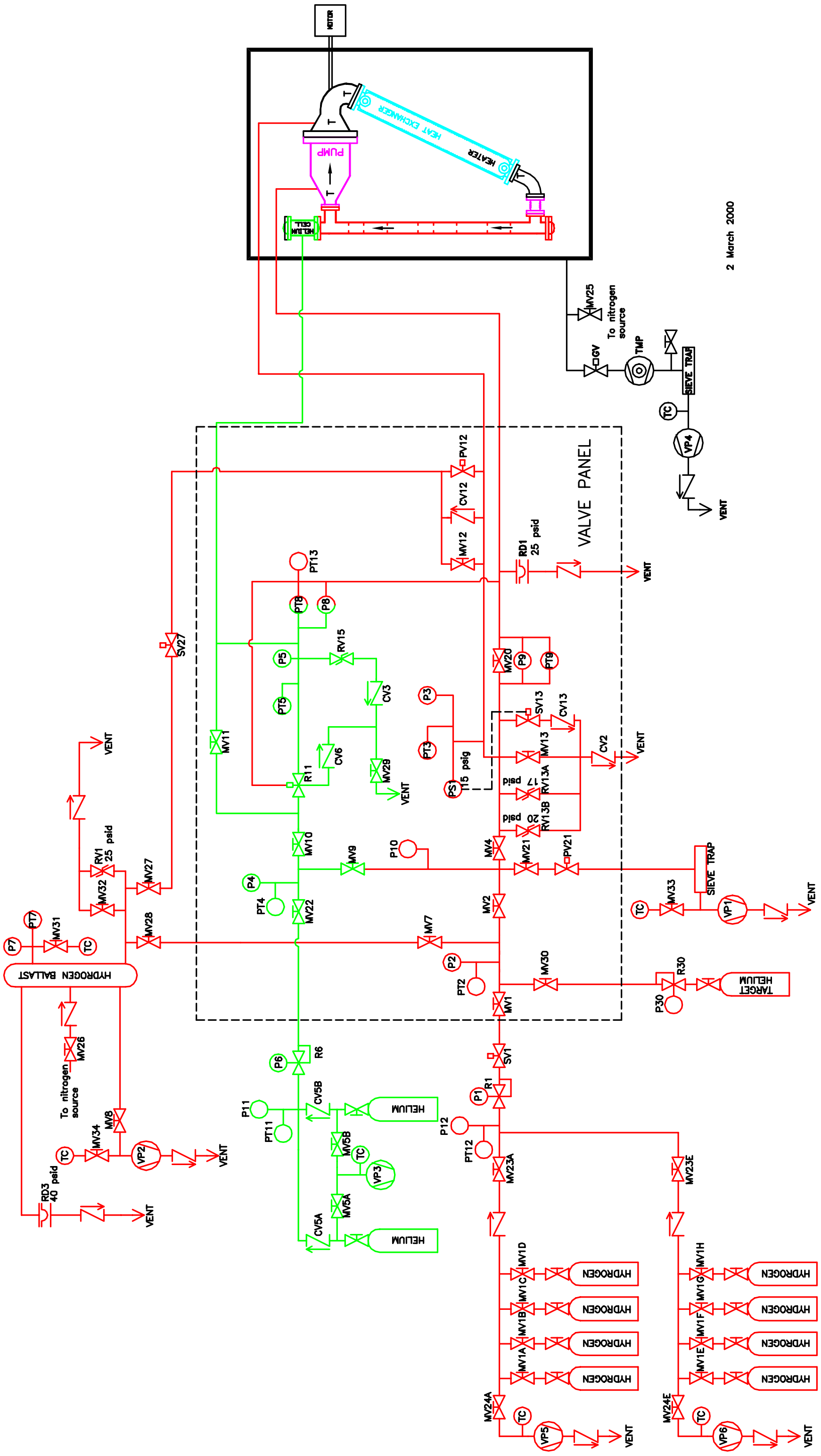

Figure 1: E158 liquid hydrogen target gas handling system.

A. Evacuation and flushing of ballast tank

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... closed
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... closed
- ☐ MV23E .... closed
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... closed
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... not in use
- ☐ P3 .... not in use
- ☐ P4 .... not in use
- ☐ P5 .... not in use
- ☐ P7 .... not in use
- ☐ P8 .... not in use
- ☐ P9 .... not in use
- ☐ P10 .... not in use
- ☐ P11 .... not in use
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... not in use
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... not in use
- ☐ TC for VP4 .... not in use
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... not in use
- ☐ IG1 .... not in use
- ☐ Target loop pump .... not in use
- ☐ GV1 .... closed

A. Evacuation and flushing of ballast tank

1. Make sure all valves on the valve panel, vacuum chamber, gas bottles and ballast tank are closed initially.

2. Turn on mechanical pump VP2.

3. Open valves MV1, MV30, MV7, MV31, MV34 and MV28.

4. Make sure the target helium and hydrogen bottles are closed, then open MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G, MV1H, MV23A and MV23E.

5. Open target helium regulator R30 and hydrogen regulator R1 by turning their handles fully clockwise.

   <u>First evacuation of ballast tank:</u>

6. Open valve MV8 and pump out the ballast tank and connecting lines to 100 mtorr as read on VP2's thermocouple gauge. The pressure on gauge P7 will drop from 0 psig to 30 in. Hg.

7. Sequentially close and reopen valves MV1, MV30, MV7, MV8 and MV28 to pump out a small dead space in each valve.

8. Close valves MV8 and MV30.

9. Close target helium regulator R30 by turning its handle fully counterclockwise.

10. Open the target helium bottle valve and adjust its regulator R30 to 0 psig.

    <u>Helium backfill of ballast tank:</u>

11. Open valve MV30 to fill the evacuated ballast tank to ~25 in. Hg helium as read on gauge P7.

12. Close valve MV30 and the target helium bottle valve.

13. Close target helium regulator R30 by turning its handle fully counterclockwise.

    <u>Second evacuation of ballast tank</u>:

14. Open valve MV8 and pump out the ballast tank and connecting lines to 100 mtorr as read on VP2's thermocouple gauge. The pressure on gauge P7 will drop from 25 in. Hg to 30 in. Hg.

15. Sequentially close and reopen valves MV1, MV7, MV8 and MV28 to pump out a small dead space in each valve.

16. Close valves MV1, MV31, MV34 and MV8.

17. Close hydrogen regulator R1 by turning its handle fully counterclockwise.

18. Open the hydrogen bottle valve connected to valve MV1A and adjust its regulator R1 to 0 psig.

19. Post "Hydrogen in End Station A" sign and turn on warning light.

First hydrogen backfill of ballast tank:

20. Open valve MV1 to fill the evacuated ballast tank to ~25 in. Hg hydrogen as read on gauge P7.

21. Close valve MV1.

Third evacuation of ballast tank:

22. Open valve MV8 and pump out the ballast tank and connecting lines to 30 in. Hg as read on gauge P7. Valves MV31 and MV34 may then be opened. Pump to a pressure of 100 mtorr as read on VP2's thermocouple gauge.

23. Sequentially close and reopen valves MV7, MV8 and MV28 to pump out a small dead space in each valve.

24. Close valves MV8, MV31 and MV34.

Second hydrogen backfill of ballast tank:

25. Open valve MV1 to fill the evacuated ballast tank to 25 in. Hg hydrogen as read on gauge P7.

26. Close the hydrogen bottle valve.

27. Open hydrogen regulator R1 by turning its handle fully clockwise.

Fourth evacuation of ballast tank:

28. Open valve MV8 and pump out the ballast tank and connecting lines to 30 in. Hg as read on gauge P7. Valves MV31 and MV34 may then be opened. Pump to a pressure of 100 mtorr as read on VP2's thermocouple gauge. Continue pumping until you are ready to fill the ballast tank with its charge of hydrogen. At that time perform the following steps:

29. Close valve MV8 and lock its handle.

30. Close valves MV31 and MV34.

31. Turn off mechanical pump VP2. Make sure the pump is vented.

32. Close valves MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.

33. Confirm that all final conditions for procedure A are met.

A. Evacuation and flushing of ballast tank

Final state:

- ☐ MV1 .... open
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... open
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... closed
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... open
- ☐ MV29 .... closed
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 30 in. Hg
- ☐ P3 .... not in use
- ☐ P4 .... not in use
- ☐ P5 .... not in use
- ☐ P7 .... 30 in. Hg
- ☐ P8 .... not in use
- ☐ P9 .... not in use
- ☐ P10 .... not in use
- ☐ P11 .... not in use
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... open
- ☐ P1 .... 30 in. Hg
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... not in use
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... not in use
- ☐ TC for VP4 .... not in use
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... not in use
- ☐ IG1 .... not in use
- ☐ Target loop pump .... not in use
- ☐ GV1 .... closed

B. Filling the ballast tank with hydrogen

Initial state:

☐	MV1	open
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	closed
☐	MV10	closed
☐	MV11	closed
☐	PV12	closed
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	open
☐	MV29	closed
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed
☐	P2	30 in. Hg
☐	P3	not in use
☐	P4	not in use
☐	P5	not in use
☐	P7	30 in. Hg
☐	P8	not in use
☐	P9	not in use
☐	P10	not in use
☐	P11	not in use
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	open
☐	P1	30 in. Hg
☐	Helium bottles	both closed
☐	R6	closed
☐	P6	not in use
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	not in use
☐	TC for VP4	not in use
☐	VP5	not in use
☐	TC for VP5	not in use
☐	VP6	not in use
☐	TC for VP6	not in use
☐	Turbopump	not in use
☐	IG1	not in use
☐	Target loop pump	not in use
☐	GV1	closed

B. Filling the ballast tank with hydrogen

1. Evacuate and flush the ballast tank as described in section A. Confirm that all initial conditions for procedure B are met. They are the same as the final conditions for procedure A.
2. Close valve MV1.
3. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
4. Open the hydrogen bottle valve connected to valve MV1A and adjust its regulator R1 to 10 psig.
5. Open and close valves MV1B, MV1C, MV1D, MV1E, MV1F, MV1G, and MV1H to introduce hydrogen to the space above each bottle.

