

# The G0 Target User's Guide

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## Gas Handling System

### Introduction

The gas handling system for G0 is based on the system used for the 25 liter liquid hydrogen target of the SAMPLE experiment at MIT-Bates Laboratory. The G0 experiment requires a target of liquid hydrogen or liquid deuterium. This section describes a liquid hydrogen target, but would also apply to liquid deuterium. Central to the system is a valve panel providing interconnection among the target loop, hydrogen, deuterium, and helium source bottles, a vacuum pump and ballast tanks for hydrogen and deuterium. With these valves the experimenter can purge air from the target and ballast, fill the target and ballast with hydrogen, liquefy hydrogen in the target loop, and dispose of hydrogen while the target warms up. The panel also has several relief and check valves to ensure safe operation of the target.

Fig. 1 is a schematic of the gas handling system. Components are labeled by abbreviations as follows:

CCG	Cold cathode gauge
CV	Check valve
GV	Gate valve
MV	Manually operated valve
P	Pressure transducer or gauge
PS	Pressure switch
PT	Pressure transmitter
PV	Pneumatically operated valve
R	Regulator
RD	Rupture disc
RV	Relief valve
SV	Solenoid valve
TC	Thermocouple vacuum gauge
VP	Mechanical vacuum pump

When the target is in operation, liquid hydrogen is driven in a loop consisting of a pump, a heat exchanger, and the target cell. The liquid is subcooled by a pressure head of 10 psig from a 2500 gallon ballast tank of gaseous hydrogen. Downstream from the hydrogen target cell is a helium cell with thin convex entrance and exit windows.

### General Gas Handling Procedures

The handles of the manual valves on the panel are color-coded to indicate their function: those with a red handle carry hydrogen, those with green carry helium. Most of the valves on the panel are equipped with microswitches to sense whether the valve is open or closed. These microswitches drive a pair of LEDs next to the valve; green means the valve is open, red means closed. The state of these valves is also read by the computer.

When the instructions refer to closing a regulator it means backing out (counterclockwise) the regulator output setting to minimum pressure. Similarly, an instruction to open a regulator without a specification of output pressure means to turn the regulator output setting handle several turns clockwise. This is only done to aid in evacuating the gas lines all the way back to the bottle valve. “Helium” refers to helium admitted through valve MV22 into the target backing cell; “target helium” is helium admitted through valve MV30 into the target loop for beam runs on a helium target.

IT IS IMPERATIVE that the hydrogen pressure in the target never exceed the helium pressure in the helium cell by more than 1 psid or else the helium cell may be damaged. The *helium* pressure may exceed the *hydrogen* by as much as 15 psid. This differential pressure may be read by gauge P8 or transmitter PT8. The detailed procedures in this guide ensure that these limits are not exceeded.

IT IS ALSO IMPERATIVE that the vacuum chamber be evacuated before pumping on the target loop. The target cell is very thin and will implode if the pressure outside it exceeds the pressure inside. Pneumatic valve PV21 is interlocked to the cold cathode gauge CCG to prevent pumping on the target loop unless the vacuum chamber is evacuated.

The first step in operating the target is the removal of all air from the target and associated plumbing. To do this, the entire system is repeatedly evacuated and backfilled with pure gas. The first backfill of any part of the system is with helium to reduce the possibility of mixing air and hydrogen. Subsequent backfills of the target loop or ballast tank use hydrogen.

The target may be filled and cooled after it has been evacuated and flushed. Hydrogen from the ballast tank condenses in the target during a cooldown. To end up with 10 psig final pressure in the loop, the ballast tank has to be charged to 21 psig. After equalizing the pressures in the loop and ballast tank, the gas is drawn to the loop through valve MV12 from the ballast tank. Helium regulated by R6 may be allowed into the evacuated helium cell. As noted, the helium cell must always be kept at the same or higher pressure than the target loop.

An alternative procedure for running the target loop with cold gaseous helium is described in Sections F and G.