   <u>Filling ballast tank with its full charge of hydrogen</u>:

6. Open valve MV1 to fill the evacuated ballast tank to 10 psig hydrogen as read on gauge P2A. Increase the output pressure on hydrogen regulator R1 if necessary to attain this pressure. Switch to another hydrogen bottle if the one in use gets below 100 psig.
7. Close the hydrogen bottle valve.
8. Close valves MV7, MV1A (and any other hydrogen manifold valves that may be open), MV28 and MV1.
9. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
10. Confirm that all final conditions for procedure B are met.

B. Filling the ballast tank with hydrogen

Final state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... closed
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... closed
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... not in use
- ☐ P3 .... not in use
- ☐ P4 .... not in use
- ☐ P5 .... not in use
- ☐ P7 .... 10 psig
- ☐ P8 .... not in use
- ☐ P9 .... not in use
- ☐ P10 .... not in use
- ☐ P11 .... not in use
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... not in use
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... not in use
- ☐ TC for VP4 .... not in use
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... not in use
- ☐ IG1 .... not in use
- ☐ Target loop pump .... not in use
- ☐ GV1 .... closed

C. Replacing depleted hydrogen bottles

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... closed
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... closed
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... not in use
- ☐ P3 .... not in use
- ☐ P4 .... not in use
- ☐ P5 .... not in use
- ☐ P7 .... 10 psig
- ☐ P8 .... not in use
- ☐ P9 .... not in use
- ☐ P10 .... not in use
- ☐ P11 .... not in use
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... not in use
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... not in use
- ☐ TC for VP4 .... not in use
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... not in use
- ☐ IG1 .... not in use
- ☐ Target loop pump .... not in use
- ☐ GV1 .... closed

C. Replacing depleted hydrogen bottles

1. Fill the hydrogen ballast tank as described in section B. Confirm that all initial conditions for procedure C are met. They are the same as the final conditions for procedure B.

2. Remove all hydrogen bottles that were depleted in filling the ballast tank (procedure B). Replace them with full bottles.

3. Vent the hydrogen manifold to air by opening MV24A or MV24E, then closing it.

4. Install and turn on mechanical pump VP5 or VP6. Wait until its thermocouple gauge reads less than 50 mtorr.

5. Gradually open valve MV24A or MV24E and pump until the thermocouple gauge reads less than 50 mtorr.

6. Open the manifold valves (MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and/or MV1H) for all bottles that have been replaced. Wait until the thermocouple gauge reads less than 50 mtorr.

7. Close valve MV24A or MV24E.

8. Momentarily open one of the new bottles to pressurize the manifold, and then close it.

9. Close all manifold valves that are open.

10. Turn off pump VP5 and remove it.

11. Cap off valves MV24A and MV24E.

12. The conditions are now the same as at the beginning of this procedure except that all the hydrogen bottles are now full.

13. Confirm that all final conditions for procedure C are met.

C. Replacing depleted hydrogen bottles

Final state:

- ☐ MV1 . . . . closed
- ☐ SV1 . . . . open
- ☐ MV1A . . . . closed
- ☐ MV1B . . . . closed
- ☐ MV1C . . . . closed
- ☐ MV1D . . . . closed
- ☐ MV1E . . . . closed
- ☐ MV1F . . . . closed
- ☐ MV1G . . . . closed
- ☐ MV1H . . . . closed
- ☐ MV2 . . . . closed
- ☐ MV4 . . . . closed
- ☐ MV5A . . . . closed
- ☐ MV5B . . . . closed
- ☐ MV7 . . . . closed
- ☐ MV8 . . . . closed
- ☐ MV9 . . . . closed
- ☐ MV10 . . . . closed
- ☐ MV11 . . . . closed
- ☐ PV12 . . . . closed
- ☐ MV12 . . . . closed
- ☐ SV13 . . . . closed
- ☐ MV13 . . . . closed
- ☐ MV20 . . . . closed
- ☐ MV21 . . . . closed
- ☐ PV21 . . . . closed
- ☐ MV22 . . . . closed
- ☐ MV23A . . . . open
- ☐ MV23E . . . . open
- ☐ MV24A . . . . closed
- ☐ MV24E . . . . closed
- ☐ MV25 . . . . closed
- ☐ MV26 . . . . closed
- ☐ MV27 . . . . closed
- ☐ SV27 . . . . open
- ☐ MV28 . . . . closed
- ☐ MV29 . . . . closed
- ☐ MV30 . . . . closed
- ☐ MV31 . . . . closed
- ☐ MV32 . . . . closed
- ☐ MV33 . . . . closed
- ☐ MV34 . . . . closed
- ☐ P2 . . . . not in use
- ☐ P3 . . . . not in use
- ☐ P4 . . . . not in use
- ☐ P5 . . . . not in use
- ☐ P7 . . . . 10 psig
- ☐ P8 . . . . not in use
- ☐ P9 . . . . not in use
- ☐ P10 . . . . not in use
- ☐ P11 . . . . not in use
- ☐ P12 . . . . not in use
- ☐ Hydrogen bottles . . . . all closed
- ☐ R1 . . . . closed
- ☐ P1 . . . . not in use
- ☐ Helium bottles . . . . both closed
- ☐ R6 . . . . closed
- ☐ P6 . . . . not in use
- ☐ Target helium bottle . . . . . closed
- ☐ R30 . . . . closed
- ☐ P30 . . . . not in use
- ☐ VP1 . . . . not in use
- ☐ TC for VP1 . . . . not in use
- ☐ VP2 . . . . not in use
- ☐ TC for VP2 . . . . not in use
- ☐ VP4 . . . . not in use
- ☐ TC for VP4 . . . . not in use
- ☐ VP5 . . . . not in use
- ☐ TC for VP5 . . . . not in use
- ☐ VP6 . . . . not in use
- ☐ TC for VP6 . . . . not in use
- ☐ Turbopump . . . . not in use
- ☐ IG1 . . . . not in use
- ☐ Target loop pump . . . . not in use
- ☐ GV1 . . . . closed

D. Evacuation of vacuum chamber

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... closed
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... closed
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... not in use
- ☐ P3 .... not in use
- ☐ P4 .... not in use
- ☐ P5 .... not in use
- ☐ P7 .... 10 psig
- ☐ P8 .... not in use
- ☐ P9 .... not in use
- ☐ P10 .... not in use
- ☐ P11 .... not in use
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... not in use
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... not in use
- ☐ TC for VP4 .... not in use
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... not in use
- ☐ IG1 .... not in use
- ☐ Target loop pump .... not in use
- ☐ GV1 .... closed

D. Evacuation of vacuum chamber

1. Confirm that all initial conditions for procedure D are met. They are the same as the final conditions for procedure C.
2. Turn on the forepump/isolation valve controller and bypass its interlock.
3. Open isolation valve GV1.
4. Turn on forepump VP4 to evacuate the chamber.
5. Continue pumping on the vacuum chamber until the pressure has reached 300 mtorr as read on VP4's thermocouple gauge.
6. Turn on the turbopump.
7. Turn off the interlock bypass when the chamber pressure is down to 10^{-4} torr as read on IG1.
8. Continue pumping on the chamber during all procedures involving the target loop.
9. Confirm that all final conditions for procedure D are met.

D. Evacuation of vacuum chamber

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	closed
☐	MV11	closed
☐	PV12	closed
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	closed
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	not in use
☐	P3	not in use
☐	P4	not in use
☐	P5	not in use
☐	P7	10 psig
☐	P8	not in use
☐	P9	not in use
☐	P10	not in use
☐	P11	not in use
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	both closed
☐	R6	closed
☐	P6	not in use
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

E. Evacuation and flushing of the target and filling lines with hydrogen

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... closed
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... closed
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... not in use
- ☐ P3 .... not in use
- ☐ P4 .... not in use
- ☐ P5 .... not in use
- ☐ P7 .... 10 psig
- ☐ P8 .... not in use
- ☐ P9 .... not in use
- ☐ P10 .... not in use
- ☐ P11 .... not in use
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... not in use
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... off
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... off
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... off
- ☐ GV1 .... open

E. Evacuation and flushing of the target and filling lines with hydrogen

1. Confirm that all initial conditions for procedure E are met. They are the same as the final conditions for procedure D.
2. The vacuum chamber must be under vacuum before proceeding. The turbopump must be on with gate valve GV1 open. DO NOT pump on the target unless the chamber is at a pressure of 10^{-4} torr or less as read on ion gauge IG1.
3. Turn on mechanical pumps VP1, VP5 and VP6.
4. Open pneumatic valve PV21 at the master vacuum interlock box.
5. Open valves MV1, MV30, MV33, MV13, MV20 and MV29.
6. Make sure all hydrogen bottles are closed, then open valves MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.
7. Open valve MV21. Gauge P10 will drop from 0 psig to 30 in. Hg.
8. Gradually open valve MV2.
9. Gradually open target helium regulator R30 by turning its handle fully clockwise.
10. Open valves MV24A and MV24E.
11. Gradually open hydrogen regulator R1 by turning its handle fully clockwise. Wait until VP1's thermocouple gauge reaches 100 mtorr. The gauges for VP5 and VP6 should do the same.

    <u>First evacuation of target loop</u>:

12. Gradually open valve MV4 to evacuate the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess. Gauge P3 will go from 0 to 30 in. Hg.
13. Open valves MV7 and MV12
14. Open valves MV10 and MV11.