Before cooling the target, it should be filled to the ballast tank pressure of 20 psig. It is important that the helium pressure not exceed the hydrogen by more than 15 psid, so the filling of the target from vacuum to the ballast tank pressure is done in three stages — first from vacuum to 0 psig, then to 15 psig, and finally to 20 psig. The target loop pump should be running during liquefaction to make the heat exchange more efficient. While the pump is running, valve MV20 must be kept closed; the differential pressure generated by the pump may be read on gauge P9 and transmitter PT9.

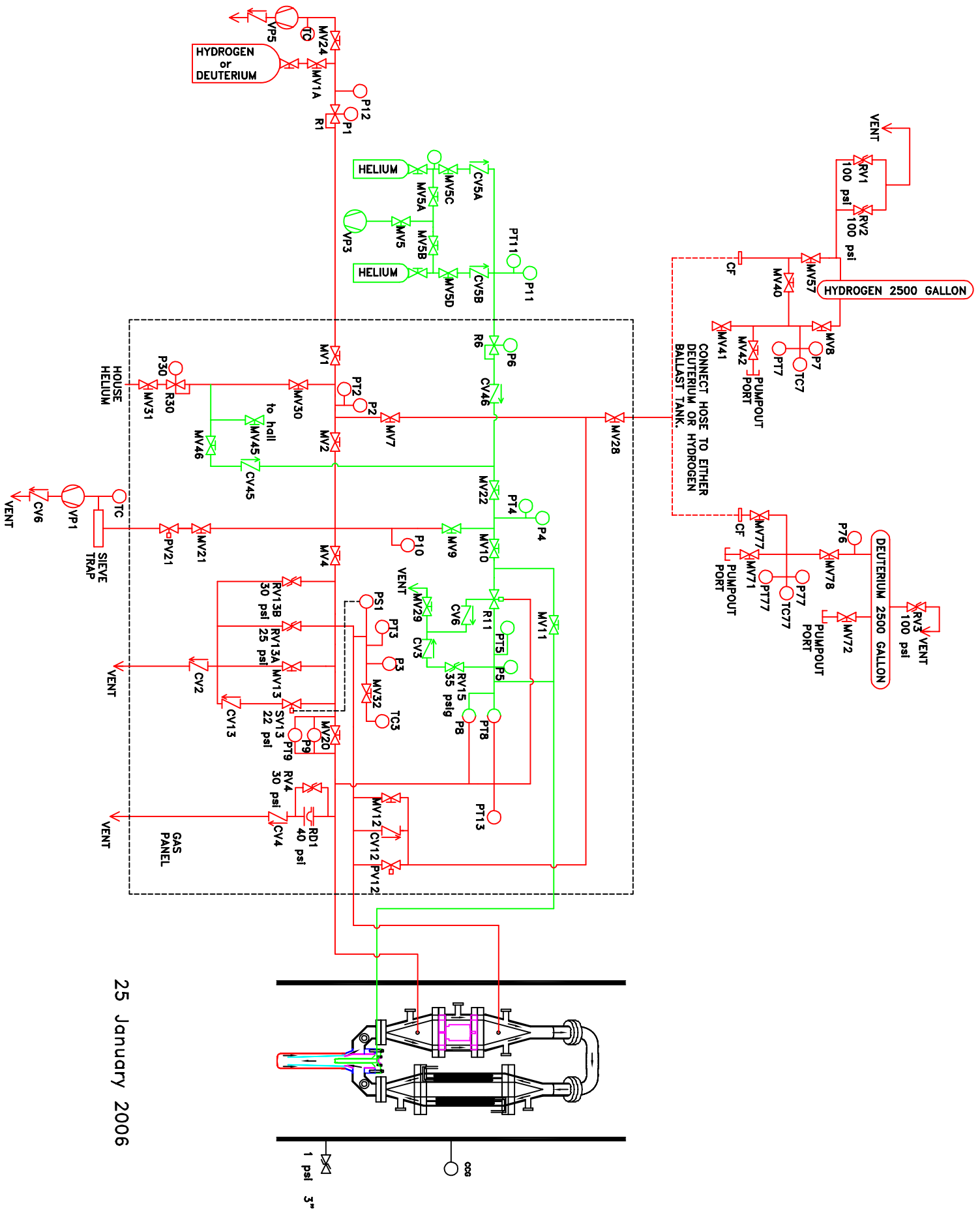
As the target cools, it will require more hydrogen and helium due to condensation. As more gas enters, the pressure difference across the convex entrance window to the helium cell is kept at 0 psid by pneumatic relay R11. It is a regulator that controls the pressure of a slave gas (helium) by the pressure of a master gas (hydrogen), keeping them in balance automatically. Gauge P5 monitors the helium output pressure.

There is a small constant venting of helium through check valve CV6 and valve MV29. This venting is inherent in the design of pneumatic relay R11. It is important to monitor the helium bottle pressure and switch in a new bottle before the helium is depleted. The helium bottle is supplemented by Hall C helium.

When the loop is full of liquid hydrogen, the operating pressure of 10 psig is maintained by the large volume of hydrogen in the ballast tank. The loop and the tank are connected through pneumatic valve PV12.

### **Emergency Operation**

In the event of a power failure, vacuum failure or coolant failure it is possible that liquid hydrogen could evaporate and create a potentially hazardous hydrogen pressure in the target. To prevent this, relief valves RV13A and RV13B provide a redundant path to the laboratory venting system. They would open at pressures of 25 psig and 30 psig respectively. As a last line of defense, rupture disc RD1 would burst at a pressure of 41.1 psig. In a vacuum failure, pneumatic valve PV12 would close, preventing the ballast tank from venting through any possible leak that might open in the target.



**A. Evacuation and flushing of the target and filling lines with hydrogen**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	not in use
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	not in use
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	not in use
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	closed	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	not in use
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	not in use
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	closed	<input type="checkbox"/> P11.....	not in use
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	both closed
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	closed
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	not in use
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	closed
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	closed
<input type="checkbox"/> MV28.....	closed	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	closed	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	closed	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	$< 10^{-4}$ torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	not in use
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**A. Evacuation and flushing of the target and filling lines with hydrogen**

- 1. Confirm that all initial conditions for procedure A are met.
- 2. The vacuum chamber must be under vacuum before proceeding. DO NOT pump on the target unless the chamber is at a pressure of  $10^{-4}$  torr or less as read on cold cathode gauge CCG.
- 3. Turn on mechanical pump VP1.
- 4. Open pneumatic valve PV21 at the master vacuum interlock box.
- 5. Open valves MV46, MV1, MV30, MV13, MV20, MV32 and MV29.
- 6. Make sure the hydrogen bottle is closed, then open valve MV1A.
- 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. Gradually open hydrogen regulator R1 by turning its handle fully clockwise. Wait until VP1's thermocouple gauge reaches 100 mtorr.

First evacuation of target loop:

- 11. Gradually open valve MV4 to evacuate the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.
- 12. Open valves MV7, MV28 and MV12
- 13. Open valves MV10 and MV11.

First evacuation of helium cell:

- 14. 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.
- 15. 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.
- 16. Open valve MV22.

- 17. Make sure both helium bottles are closed, then gradually open helium regulator R6 by turning its handle fully clockwise.
- 18. Continue pumping on the target loop, helium cell and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 19. Sequentially close and reopen valves MV1, MV30, MV2, MV7, MV28, MV21, MV4, MV13, MV20, MV12, MV22, MV9, MV10, MV11, MV32 and MV29 to pump out a small dead space in each valve.
- 20. Close valves MV2, MV4, MV9 and MV22.
- 21. Close helium regulator R6 by turning its handle fully counterclockwise.
- 22. Open valves MV5C and MV5D.
- 23. Open both helium bottle valves and adjust their regulator R6 to 0 psig.
- 24. Close valve MV5D and the helium bottle connected to it.