    <u>First evacuation of helium cell</u>:

15. When VP1's thermocouple gauge reads 500 mtorr or less, gradually open valve MV9 to evacuate the helium cell. Gauge P8 will return to 0 psid. Gauge P5 will drop from 0 psig to 30 in. Hg.
16. Open solenoid valve SV13 for several seconds to pump the space between it and check valve CV13. Push the button next to SV13 to do this.
17. Open valve MV22.
18. Make sure both helium bottles are closed, then gradually open helium regulator R6 by turning its handle fully clockwise.

19. Continue pumping on the target loop, helium cell and plumbing until VP1's thermocouple gauge reaches 100 mtorr.

20. Sequentially close and reopen valves MV1, MV30, MV2, MV7, MV21, MV4, MV13, MV20, MV12, MV22, MV9, MV10, MV11 and MV29 to pump out a small dead space in each valve.

21. Close valves MV2, MV4, MV9 and MV22.

22. Close helium regulator R6 by turning its handle fully counterclockwise.

23. Open both helium bottle valves and adjust their regulator R6 to 0 psig.

24. Close one of the helium bottles.

<u>First backfill of helium cell with helium</u>:

25. Gradually open valve MV22 to fill the helium cell. Gauge P5 will go from 30 in. Hg to 0 psig. Gauge P8 will go from 0 psid to full scale helium excess.

26. Close valve MV22.

<u>Second evacuation of helium cell</u>:

27. Gradually open valve MV9 to pump out the helium cell and plumbing. Gauge P8 will go from full scale helium excess to 0 psid.

28. Close valve MV9 when VP1's thermocouple gauge has reached 100 mtorr.

<u>Second backfill of helium cell with helium</u>:

29. Gradually open valve MV22 to fill the helium cell with helium. Gauge P8 will go from 0 to full scale helium excess.

30. Close valve MV22.

<u>Third evacuation of helium cell</u>:

31. Gradually open valve MV9 to pump out the helium cell and plumbing. Gauge P8 will go from full scale helium excess to 0 psid.

32. Close valve MV9 when VP1's thermocouple gauge has reached 100 mtorr.

<u>Third backfill of helium cell with helium</u>:

33. Gradually open valve MV22 to fill the helium cell with helium. Gauge P8 will go from 0 to full scale helium excess.

34. Close valve MV22.

35. Close valves MV21 and MV30.

36. Close target helium regulator R30 by turning its handle fully counterclockwise.

37. Open the target helium bottle and adjust its regulator R30 to 0 psig.

38. Open valves MV2 and MV4.

<u>Backfill of target loop with helium</u>:

39. Gradually open valve MV30 to fill the target loop with helium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

40. Close valve MV30 when gauge P8 reaches 0 psid.

41. Close the target helium bottle and its regulator R30.

42. Open solenoid valve SV13 momentarily to introduce helium into the space between it and check valve CV13. Push the button next to SV13 to do this.

43. Pause at this point if the target is not to be filled with hydrogen right away. To pause, close valve MV30 and the helium bottle. Do not change the setting of helium regulator R6. Open valve MV9 to guarantee the target and the helium cell will be at the same pressure. When you want to resume flushing with hydrogen, close valve MV9 and open valve MV30 and the helium bottle. Ignore this entire step is no pause is desired.

<u>Second evacuation of target loop</u>:

44. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess.

45. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.

46. Open solenoid valve SV13 for several seconds to pump the space between it and check valve CV13. Push the button next to SV13 to do this.

47. Close MV1 and MV21.

48. Close hydrogen regulator R1 by turning its handle fully counterclockwise.

49. Open the hydrogen bottle valve connected to valve MV1A and adjust its regulator R1 to 0 psig.

50. Close valves MV33, MV24A, MV24E, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.

51. Turn off mechanical pumps VP5 and VP6. Vent them.

<u>First backfill of target loop with hydrogen</u>:

52. Gradually open valve MV1 to fill the target loop with hydrogen. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

53. Close valve MV1 when gauge P8 reaches 0 psid.

54. Open solenoid valve SV13 momentarily to introduce hydrogen to the space between it and check valve CV13. Push the button next to SV13 to do this.

55. Post "Hydrogen in End Station A" sign and turn on warning light.

Third evacuation of target loop:

56. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess.

57. Open valve MV33.

58. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.

59. Open solenoid valve SV13 for several seconds to pump the space between it and check valve CV13. Push the button next to SV13 to do this.

60. Close valves MV21 and MV33.

Second backfill of target loop with hydrogen:

61. Gradually open valve MV1 to fill the target loop with hydrogen. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

62. Close valve MV1 when gauge P8 reaches 0 psid.

63. Open solenoid valve SV13 momentarily to introduce hydrogen to the space between it and check valve CV13. Push the button next to SV13 to do this.

Fourth evacuation of target loop:

64. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess.

65. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.

66. Confirm that all final conditions for procedure E are met.

67. Go to Section F to fill and cool the target.

E. Evacuation and flushing of the target and filling lines with hydrogen

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	open
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	open
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	open
☐	MV20	open
☐	MV21	open
☐	PV21	open
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	30 in. Hg
☐	P3	30 in. Hg
☐	P4	0 psig
☐	P5	0 psig
☐	P7	10 psig
☐	P8	15 psid He excess
☐	P9	0
☐	P10	30 in. Hg
☐	P11	0 psig
☐	P12	0 psig
☐	Hydrogen bottles	one open
☐	R1	0 psig
☐	P1	0 psig
☐	Helium bottles	one open
☐	R6	0 psig
☐	P6	0 psig
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	closed
☐	VP1	on
☐	TC for VP1	$<$100 mtorr
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	$<$300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

F. Filling and cooling the target with hydrogen

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	open
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	open
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	open
☐	MV20	open
☐	MV21	open
☐	PV21	open
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	30 in. Hg
☐	P3	30 in. Hg
☐	P4	0 psig
☐	P5	0 psig
☐	P7	10 psig
☐	P8	15 psid He excess
☐	P9	0
☐	P10	30 in. Hg
☐	P11	0 psig
☐	P12	0 psig
☐	Hydrogen bottles	one open
☐	R1	0 psig
☐	P1	0 psig
☐	Helium bottles	one open
☐	R6	0 psig
☐	P6	0 psig
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	closed
☐	VP1	on
☐	TC for VP1	<100 mtorr
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

F. Filling and cooling the target with hydrogen

1. Evacuate and flush the target and filling lines as described in section E.
2. Confirm that all initial conditions for section F are met. They are the same as the final conditions for section E.
3. Close valve MV21.
4. Close pneumatic valve PV21 at the master vacuum interlock box.
5. Turn off mechanical pump VP1 and vent it.
6. Remove pump VP1 and cap off the inlet to pneumatic valve PV21.

   <u>Fill target loop to one absolute atmosphere hydrogen</u>:

7. Gradually open valve MV1 to reduce gauge P8 from 15 psid to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
8. Close valves MV1 and MV13.
9. Increase the helium regulator R6 to 10 psig.
10. Close valve MV29.

    <u>Fill helium cell to two absolute atmospheres helium</u>:

11. Gradually open valve MV22 until gauge P5 increases from 0 to 10 psig. Gauge P8 will increase to 10 psid helium excess. Do not close MV22.
12. Increase the hydrogen regulator R1 to 10 psig.

    <u>Fill target loop to two absolute atmospheres hydrogen</u>:

13. Gradually open valve MV1 until gauge P8 is reduced from full scale to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
14. Close valve MV11.
15. Increase the helium regulator R6 to 30 psig.
16. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK.
17. Open valve MV1. Increase the output pressure on hydrogen regulator R1 if necessary to get gauge P2 up to 10 psig. Do not close valve MV1.
18. Close valve MV20.
19. Gradually open valve MV27. This will equalize the hydrogen pressures in the target loop and the ballast tank.
20. Open valve MV28.

21. Close valves MV2 and MV4.

<u>Cooling the target loop</u>:

22. Turn on the target loop pump. As the hydrogen cools, gauge P9 will rise very slowly.
23. Ask the cryo group to provide coolant to the target. As the loop cools, hydrogen will be drawn from the bottle to maintain 10 psig in the loop. When a hydrogen bottle has less than 100 psig, close its valve and its manifold valve and switch to another bottle. Put an "empty" bottle tag on the depleted bottle.

<u>Signs that the target is full:</u>

a) Consumption of hydrogen levels off. This is monitored on the computer as the hydrogen bottle pressure (P12) vs. time.

b) The loop pressure (PT3) will rise to, or above, the hydrogen regulator pressure (P1) before filling began.

24. Close valve MV7 when the loop is full of liquid hydrogen.
25. Open pneumatic valve PV12 at the master vacuum interlock box.
26. Close valve MV12.
27. Close valve MV1 and the hydrogen bottle valve.
28. Close all valves on the hydrogen manifold.
29. Open gate valve XXX before putting beam on the target.
30. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.
31. Confirm that all final conditions for procedure F are met.