First backfill of helium cell with helium:

- 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.

Second evacuation of helium cell:

- 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.

Second backfill of helium cell with helium:

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

Third evacuation of helium cell:

- 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.

Third backfill of helium cell with helium:

- 33. Gradually open valve MV22 to fill the helium cell with helium. Gauge P8 will go from 0 psid 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 valve MV31 and adjust its regulator R30 to 0 psig.
- 38. Open valves MV2 and MV4.

Backfill of target loop with helium:

- 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 valves MV46 and MV30 when gauge P8 reaches 0 psid.
- 41. Close valve MV31 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.

Second evacuation of target loop:

- 43. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess.
- 44. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 45. 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.
- 46. Close MV1 and MV21.
- 47. Close hydrogen regulator R1 by turning its handle fully counterclockwise.

- 48. Open the hydrogen bottle valve and adjust its regulator R1 to 0 psig.

First backfill of target loop with hydrogen:

- 49. 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.
- 50. Close valve MV1 when gauge P8 reaches 0 psid.
- 51. 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.

Third evacuation of target loop:

- 52. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess.
- 53. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 54. 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.
- 55. Close valve MV21.

Second backfill of target loop with hydrogen:

- 56. 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.
- 57. Close valve MV1 when gauge P8 reaches 0 psid.
- 58. 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:

- 59. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess.
- 60. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 61. Confirm that all final conditions for procedure A are met.

62. Go to Section B to fill and cool the target.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

### A. Evacuation and flushing of the target and filling lines with hydrogen

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	30 in. Hg
<input type="checkbox"/> MV1A.....	open	<input type="checkbox"/> P3.....	30 in. Hg
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	0 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	15 psid He excess
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	30 in. Hg
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	open	<input type="checkbox"/> P12.....	> 200 psig
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	open
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	0 psig
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	0 psig
<input type="checkbox"/> MV20.....	open	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	open	<input type="checkbox"/> R6.....	0 psig
<input type="checkbox"/> PV21.....	open	<input type="checkbox"/> P6.....	0 psig
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	closed
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	not in use
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	on
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	< 100 mtorr
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	closed	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	open	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**B. Filling and cooling the target with hydrogen**

Initial state:

<input type="checkbox"/>	MV1.....	closed	<input type="checkbox"/>	P2.....	30 in. Hg
<input type="checkbox"/>	MV1A.....	open	<input type="checkbox"/>	P3.....	30 in. Hg
<input type="checkbox"/>	MV2.....	open	<input type="checkbox"/>	P4.....	0 psig
<input type="checkbox"/>	MV4.....	open	<input type="checkbox"/>	P5.....	0 psig
<input type="checkbox"/>	MV5A.....	closed	<input type="checkbox"/>	P7.....	20 psig
<input type="checkbox"/>	MV5B.....	closed	<input type="checkbox"/>	P76.....	20 psig
<input type="checkbox"/>	MV5C.....	open	<input type="checkbox"/>	P77.....	not in use
<input type="checkbox"/>	MV5D.....	closed	<input type="checkbox"/>	P8.....	15 psid He excess
<input type="checkbox"/>	MV7.....	open	<input type="checkbox"/>	P9.....	0 psid
<input type="checkbox"/>	MV9.....	closed	<input type="checkbox"/>	P10.....	30 in. Hg
<input type="checkbox"/>	MV10.....	open	<input type="checkbox"/>	P11.....	> 200 psig
<input type="checkbox"/>	MV11.....	open	<input type="checkbox"/>	P12.....	> 200 psig
<input type="checkbox"/>	PV12.....	closed	<input type="checkbox"/>	Hydrogen bottle.....	open
<input type="checkbox"/>	MV12.....	open	<input type="checkbox"/>	Deuterium bottle.....	not in use
<input type="checkbox"/>	SV13.....	closed	<input type="checkbox"/>	R1.....	0 psig
<input type="checkbox"/>	MV13.....	open	<input type="checkbox"/>	P1.....	0 psig
<input type="checkbox"/>	MV20.....	open	<input type="checkbox"/>	Helium bottles.....	one open
<input type="checkbox"/>	MV21.....	open	<input type="checkbox"/>	R6.....	0 psig
<input type="checkbox"/>	PV21.....	open	<input type="checkbox"/>	P6.....	0 psig
<input type="checkbox"/>	MV22.....	closed	<input type="checkbox"/>	R30.....	closed
<input type="checkbox"/>	MV24.....	closed	<input type="checkbox"/>	P30.....	not in use
<input type="checkbox"/>	MV28.....	open	<input type="checkbox"/>	VP1.....	on
<input type="checkbox"/>	MV29.....	open	<input type="checkbox"/>	TC for VP1.....	< 100 mtorr
<input type="checkbox"/>	MV30.....	closed	<input type="checkbox"/>	VP3.....	not in use
<input type="checkbox"/>	MV31.....	closed	<input type="checkbox"/>	TC for VP3.....	not in use
<input type="checkbox"/>	MV32.....	open	<input type="checkbox"/>	VP5.....	not in use
<input type="checkbox"/>	MV45.....	closed	<input type="checkbox"/>	TC for VP5.....	not in use
<input type="checkbox"/>	MV46.....	closed	<input type="checkbox"/>	CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/>	MV57.....	closed	<input type="checkbox"/>	Target loop pump.....	off
<input type="checkbox"/>	MV77.....	closed	<input type="checkbox"/>	TC3.....	not in use
<input type="checkbox"/>	MV78.....	closed	<input type="checkbox"/>	Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**B. Filling and cooling the target with hydrogen**

- 1. Evacuate and flush the target and filling lines as described in section A.
- 2. Confirm that all initial conditions for section B are met. They are the same as the final conditions for section A.
- 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.  
Fill target loop to one absolute atmosphere hydrogen:
- 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, MV32 and MV13.
- 9. Increase the helium regulator R6 to 15 psig.
- 10. Close valve MV29.  
Fill helium cell to two absolute atmospheres helium:
- 11. Gradually open valve MV22 until gauge P5 increases from 0 to 15 psig. Gauge P8 will increase to 15 psid helium excess.
- 12. Close valve MV22.
- 13. Increase the hydrogen regulator R1 to 15 psig.  
Fill target loop to two absolute atmospheres hydrogen:
- 14. Gradually open valve MV1 until gauge P8 is reduced from 15 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 15. Increase the helium regulator R6 to 20 psig.  
Fill helium cell to 2.3 absolute atmospheres helium:
- 16. Gradually open valve MV22 until gauge P5 increases from 15 to 20 psig. Gauge P8 will increase to 5 psid helium excess. Do not close MV22.
- 17. Increase the hydrogen regulator R1 to 20 psig.

Fill target loop to 2.3 absolute atmospheres hydrogen:

- 18. Gradually open valve MV1 until gauge P8 is reduced from 5 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 19. Close valve MV11.
- 20. Increase the helium regulator R6 to 40 psig.
- 21. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK. Install lock on MV29 to keep it open.
- 22. Open valve MV31.
- 23. Set target helium regulator R30 to 45 psig.
- 24. Open valve MV46.
- 25. Close valves MV20 and MV28.
- 26. Open valve MV57.
- 27. Gradually open valve MV28. This will equalize the hydrogen pressures in the target loop and the ballast tank.
- 28. Close valves MV2, MV4 and MV7.

Cooling the target loop:

- 29. Turn on the target loop pump. As the hydrogen cools, gauge P9 will rise very slowly.
- 30. Ask the cryo group to provide coolant to the target. As the loop cools, hydrogen will be drawn from the ballast tank.