F. Filling and cooling the target with hydrogen

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	closed
☐	PV12	open
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	open
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	open
☐	SV27	open
☐	MV28	open
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	10 psig
☐	P3	10 psig
☐	P4	30 psig
☐	P5	10 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	>0 psid
☐	P10	not in use
☐	P11	2000 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	10 psig
☐	P1	10 psig
☐	Helium bottles	one open
☐	R6	30 psig
☐	P6	30 psig
☐	Target helium bottle	not in use
☐	R30	not in use
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	not in use
☐	TC for VP5	not in use
☐	VP6	not in use
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	on
☐	GV1	open

G. Replacing the helium bottle

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... open
- ☐ MV11 .... closed
- ☐ PV12 .... open
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... open
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... open
- ☐ SV27 .... open
- ☐ MV28 .... open
- ☐ MV29 .... open
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 10 psig
- ☐ P3 .... 10 psig
- ☐ P4 .... 30 psig
- ☐ P5 .... 10 psig
- ☐ P7 .... 10 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... >0 psid
- ☐ P10 .... not in use
- ☐ P11 .... 2000 psig
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... 10 psig
- ☐ P1 .... 10 psig
- ☐ Helium bottles .... one open
- ☐ R6 .... 30 psig
- ☐ P6 .... 30 psig
- ☐ Target helium bottle .... not in use
- ☐ R30 .... not in use
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... on
- ☐ GV1 .... open

G. Replacing the helium bottle

1. The helium bottle being used to fill the helium cell is constantly being bled by pneumatic relay R11. It must be replaced when its pressure falls below 200 psig.
2. The target loop is at operating temperature and contains liquid hydrogen as described in section F.
3. Confirm that all initial conditions for section G are met. They are the same as the final conditions for section F.
4. Open the full helium bottle that is in reserve on the manifold. Make sure the regulator pressure of R6 remains at 30 psig.
5. Close the expended helium bottle valve.
6. Replace the expended helium bottle with a full one.
7. Turn on mechanical pump VP3. Wait until its thermocouple gauge reads less than 50 mtorr.
8. Open the pump valve (either MV5A or MV5B) to the new bottle that was just placed on the manifold. Pump until the thermocouple gauge reads less than 50 mtorr, then close the pump valve.
9. Momentarily open the new bottle to pressurize the small volume up to its check valve.
10. Close the new bottle.
11. Turn off pump VP3 and vent it.
12. The conditions are now the same as at the beginning of this procedure except that a full helium bottle is being used rather than a depleted one.
13. Confirm that all final conditions for procedure G are met.

G. Replacing the helium bottle

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	closed
☐	PV12	open
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	open
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	open
☐	SV27	open
☐	MV28	open
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	10 psig
☐	P3	10 psig
☐	P4	30 psig
☐	P5	10 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	>0 psid
☐	P10	not in use
☐	P11	2000 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	10 psig
☐	P1	10 psig
☐	Helium bottles	one open
☐	R6	30 psig
☐	P6	30 psig
☐	Target helium bottle	not in use
☐	R30	not in use
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	not in use
☐	TC for VP5	not in use
☐	VP6	not in use
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	on
☐	GV1	open

H. Warming the hydrogen-filled target to room temperature

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... open
- ☐ MV11 .... closed
- ☐ PV12 .... open
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... open
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... open
- ☐ SV27 .... open
- ☐ MV28 .... open
- ☐ MV29 .... open
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 10 psig
- ☐ P3 .... 10 psig
- ☐ P4 .... 30 psig
- ☐ P5 .... 10 psig
- ☐ P7 .... 10 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... >0 psid
- ☐ P10 .... not in use
- ☐ P11 .... 2000 psig
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... 10 psig
- ☐ P1 .... 10 psig
- ☐ Helium bottles .... one open
- ☐ R6 .... 30 psig
- ☐ P6 .... 30 psig
- ☐ Target helium bottle .... not in use
- ☐ R30 .... not in use
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... on
- ☐ GV1 .... open

H. Warming the hydrogen-filled target to room temperature

1. The target is filled with circulating liquid hydrogen as described in section F.

2. Turn off the beam and set the interlock so beam may not be put on the target.

3. Take the target heater out of automatic control and slowly turn the heater down to 0 in steps of 100 W.

4. Turn off the target heater voltage.

   At this point it will be necessary to enter End Station A. Install the target computer there.

5. Confirm that all initial conditions for procedure H are met. They are the same as the final conditions for section F or G.

6. Close gate valve XXX from the master vacuum interlock box.

   <u>NOTE</u>: The target circulating pump should be ON (> 20 Hz) during the boiloff process. If the pump has shut off for some reason, DO NOT turn the pump back on until the liquid has completely boiled away. If the pump is turned on in the middle of the boiloff process it may cause a sudden pressure surge and damage the helium cell.

7. Ask the cryo group to reduce coolant to the target. The target should immediately begin to warm up.

8. Watch the pressure in the target either on the computer screen (in the counting bay) or at gauge P3 on the gas panel. As the target starts to boil, its pressure will increase. When the target pressure reaches 15 psig, pressure switch PSI will cause solenoid valve SV13 to open and the target should begin to vent. The target pressure should stabilize once SV13 is open. **If the target pressure continues to rise**, have the cryo group send more coolant to the target. When the target has completed boiling, the pressure will quickly drop. SV13 will close when the target pressure drops to 12 psig.

9. Close pneumatic valve PV12 after the target has stopped boiling and SV13 is closed.

10. Once all liquid has boiled away, the target will slowly warm up to room temperature. This process may be accelerated by turning on the target heater to 50–100 watts.

11. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section III.G to change the helium bottle).

    <u>NOTE</u>: When the target temperature is approximately 30 K, the vacuum chamber pressure will rise by about a factor of 10–50 from its cold value. If the ion gauge IG1 gets high on the 10^{-4} range the turbopump interlock should be bypassed to keep it from tripping off and the gate valve GV1 from closing. As the target continues to warm the vacuum should return to the warm value.

12. When the target reaches 100 K, set the target heater to 0 W and turn off the power supply.

13. Turn off the target loop pump.

14. Slightly crack open valve MV13. Gauge P3 will drop from 15 psig to 0 psig.
15. Proceed to section I to purge hydrogen from the target loop.
16. Confirm that all final conditions for procedure H are met.

H. Warming the hydrogen-filled target to room temperature

Final state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... open
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... open
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... open
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... open
- ☐ SV27 .... open
- ☐ MV28 .... open
- ☐ MV29 .... open
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... not in use
- ☐ P3 .... 0 psig
- ☐ P4 .... 30 psig
- ☐ P5 .... 0 psig
- ☐ P7 .... 10 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... 0 psid
- ☐ P10 .... not in use
- ☐ P11 .... >200 psig
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... 10 psig
- ☐ P1 .... not in use
- ☐ Helium bottles .... one open
- ☐ R6 .... 30 psig
- ☐ P6 .... 30 psig
- ☐ Target helium bottle .... closed
- ☐ R30 .... not in use
- ☐ P30 .... not in use
- ☐ VP1 .... off and removed
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... off and removed
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... off and removed
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... off and removed
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... off
- ☐ GV1 .... open

I. Purging hydrogen from the target loop.

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	closed
☐	PV12	closed
☐	MV12	closed
☐	SV13	closed
☐	MV13	open
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	open
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	open
☐	SV27	open
☐	MV28	open
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	not in use
☐	P3	0 psig
☐	P4	30 psig
☐	P5	0 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	0 psid
☐	P10	not in use
☐	P11	$>$200 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	10 psig
☐	P1	not in use
☐	Helium bottles	one open
☐	R6	30 psig
☐	P6	30 psig
☐	Target helium bottle	closed
☐	R30	not in use
☐	P30	not in use
☐	VP1	off and removed
☐	TC for VP1	not in use
☐	VP2	off and removed
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	$<$300 mtorr
☐	VP5	off and removed
☐	TC for VP5	not in use
☐	VP6	off and removed
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

I. Purging hydrogen from the target loop

1. The hydrogen must be removed from the target loop before working on the loop or putting it aside for a substantial length of time.
2. Make sure that the target loop has been warmed to room temperature as described in section H.
3. Confirm that all initial conditions for procedure I are met. They are the same as the final conditions for procedure H.
4. Re-install pump VP1 and turn it on.
5. Open valve PV21 at the master vacuum interlock box.
6. Close valves MV27 and MV28.
7. Make sure all hydrogen bottles are closed, then open valves MV21, MV1, MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G, MV1H, MV7, MV20 and MV12.
8. Gradually open valve MV2.
9. Wait until the pressure at gauge P1 has dropped to 0 psig, then open hydrogen regulator R1 by turning its handle fully clockwise.

   <u>First evacuation of target loop</u>:

10. Gradually open valve MV4 to evacuate the target loop. Gauge P3 will go from 0 psig to 30 in. Hg. Gauge P8 will go from 0 psid to full scale helium excess.
11. Open solenoid valve SV13 for several seconds to pump the space between it and check valve CV13. Push the button next to SV13 to do this.
12. Open valve MV33.
13. Pump until VP1's thermocouple gauge reaches 100 mtorr.
14. Make sure the target helium bottle is closed, then open valve MV30.
15. Open target helium regulator R30 by turning its handle fully clockwise. Gauge P30 will drop to 30 in. Hg.
16. Close valve MV30.
17. Close target helium regulator R30 by turning its handle fully counterclockwise.
18. Open the target helium bottle and adjust its regulator R30 to 0 psig.
19. Close valve MV21.

    <u>First backfill of target loop with helium</u>:

20. Gradually open valve MV30 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

21. Close valve MV30.

    Second evacuation of target loop:

22. Gradually open valve MV21 to evacuate the target loop. Gauge P3 will go from 0 psig to 30 in. Hg. Gauge P8 will go from 0 psid to full scale helium excess.
23. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
24. Close valve MV21.

    Second backfill of target loop with helium:

25. Gradually open valve MV30 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
26. Close valve MV30.
27. Close valve MV22.
28. Open valve MV9.
29. Open valve MV11.
30. Close valves MV13 and MV33.
31. Close pneumatic valve PV21 at the master vacuum interlock box.
32. Close valves MV1, MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.
33. Turn off mechanical pump VP1 and vent it.
34. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
35. Close the helium bottle valve.
36. Close helium regulator R6 by turning its handle fully counterclockwise.
37. Close the target helium bottle.
38. Close the target helium bottle regulator R30 by turning its handle fully counterclockwise.
39. Confirm that all final conditions for procedure I are met.
40. Go to procedure K if you want to vent the vacuum chamber.