After the loop is filled with liquid hydrogen:

- 32. Open pneumatic valve PV12 at the master vacuum interlock box.
- 33. Close valve MV12.
- 34. Close valve MV1A and the hydrogen bottle valve.
- 34. Close the hydrogen regulator R1 by turning its handle fully counterclockwise.
- 35. Open gate valve XXX before putting beam on the target.
- 36. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section F for this procedure.

37. Confirm that all final conditions for procedure B are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**B. Filling and cooling the target with hydrogen**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### C. Replacing the helium bottle

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### C. 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 B.
- 3. Confirm that all initial conditions for section C are met. They are the same as the final conditions for section B.
- 4. Open the full helium bottle that is in reserve on the manifold. Open its manifold valve (MV5C or MV5D). Make sure the regulator pressure of R6 remains at 40 psig.
- 5. Close the expended helium bottle valve and its manifold valve (MV5C or MV5D).
- 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) and valve MV5 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 and valve MV5.
- 9. Momentarily open the new bottle to pressurize the small volume up to its manifold 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 C are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

### C. Replacing the helium bottle

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**D. Warming the hydrogen-filled target to room temperature**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

#### D. Warming the hydrogen-filled target to room temperature

- 1. The target is filled with circulating liquid hydrogen as described in section B.
- 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 Hall C. Install the target computer there.

- 5. Confirm that all initial conditions for procedure D are met. They are the same as the final conditions for section B or C.
- 6. Close gate valve XXX from the master vacuum interlock box.

NOTE: 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 or at gauge P3 on the gas panel. As the target starts to boil, its pressure will increase and hydrogen will go to the ballast tank through check valve CV12. If the target pressure reaches 22 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 20 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.
- 11. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section C to change the helium bottle).

NOTE: 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 cold cathode gauge CCG 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. Turn off the target loop pump.
- 13. Slightly crack open valve MV13. Gauge P3 will drop from ~20 psig to 0 psig.
- 14. Open valve MV13 fully.
- 15. Proceed to section E to purge hydrogen from the target loop.
- 16. Confirm that all final conditions for procedure D are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**D. Warming the hydrogen-filled target to room temperature**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P77.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P78.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**E. Purging hydrogen from the target loop.**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P77.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P78.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**E. 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 D.
- 3. Confirm that all initial conditions for procedure E are met. They are the same as the final conditions for procedure D.
- 4. Re-install pump VP1 and turn it on.
- 5. Open valve PV21 at the master vacuum interlock box.
- 6. Close valve MV57.
- 7. Make sure the hydrogen bottle is closed, then open valves MV21, MV1, MV1A, MV32 and MV20. Gauge P10 will go to 30 in. Hg.
- 8. Gradually open valve MV12 to vent the line to the ballast tank to 0 psig.
- 9. Gradually open valve MV2.
- 10. Wait until the pressure at gauge P1 has dropped to 0 psig, then open hydrogen regulator R1 by turning its handle fully clockwise.  
First evacuation of target loop:
- 11. 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.
- 12. 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.
- 13. Pump until VP1's thermocouple gauge reaches 100 mtorr.
- 14. Close valve MV31.
- 15. Open valve MV30.
- 16. Open target helium regulator R30 by turning its handle fully clockwise. Gauge P30 will drop to 30 in. Hg.
- 17. Close valve MV30.
- 18. Close target helium regulator R30 by turning its handle fully counterclockwise.

19. Open valve MV31 and adjust its regulator R30 to 0 psig.

20. Close valve MV21.

First backfill of target loop with helium:

21. 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.

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

23. Close valve MV30.

Second evacuation of target loop:

24. 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.

25. 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.

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

27. Close valve MV21.

Second backfill of target loop with helium:

28. 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.