I. Purging hydrogen from the target loop.

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	open
☐	MV10	open
☐	MV11	open
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	closed
☐	MV20	open
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	0 psig
☐	P3	0 psig
☐	P4	0 psig
☐	P5	0 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	0 psid
☐	P10	0 psig
☐	P11	0 psig
☐	P12	0 psig
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	both closed
☐	R6	closed
☐	P6	not in use
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	not in use
☐	VP1	off
☐	TC for VP1	not in use
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

J. Purging hydrogen from the ballast tank

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	open
☐	MV10	open
☐	MV11	open
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	closed
☐	MV20	open
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	0 psig
☐	P3	0 psig
☐	P4	0 psig
☐	P5	0 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	0 psid
☐	P10	0 psig
☐	P11	0 psig
☐	P12	0 psig
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	both closed
☐	R6	closed
☐	P6	not in use
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	not in use
☐	VP1	off
☐	TC for VP1	not in use
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

J. Purging hydrogen from the ballast tank

1. Confirm that all initial conditions for procedure J have been met. They are the same as the final conditions for procedure I.
2. Notify the chief operator that the hydrogen sniffer in the vent line will be detecting hydrogen.
3. Open valve MV32 and bleed the ballast tank down to 0 psig hydrogen as read on gauge P7.
4. Close valve MV32.
5. Install mechanical pump VP2 and turn it on.
6. Open valve MV8 and pump out the ballast tank The pressure on gauge P7 will drop from 0 psig to 30 in. Hg.
7. Open valves MV31 and MV34. Continue to pump until VP2's thermocouple gauge reads 100 mtorr.
8. Close valves MV8, MV31 and MV34.
9. Open valve MV26 and fill the ballast tank with nitrogen. Gauge P7 will go from 30 in. Hg to 0 psig.
10. Close valve MV26.
11. Turn off pump VP2 and remove it.
12. Confirm that all final conditions for procedure J are met.

J. Purging hydrogen from the ballast tank

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	open
☐	MV10	open
☐	MV11	open
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	closed
☐	MV20	open
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	0 psig
☐	P3	0 psig
☐	P4	0 psig
☐	P5	0 psig
☐	P7	0 psig
☐	P8	0 psid
☐	P9	0 psid
☐	P10	0 psig
☐	P11	0 psig
☐	P12	0 psig
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	both closed
☐	R6	closed
☐	P6	not in use
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	not in use
☐	VP1	off
☐	TC for VP1	not in use
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

K. Venting the vacuum chamber

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	open
☐	MV10	open
☐	MV11	open
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	closed
☐	MV20	open
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	0 psig
☐	P3	0 psig
☐	P4	0 psig
☐	P5	0 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	0 psid
☐	P10	0 psig
☐	P11	0 psig
☐	P12	0 psig
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	both closed
☐	R6	closed
☐	P6	not in use
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	not in use
☐	VP1	off
☐	TC for VP1	not in use
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

K. Venting the vacuum chamber

1. Backfill the target loop with helium as described in procedure I. Confirm that all initial conditions for procedure K are met. They are the same as the final conditions for procedure I.

2. Close gate valve XXX from the master vacuum interlock box.

3. Close gate valve GV1.

4. Bypass the interlock on the isolation valve controller.

5. Turn off the turbopump and mechanical pump VP4. Wait 30 minutes for the turbopump to spin down.

6. Vent the chamber with nitrogen by cracking open valve MV25 to a regulated nitrogen source. The chamber pressure may be monitored with the convection gauge.

7. Close valve MV25 after the chamber is filled with nitrogen.

8. Confirm that all final conditions for procedure K are met.

K. Venting the vacuum chamber

Final state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... open
- ☐ MV4 .... open
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... open
- ☐ MV8 .... closed
- ☐ MV9 .... open
- ☐ MV10 .... open
- ☐ MV11 .... open
- ☐ PV12 .... closed
- ☐ MV12 .... open
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... open
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... open
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed
- ☐ P2 .... 0 psig
- ☐ P3 .... 0 psig
- ☐ P4 .... 0 psig
- ☐ P5 .... 0 psig
- ☐ P7 .... 10 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... 0 psid
- ☐ P10 .... 0 psig
- ☐ P11 .... 0 psig
- ☐ P12 .... 0 psig
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... not in use
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... off
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... off
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... off
- ☐ TC for VP4 .... not in use
- ☐ VP5 .... off
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... off
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... off
- ☐ IG1 .... off
- ☐ Target loop pump .... off
- ☐ GV1 .... closed

L. Replenishing the target loop with hydrogen

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	closed
☐	PV12	open
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	open
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	open
☐	SV27	open
☐	MV28	open
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	10 psig
☐	P3	10 psig
☐	P4	30 psig
☐	P5	10 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	>0 psid
☐	P10	not in use
☐	P11	2000 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	10 psig
☐	P1	10 psig
☐	Helium bottles	one open
☐	R6	30 psig
☐	P6	30 psig
☐	Target helium bottle	not in use
☐	R30	not in use
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	not in use
☐	TC for VP5	not in use
☐	VP6	not in use
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	on
☐	GV1	open

L. Replenishing the target loop with hydrogen

1. If the target has warmed significantly due to refrigerator failure, it may be necessary to replace hydrogen that has vented.
2. The target has been running as in section F.
3. Turn on the refrigerator to resume cooling the target.
4. Confirm that all initial conditions for section L are met. They are the same as the final conditions for section F.
5. Open one hydrogen bottle and its manifold valve. Hydrogen regulator R1 should still be set at 10 psig.
6. Open valve MV1. Gauge P2 should read 10 psig.
7. Open valve MV7 to admit hydrogen to the target.
8. Monitor the hydrogen and helium bottles to ensure they don't empty. Switch in bottles as necessary.
9. Close valve MV7 when the loop is full of liquid hydrogen.
10. Close valve MV1 and all hydrogen bottle and manifold valves.
11. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.
12. The conditions are now the same as at the beginning of this procedure.
13. Confirm that all final conditions for procedure L are met.

L. Replenishing the target loop with hydrogen

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	closed
☐	PV12	open
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	open
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	open
☐	SV27	open
☐	MV28	open
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	10 psig
☐	P3	10 psig
☐	P4	30 psig
☐	P5	10 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	>0 psid
☐	P10	not in use
☐	P11	2000 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	10 psig
☐	P1	10 psig
☐	Helium bottles	one open
☐	R6	30 psig
☐	P6	30 psig
☐	Target helium bottle	not in use
☐	R30	not in use
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	not in use
☐	TC for VP5	not in use
☐	VP6	not in use
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	on
☐	GV1	open

M. Evacuation and flushing of target and filling lines with helium

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	closed
☐	MV11	closed
☐	PV12	closed
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	closed
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	not in use
☐	P3	not in use
☐	P4	not in use
☐	P5	not in use
☐	P7	0 psig
☐	P8	not in use
☐	P9	not in use
☐	P10	not in use
☐	P11	not in use
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	both closed
☐	R6	closed
☐	P6	not in use
☐	Target helium bottle	closed
☐	R30	closed
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

M. Evacuation and flushing of target and filling lines with helium

1. Confirm that all initial conditions for procedure M are met. They are the same as the final conditions for procedure D except that the ballast tank is filled with 0 psig nitrogen as read on P7.

2. The vacuum chamber must be under vacuum before proceding. The turbopump must be on with gate valve GV1 open. DO NOT pump on the target unless the vacuum chamber is at a pressure of 10^{-4} torr or less as read on ion gauge IG1.

3. Turn on mechanical pump VP1.

4. Open pneumatic valve PV21 at the master vacuum interlock box.

5. Open valves MV30, MV33, MV20 and MV29.

6. Open valve MV21. Gauge P10 will drop from 0 psig to 30 in. Hg.

7. Gradually open valve MV2. Gauge P1 will drop from 0 psig to 30 in. Hg.

8. Gradually open target helium regulator R30 by turning its handle fully clockwise. Wait until VP1's thermocouple gauge reaches 100 mtorr.

   <u>First evacuation of target loop</u>:

9. Gradually open valve MV4 to evacuate the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess. Gauge P3 will go from 0 to 30 in. Hg.

10. Open valves MV7 and MV12.

11. Open valves MV10 and MV11.

    <u>First evacuation of helium cell</u>:

12. When VP1's thermocouple gauge reads 500 mtorr or less, gradually open valve MV9 to evacuate the helium cell. Gauge P8 will return to 0 psid. Gauge P5 will drop from 0 to 30 in. Hg.

13. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the button next to SV13 to do this.

14. Open valve MV22.

15. Make sure both helium bottles are closed, then gradually open helium regulator R6 by turning its handle fully clockwise.

16. Continue pumping on the target loop, helium cell and plumbing until VP1's thermocouple gauge reaches 100 mtorr.

17. Sequentially close and reopen valves MV30, MV2, MV7, MV21, MV4, MV13, MV20, MV12, MV22, MV9, MV10, MV11 and MV29 to pump out a small dead space in each valve.

18. Close valves MV2, MV4, MV9 and MV22.

19. Close helium regulator R6 by turning its handle fully counterclockwise.
20. Open both helium bottle valves and adjust their regulator R6 to 0 psig.
21. Close one of the helium bottles.

    First backfill of helium cell with helium:

22. Gradually open valve MV22 to fill the helium cell. Gauge P5 will go from 30 in. Hg to 0 psig. Gauge P8 will go from 0 psid to full scale helium excess.
23. Close valve MV22.

    Second evacuation of helium cell:

24. Gradually open valve MV9 to pump out the helium cell and plumbing. Gauge P8 will go from full scale helium excess to 0 psid.
25. Close valve MV9 when VP1's thermocouple gauge has reached 100 mtorr.

    Second backfill of helium cell with helium:

26. Gradually open valve MV22 to fill the helium cell with helium. Gauge P8 will go from 0 to full scale helium excess.
27. Close valve MV22.

    Third evacuation of helium cell:

28. Gradually open valve MV9 to pump out the helium cell and plumbing. Gauge P8 will go from full scale helium excess to 0 psid.
29. Close valve MV9 when VP1's thermocouple gauge has reached 100 mtorr.

    Third basefill of helium cell with helium:

30. Gradually open valve MV22 to fill the helium cell. Gauge P5 will go from 30 in. Hg to 0 psig. Gauge P8 will go from 0 psid to full scale helium excess.
31. Close valve MV22.
32. Close valves MV30 and MV21.
33. Close target helium regulator R30 by turning its handle fully counterclockwise.
34. Open the target helium bottle valve and adjust its regulator R30 to 0 psig.
35. Open valves MV2 and MV4.

    First backfill of target loop with helium:

36. Gradually open valve MV30 to fill the target loop with helium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
37. Close valve MV30 when gauge P8 reaches 0 psid.

    Second evacuation of target loop:

38. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess.

39. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
40. Close valve MV21.

Second backfill of target loop with helium:

41. Gradually open valve MV30 to fill the target loop with helium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
42. Close valve MV30 when gauge P8 reaches 0 psid.

Third evacuation of target loop:

43. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess.
44. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
45. Close valve MV21.
46. Close pneumatic valve PV21 at the master vacuum interlock box.
47. Turn off mechanical pump VP1 and vent it.
48. Remove mechanical pump VP1 and cap off the inlet to pneumatic valve PV21.

Fill target loop to one absolute atmosphere helium:

49. Gradually open valve MV30 to reduce gauge P8 from full scale helium excess to 0 psid. DO NOT let gauge P8 go to "hydrogen" excess.

50. Close valves MV30, MV33 and MV13.

51. Confirm that all final conditions for procedure M are met.

M. Evacuation and flushing of target and filling lines with helium

Final state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... open
- ☐ MV4 .... open
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... open
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... open
- ☐ MV11 .... open
- ☐ PV12 .... closed
- ☐ MV12 .... open
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... open
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... closed
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... open
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 0 psig
- ☐ P3 .... 0 psig
- ☐ P4 .... 0 psig
- ☐ P5 .... 0 psig
- ☐ P7 .... 0 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... 0 psid
- ☐ P10 .... 0 psig
- ☐ P11 .... >200 psig
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... one open
- ☐ R6 .... 0 psig
- ☐ P6 .... 0 psig
- ☐ Target helium bottle .... open
- ☐ R30 .... 0 psig
- ☐ P30 .... 0 psig
- ☐ VP1 .... off
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... off
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... off
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... off
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... off
- ☐ GV1 .... open

N. Filling and cooling the target with helium

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	open
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	closed
☐	MV20	open
☐	MV21	closed
☐	PV21	closed
☐	MV22	closed
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	0 psig
☐	P3	0 psig
☐	P4	0 psig
☐	P5	0 psig
☐	P7	0 psig
☐	P8	0 psid
☐	P9	0 psid
☐	P10	0 psig
☐	P11	>200 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	one open
☐	R6	0 psig
☐	P6	0 psig
☐	Target helium bottle	open
☐	R30	0 psig
☐	P30	0 psig
☐	VP1	off
☐	TC for VP1	not in use
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	off
☐	GV1	open

N. Filling and cooling the target with helium

1. Evacuate and flush the target and filling lines with helium as described in section M.
2. Confirm that all initial conditions for section N are met. They are the same as the final conditions for section M.
3. Increase the helium regulator R6 to 10 psig.
4. Close valve MV29.

   Fill helium cell to 1.7 absolute atmospheres helium:

5. Gradually open valve MV22 until gauge P5 increases from 0 to 10 psig. Gauge P8 will go from 0 to 10 psid helium excess. Do not close MV22.
6. Increase the target helium regulator R30 to 10 psig.

   Fill target loop to 1.7 absolute atmospheres helium:

7. Gradually open valve MV30 until gauge P8 is reduced from full scale to 0 psid helium excess, and then close valve MV30. DO NOT let gauge P8 go to "hydrogen" excess.
8. Close valve MV11.
9. Increase the helium regulator R6 to 30 psig.
10. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK.
11. Open valve MV30. Increase the output pressure on the target helium regulator R30 if necessary to get gauge P2 up to 10 psig. Do not close MV30.
12. Close valve MV20.

    Cooling the target loop:

13. Turn on the target loop pump.
14. Ask the cryo group to provide coolant to the target. As the loop cools, helium will be drawn from the target helium bottle to maintain 10 psig in the loop.
15. Open gate valve XXX before putting beam on the target.
16. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.
17. Confirm that all final conditions for procedure N are met.

N. Filling and cooling the target with helium

Final state:

- ☐ MV1 . . . . closed
- ☐ SV1 . . . . open
- ☐ MV1A . . . . closed
- ☐ MV1B . . . . closed
- ☐ MV1C . . . . closed
- ☐ MV1D . . . . closed
- ☐ MV1E . . . . closed
- ☐ MV1F . . . . closed
- ☐ MV1G . . . . closed
- ☐ MV1H . . . . closed
- ☐ MV2 . . . . open
- ☐ MV4 . . . . open
- ☐ MV5A . . . . closed
- ☐ MV5B . . . . closed
- ☐ MV7 . . . . open
- ☐ MV8 . . . . closed
- ☐ MV9 . . . . closed
- ☐ MV10 . . . . open
- ☐ MV11 . . . . closed
- ☐ PV12 . . . . closed
- ☐ MV12 . . . . open
- ☐ SV13 . . . . closed
- ☐ MV13 . . . . closed
- ☐ MV20 . . . . closed
- ☐ MV21 . . . . closed
- ☐ PV21 . . . . closed
- ☐ MV22 . . . . open
- ☐ MV23A . . . . open
- ☐ MV23E . . . . open
- ☐ MV24A . . . . closed
- ☐ MV24E . . . . closed
- ☐ MV25 . . . . closed
- ☐ MV26 . . . . closed
- ☐ MV27 . . . . closed
- ☐ SV27 . . . . open
- ☐ MV28 . . . . closed
- ☐ MV29 . . . . open
- ☐ MV30 . . . . open
- ☐ MV31 . . . . closed
- ☐ MV32 . . . . closed
- ☐ MV33 . . . . closed
- ☐ MV34 . . . . closed

- ☐ P2 . . . . 10 psig
- ☐ P3 . . . . 10 psig
- ☐ P4 . . . . 30 psig
- ☐ P5 . . . . 10 psig
- ☐ P7 . . . . 0 psig
- ☐ P8 . . . . 0 psid
- ☐ P9 . . . . 0 psid
- ☐ P10 . . . . 10 psig
- ☐ P11 . . . . >200 psig
- ☐ P12 . . . . not in use
- ☐ Hydrogen bottles . . . . all closed
- ☐ R1 . . . . closed
- ☐ P1 . . . . not in use
- ☐ Helium bottles . . . . one open
- ☐ R6 . . . . 30 psig
- ☐ P6 . . . . 30 psig
- ☐ Target helium bottle . . . . . open
- ☐ R30 . . . . 10 psig
- ☐ P30 . . . . 10 psig
- ☐ VP1 . . . . off
- ☐ TC for VP1 . . . . not in use
- ☐ VP2 . . . . off
- ☐ TC for VP2 . . . . not in use
- ☐ VP4 . . . . on
- ☐ TC for VP4 . . . . <300 mtorr
- ☐ VP5 . . . . off
- ☐ TC for VP5 . . . . not in use
- ☐ VP6 . . . . off
- ☐ TC for VP6 . . . . not in use
- ☐ Turbopump . . . . on
- ☐ IG1 . . . . $<10^{-4}$ torr
- ☐ Target loop pump . . . . on
- ☐ GV1 . . . . open

O. Replacing helium with hydrogen while the target is cold

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... open
- ☐ MV4 .... open
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... open
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... open
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... open
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... open
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... open
- ☐ MV30 .... open
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 10 psig
- ☐ P3 .... 10 psig
- ☐ P4 .... 30 psig
- ☐ P5 .... 15 psig
- ☐ P7 .... 10 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... 0 psid
- ☐ P10 .... 15 psig
- ☐ P11 .... >200 psig
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... one open
- ☐ R6 .... 30 psig
- ☐ P6 .... 30 psig
- ☐ Target helium bottle .... open
- ☐ R30 .... 15 psig
- ☐ P30 .... 15 psig
- ☐ VP1 .... off
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... off
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... off
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... off
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... on
- ☐ GV1 .... open

O. Replacing helium with hydrogen while the target is cold

1. The target is filled with circulating helium as described in section N.
2. Turn off the beam and set the interlock so beam may not be put on the target.
3. Take the target heater out of automatic control and slowly turn the heater down to 0 in steps of 100 W.
4. Turn off the target heater voltage.

   At this point it will be necessary to enter End Station A. Install the target computer there.
5. Confirm that all initial conditions for procedure O are met. They are the same as the final conditions for section N.
6. Close gate valve XXX from the master vacuum interlock box.
7. Ask the cryo group to raise the temperature of the coolant to 80 K. We may need to reduce the coolant flow as well. Helium will vent through SV13. Wait until the loop comes to 80 K.
8. Turn on mechanical pumps VP5 and VP6 while the target is warming. Make sure all hydrogen bottles are closed, then open valves MV24A, MV24E, MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.
9. Close valves MV30, MV2 and MV4.
10. Close the target helium bottle.
11. Close the target helium regulator R30 by turning its handle fully counterclockwise.
12. Slightly crack open valve MV13. Gauge P3 will drop from 10 psig to 0 psig. Gauge P5 will do the same.
13. Close valve MV13.
14. Turn off the target loop pump.
15. Turn on mechanical pump VP1.
16. Open pneumatic valve PV21 at the master vacuum interlock box.
17. Open valves MV20 and MV21.

   <u>First evacuation of target loop</u>
18. Gradually open valve MV4 to pump out the target loop and connecting lines. Gauge P8 will go from 0 to full scale helium excess. Gauge P3 will go from 0 to 30 in. Hg.
19. Close valve MV4.
20. Very gradually open valves MV2 and MV1, as there is a large volume of 10 psig hydrogen in the line going to the ballast tank.

21. Open valve MV4. Wait until VP1's thermocouple gauge reaches 100 mtorr.
22. Close helium regulator R6 by turning its handle fully counterclockwise.
23. Gradually open valve MV9. Gauge P6 will drop from 30 psig to 30 in. Hg.
24. Close valves MV22 and MV9.
25. Adjust helium regulator R6 to 0 psig.
26. Open valve MV22.
27. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the button next to SV13 to do this.
28. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
29. Close valves MV21 and MV1.
30. Open valves MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.
31. Open the hydrogen bottle connected to valve MV1A and adjust its regulator R1 to 0 psig.
32. Close valves MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.

    <u>First backfill of target loop with hydrogen</u>:

33. Gradually open valve MV1 to fill the target loop with hydrogen. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
34. Close valve MV1 when gauge P8 reaches 0 psid.
35. Open solenoid valve SV13 momentarily to introduce hydrogen to the space between it and check valve CV13. Push the button next to SV13 to do this.
36. Notify the chief operator that the hydrogen sniffer in the vent line will be detecting hydrogen.

    <u>Second evacuation of target loop</u>:

37. Gradually open valve MV21 to evacuate the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess. Gauge P3 will go from 0 to 30 in. Hg.
38. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
39. Close valve MV21.

    <u>Second backfill of target loop</u>:

40. Gradually open valve MV1 to fill the target loop with hydrogen. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
41. Close valve MV1 when gauge P8 reaches 0 psid.

    <u>Third evacuation of target loop</u>:

42. Gradually open valve MV21 to evacuate the target loop and plumbing. Gauge P8 will go from 0 to full scale helium excess. Gauge P3 will go from 0 to 30 in. Hg.

43. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.

44. Close valve MV21.

    <u>Third backfill of target loop</u>:

45. Gradually open valve MV1 to fill the target loop with hydrogen. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

46. Close valve MV1 when gauge P8 reaches 0 psid.

47. Close valves MV22 and MV29.

48. Open valve MV11.

49. Adjust helium regulator R6 to 10 psig.

    <u>Fill helium cell to 1.7 absolute atmospheres helium</u>:

50. Gradually open valve MV22 until gauge P5 increases from 0 to 10 psig. Gauge P8 will go from 0 to 10 psid helium excess. Do not close MV22.

51. Increase the hydrogen regulator R1 to 10 psig.

52. Close valve MV20.

53. Turn on the target loop pump.

    <u>Fill target loop to 1.7 absolute atmospheres hydrogen</u>:

54. Gradually open valve MV1 until gauge P8 is reduced from full scale helium excess to 0 psid, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.

55. Close valve MV11.

56. Increase the helium regulator R6 to 30 psig.

57. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK.

58. Open valve MV1. Increase the output pressure on hydrogen regulator R1 if necessary to get gauge P2A up to 10 psig. Do not close MV1.

59. Gradually open valve MV27. This will equalize the hydrogen pressures in the target loop and the ballast tank.

60. Open valve MV28.

61. Close valve MV2 and MV4.

    <u>Resume cooling the target loop</u>:

62. Ask the cryo group to resume cooling the loop to 20 K. As the loop cools, hydrogen will be drawn from the bottle to maintain 10 psig in the loop. When a hydrogen bottle has less than 200 psig, close its valve and its manifold valve and switch to another bottle. Put an "empty" bottle tag on the depleted bottle.

63. Close pneumatic valve PV21.

64. Turn off mechanical pump VP1 and vent it.

65. Remove pump VP1 and cap off the inlet to pneumatic valve PV21.

    Signs that the target is full:

    a) Consumption of hydrogen levels off. This is monitored on the computer as the hydrogen bottle pressure (P12) vs. time.
    b) The loop pressure (P2B) will rise to, or above, the hydrogen regulator pressure (P1) before filling began.

66. Close valve MV7 when the loop is full of liquid hydrogen.

67. Open pneumatic valve PV12 at the master vacuum interlock box.

68. Close valve MV12.

69. Close valve MV1 and the hydrogen bottle valve.

70. Close all valves on the hydrogen manifold.

71. Open gate valve XXX before putting beam on the target and enable the target heater.

72. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.

73. Confirm that all final conditions for procedure O are met.

O. Replacing helium with hydrogen while the target is cold

Final state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	closed
☐	MV4	closed
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	closed
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	closed
☐	PV12	open
☐	MV12	closed
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	open
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	open
☐	SV27	open
☐	MV28	open
☐	MV29	open
☐	MV30	closed
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	10 psig
☐	P3	10 psig
☐	P4	30 psig
☐	P5	10 psig
☐	P7	10 psig
☐	P8	0 psid
☐	P9	>0 psid
☐	P10	not in use
☐	P11	2000 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	10 psig
☐	P1	10 psig
☐	Helium bottles	one open
☐	R6	30 psig
☐	P6	30 psig
☐	Target helium bottle	not in use
☐	R30	not in use
☐	P30	not in use
☐	VP1	not in use
☐	TC for VP1	not in use
☐	VP2	not in use
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	not in use
☐	TC for VP5	not in use
☐	VP6	not in use
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	on
☐	GV1	open

P. Replacing hydrogen with helium while the target is cold

Initial state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... closed
- ☐ MV4 .... closed
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... closed
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... open
- ☐ MV11 .... closed
- ☐ PV12 .... open
- ☐ MV12 .... closed
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... open
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... open
- ☐ SV27 .... open
- ☐ MV28 .... open
- ☐ MV29 .... open
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 10 psig
- ☐ P3 .... 10 psig
- ☐ P4 .... 30 psig
- ☐ P5 .... 10 psig
- ☐ P7 .... 10 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... >0 psid
- ☐ P10 .... not in use
- ☐ P11 .... 2000 psig
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... 10 psig
- ☐ P1 .... 10 psig
- ☐ Helium bottles .... one open
- ☐ R6 .... 30 psig
- ☐ P6 .... 30 psig
- ☐ Target helium bottle .... not in use
- ☐ R30 .... not in use
- ☐ P30 .... not in use
- ☐ VP1 .... not in use
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... not in use
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... not in use
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... not in use
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... on
- ☐ GV1 .... open

P. Replacing hydrogen with helium while the target is cold.

1. The target is filled with circulating liquid hydrogen as described in section F or O.

2. Turn off the beam and set the interlock so beam may not be put on the target.

3. Take the target heater out of automatic control and slowly turn the heater down to 0 in steps of 100 W.

4. Turn off the target heater voltage.

   At this point it will be necessary to enter End Station A. Install the target computer there.

5. Confirm that all initial conditions for procedure P are met. They are the same as the final conditions for section F or O.

6. Close gate valve XXX from the master vacuum interlock box.

7. Ask the cryo group to raise the temperature of the coolant to 80K. We may need to reduce the coolant flow rate as well. Hydrogen will vent through solenoid valve SV13. Wait until the loop comes to 80K.

8. Close pneumatic valve PV12 after the target has stopped boiling and SV13 is closed.

9. Once all liquid has boiled away, the target will slowly warm up. This process may be accelerated by turning on the target heater to 50–100 watts.

10. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section G to change the helium bottle).

    <u>NOTE</u>: When the target temperature is approximately 30 K, the vacuum chamber pressure will rise by about a factor of 10–50 from its cold value. As the target continues to warm the vacuum should return to the warm value.

11. When the target reaches 80 K, set the target heater to 0 W and turn off the power supply.

12. Slightly crack open valve MV13. Gauge P3 will drop from 15 psig to 0 psig.

13. Close valve MV13.

14. Re-install pump VP1 and turn it on.

15. Open valve PV21 at the master vacuum interlock box.

16. Close valves MV27 and MV28.

17. Make sure all hydrogen bottles are closed, then open valves MV21, MV1, MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G, MV1H, MV7, MV20 and MV12.

18. Gradually open valve MV2.

19. Wait until the pressure at gauge P1 has dropped to 0 psig, then open hydrogen regulator R1 by turning its handle fully clockwise.

20. Turn on mechanical pumps VP5 and VP6.
21. Open valves MV24A and MV24E.
22. Turn off the loop pump.
23. Wait until the pressure at gauge P2 has reached 100 mtorr, then close valve MV2.
24. Close valves MV24A and MV24E.
25. Turn off mechanical pumps VP5 and VP6. Vent them.
26. Make sure target helium regulator R30 is closed by turning its handle fully counterclockwise.

    First evacuation of target loop:

27. Gradually open valve MV4 to evacuate the target loop. Gauge P3 will go from 0 psig to 30 in. Hg. Gauge P8 will go from 0 psid to full scale helium excess.
28. Open valves MV30, MV33 and MV2.
29. Make sure the target helium bottle is closed, then open its regulator R30 by turning its handle fully clockwise.
30. Pump until the thermocouple gauge for pump VP1 reads 100 mtorr, then close valve MV21.
31. Close the target helium regulator R30 by turning its handle fully counterclockwise.
32. Close valve MV30.
33. Open the target helium bottle and set its regulator R30 to 0 psig.

    First backfill of target loop with helium:

34. Gradually open valve MV30 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
35. Close valves MV30, MV7 and MV12.

    Second evacuation of target loop:

36. Gradually open valve MV21 to evacuate the target loop. Gauge P3 will go from 0 to 30 in. Hg. Gauge P8 will go from 0 psid to full scale helium excess.
37. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
38. Close valve MV21.

    Second backfill of target loop with helium:

39. Gradually open valve MV30 until gauge P8 goes from full scale helium excess to 10 psid helium excess. DO NOT let gauge P8 go to hydrogen excess.
40. Close valve MV30.

    Third evacuation of target loop:

41. Gradually open valve MV21 to evacuate the target loop. Gauge P3 will go from 20 in. Hg to 30 in Hg. Gauge P8 will go from 10 psid to full scale helium excess.

42. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.

43. Close valve MV21.

    Third backfill of target loop with helium:

44. Open valve MV30 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

45. Close valve MV30.

46. Close valves MV1, MV1A, MV1B, MV1C, MV1D, MV1E, MV1F, MV1G and MV1H.

47. Close hydrogen regulator R1 by turning its handle fully counterclockwise.

48. Close valve MV22.

49. Gradually open valve MV11 to bleed gauge P4 down to 0 psig.

50. Close valve MV29.

51. Gradually crack open valve MV22 until gauge P8 reads 15 psid helium excess, then close valve MV22.

52. Close valve MV11.

53. Set target helium regulator R30 to 10 psig.

54. Open valve MV30. Gauge P8 will go to 5 psid helium excess. DO NOT let gauge P8 go to hydrogen excess. Do not close valve MV30.

55. Open valve MV29. Gauge P8 will go to 0 psid.

56. Open valve MV22.

57. Close valve MV20.

58. Close pneumatic valve PV21.

59. Turn on the target loop pump.

    Resume cooling the target loop:

60. Ask the cryo group to resume cooling the loop to 20K. As the loop cools, gauge P9 will rise very slowly.

61. Turn off mechanical pump VP1 and remove it. Cap the inlet to pneumatic valve PV21.

62. Open gate valve XXX before putting beam on the target.

63. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.

64. Purge the ballast tank of hydrogen if no further hydrogen running is contemplated. See section J for these instructions.

65. Confirm that all final conditions for procedure P are met.

P. Replacing hydrogen with helium while the target is cold.

Final state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... open
- ☐ MV4 .... open
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... open
- ☐ MV8 .... closed
- ☐ MV9 .... closed
- ☐ MV10 .... open
- ☐ MV11 .... closed
- ☐ PV12 .... closed
- ☐ MV12 .... open
- ☐ SV13 .... closed
- ☐ MV13 .... closed
- ☐ MV20 .... closed
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... open
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... open
- ☐ MV30 .... open
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 10 psig
- ☐ P3 .... 10 psig
- ☐ P4 .... 30 psig
- ☐ P5 .... 10 psig
- ☐ P7 .... 0 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... 0 psid
- ☐ P10 .... 10 psig
- ☐ P11 .... >200 psig
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... one open
- ☐ R6 .... 30 psig
- ☐ P6 .... 30 psig
- ☐ Target helium bottle .... open
- ☐ R30 .... 10 psig
- ☐ P30 .... 10 psig
- ☐ VP1 .... off
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... off
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... off
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... off
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... on
- ☐ GV1 .... open

Q. Warming the helium-filled target to room temperature

Initial state:

☐	MV1	closed
☐	SV1	open
☐	MV1A	closed
☐	MV1B	closed
☐	MV1C	closed
☐	MV1D	closed
☐	MV1E	closed
☐	MV1F	closed
☐	MV1G	closed
☐	MV1H	closed
☐	MV2	open
☐	MV4	open
☐	MV5A	closed
☐	MV5B	closed
☐	MV7	open
☐	MV8	closed
☐	MV9	closed
☐	MV10	open
☐	MV11	closed
☐	PV12	closed
☐	MV12	open
☐	SV13	closed
☐	MV13	closed
☐	MV20	closed
☐	MV21	closed
☐	PV21	closed
☐	MV22	open
☐	MV23A	open
☐	MV23E	open
☐	MV24A	closed
☐	MV24E	closed
☐	MV25	closed
☐	MV26	closed
☐	MV27	closed
☐	SV27	open
☐	MV28	closed
☐	MV29	open
☐	MV30	open
☐	MV31	closed
☐	MV32	closed
☐	MV33	closed
☐	MV34	closed

☐	P2	10 psig
☐	P3	10 psig
☐	P4	30 psig
☐	P5	10 psig
☐	P7	0 psig
☐	P8	0 psid
☐	P9	0 psid
☐	P10	10 psig
☐	P11	>200 psig
☐	P12	not in use
☐	Hydrogen bottles	all closed
☐	R1	closed
☐	P1	not in use
☐	Helium bottles	one open
☐	R6	30 psig
☐	P6	30 psig
☐	Target helium bottle	open
☐	R30	10 psig
☐	P30	10 psig
☐	VP1	off
☐	TC for VP1	not in use
☐	VP2	off
☐	TC for VP2	not in use
☐	VP4	on
☐	TC for VP4	<300 mtorr
☐	VP5	off
☐	TC for VP5	not in use
☐	VP6	off
☐	TC for VP6	not in use
☐	Turbopump	on
☐	IG1	$<10^{-4}$ torr
☐	Target loop pump	on
☐	GV1	open

Q. Warming the helium-filled target to room temperature

1. The target is filled with circulating helium as described in section N.
2. Turn off the beam and set the interlock so beam may not be put on the target.
3. Make sure the target heater is off.

   At this point it will be necessary to enter End Station A. Install the target computer there.
4. Confirm that all initial conditions for procedure Q are met. They are the same as the final conditions for section N.
5. Close gate valve XXX from the master vacuum interlock box.
6. Ask the cryo group to raise the temperature of the coolant to 80K. We may need to reduce the coolant flow rate as well. Helium will vent through solenoid valve SV13. Wait until the loop comes up to 80K.

   <u>NOTE</u>: When the target temperature is approximately 30 K, the vacuum chamber pressure will rise by about a factor of 10–50 from its cold value. If the ion gauge IG1 gets high on the 10^{-4} range the turbopump interlock should be bypassed to keep it from tripping off and the gate valve GV1 from closing. As the target continues to warm the vacuum should return to the warm value.
7. The target will slowly warm up to room temperature. This process may be accelerated by turning on the target heater to 50–100 watts.
8. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section III.G to change the helium bottle).
9. When the target reaches 100 K, set the target heater to 0 W and turn off the power supply.
10. Turn off the target loop pump.
11. Close valve MV30.
12. Open valve MV13. Gauge P3 will drop from 15 psig to 0 psig.
13. Close the helium bottle valve. Wait until gauge P4 slowly bleeds down to 0 psig through valve MV29.
14. Open valve MV9.
15. Open valves MV11 and MV20.
16. Close regulators R30 and R6 by turning their handles fully counterclockwise.
17. Close the helium and target helium bottles.
18. Confirm that all final conditions for procedure Q are met.

Q. Warming the helium-filled target to room temperature

Final state:

- ☐ MV1 .... closed
- ☐ SV1 .... open
- ☐ MV1A .... closed
- ☐ MV1B .... closed
- ☐ MV1C .... closed
- ☐ MV1D .... closed
- ☐ MV1E .... closed
- ☐ MV1F .... closed
- ☐ MV1G .... closed
- ☐ MV1H .... closed
- ☐ MV2 .... open
- ☐ MV4 .... open
- ☐ MV5A .... closed
- ☐ MV5B .... closed
- ☐ MV7 .... open
- ☐ MV8 .... closed
- ☐ MV9 .... open
- ☐ MV10 .... open
- ☐ MV11 .... open
- ☐ PV12 .... closed
- ☐ MV12 .... open
- ☐ SV13 .... closed
- ☐ MV13 .... open
- ☐ MV20 .... open
- ☐ MV21 .... closed
- ☐ PV21 .... closed
- ☐ MV22 .... open
- ☐ MV23A .... open
- ☐ MV23E .... open
- ☐ MV24A .... closed
- ☐ MV24E .... closed
- ☐ MV25 .... closed
- ☐ MV26 .... closed
- ☐ MV27 .... closed
- ☐ SV27 .... open
- ☐ MV28 .... closed
- ☐ MV29 .... open
- ☐ MV30 .... closed
- ☐ MV31 .... closed
- ☐ MV32 .... closed
- ☐ MV33 .... closed
- ☐ MV34 .... closed

- ☐ P2 .... 0 psig
- ☐ P3 .... 0 psig
- ☐ P4 .... 0 psig
- ☐ P5 .... 0 psig
- ☐ P7 .... 0 psig
- ☐ P8 .... 0 psid
- ☐ P9 .... 0 psid
- ☐ P10 .... 0 psig
- ☐ P11 .... not in use
- ☐ P12 .... not in use
- ☐ Hydrogen bottles .... all closed
- ☐ R1 .... closed
- ☐ P1 .... not in use
- ☐ Helium bottles .... both closed
- ☐ R6 .... closed
- ☐ P6 .... closed
- ☐ Target helium bottle .... closed
- ☐ R30 .... closed
- ☐ P30 .... not in use
- ☐ VP1 .... off
- ☐ TC for VP1 .... not in use
- ☐ VP2 .... off
- ☐ TC for VP2 .... not in use
- ☐ VP4 .... on
- ☐ TC for VP4 .... <300 mtorr
- ☐ VP5 .... off
- ☐ TC for VP5 .... not in use
- ☐ VP6 .... off
- ☐ TC for VP6 .... not in use
- ☐ Turbopump .... on
- ☐ IG1 .... $<10^{-4}$ torr
- ☐ Target loop pump .... off
- ☐ GV1 .... open