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

30. Close valves MV30, MV32 and MV46.

31. Close valve MV22.

32. Open valve MV9.

33. Open valve MV11.

34. Open valve MV7.

35. Close pneumatic valve PV21 at the master vacuum interlock box.

36. Close valves MV1 and MV1A.

- 37. Turn off mechanical pump VP1 and vent it.
- 38. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
- 39. Close the helium bottle valve and valve MV5C.
- 40. Close helium regulator R6 by turning its handle fully counterclockwise.
- 41. Close valve MV31.
- 42. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 43. Confirm that all final conditions for procedure E are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**E. Purging hydrogen from the target loop.**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	0 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	0 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	closed	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	open	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	0 psig
<input type="checkbox"/> MV11.....	open	<input type="checkbox"/> P12.....	0 psig
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	open	<input type="checkbox"/> Helium bottles.....	both closed
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	closed
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	not in use
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	closed
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	not in use
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	off
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	closed	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	$< 10^{-4}$ torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**F. Evacuation and flushing of target and filling lines with helium**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	not in use
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	not in use
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	not in use
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	closed	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	not in use
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	not in use
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	closed	<input type="checkbox"/> P11.....	not in use
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	both closed
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	closed
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	not in use
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	closed
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	closed
<input type="checkbox"/> MV28.....	closed	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	closed	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	closed	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	$< 10^{-4}$ torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	not in use
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**F. Evacuation and flushing of target and filling lines with helium**

- 1. Confirm that all initial conditions for procedure F are met.
- 2. The vacuum chamber must be under vacuum before proceeding. The turbopump must be on with gate valve XXX open. DO NOT pump on the target unless the vacuum chamber is at a pressure of  $10^{-4}$  torr or less as read on cold cathode gauge CCG.
- 3. Turn on mechanical pump VP1.
- 4. Open pneumatic valve PV21 at the master vacuum interlock box.
- 5. Make sure the hydrogen bottle is closed, then open valves MV1A and MV1.
- 6. Open hydrogen regulator R1 by turning its handle fully clockwise.
- 7. Open valves MV30, MV46, MV32, MV13, MV20 and MV29.
- 8. Open valve MV21. Gauge P10 will drop from 0 psig to 30 in. Hg.
- 9. Gradually open valve MV2. Gauge P1 will drop from 0 psig to 30 in. Hg.
- 10. Make sure valve MV31 is closed, then gradually open target helium regulator R30 by turning its handle fully clockwise. Wait until VP1's thermocouple gauge reaches 100 mtorr.

First evacuation of target loop:

- 11. Gradually open valve MV4 to evacuate the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.
- 12. Open valves MV7, MV28 and MV12.
- 13. Open valves MV10 and MV11.

First evacuation of helium cell:

- 14. 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.
- 15. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 16. Open valve MV22.
- 17. Make sure both helium bottles are closed, then gradually open helium regulator R6 by turning its handle fully clockwise.

- 18. Open valves MV5C and MV5D.
- 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, MV28, MV21, MV4, MV13, MV20, MV32, MV12, MV22, MV9, MV10, MV11, MV32 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 valve MV5D and the helium bottle connected to it.

First backfill of helium cell with helium:

- 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.

Second evacuation of helium cell:

- 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.

Second backfill of helium cell with helium:

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

Third evacuation of helium cell:

- 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.

Third backfill of helium cell with helium:

- 33. 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.
- 34. Close valve MV22.
- 35. Close valves MV30 and MV21.
- 36. Close target helium regulator R30 by turning its handle fully counterclockwise.
- 37. Open valve MV31 and adjust its regulator R30 to 0 psig.
- 38. Open valves MV2 and MV4.

First backfill of target loop with helium:

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

Second evacuation of target loop:

- 42. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess.
- 43. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 44. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 45. Close valve MV21.

Second backfill of target loop with helium:

- 46. 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.
- 47. Close valve MV30 when gauge P8 reaches 0 psid.
- 48. Open solenoid valve SV13 momentarily to introduce helium into the space between it and check valve CV13. Push the switch next to SV13 to do this.

Third evacuation of target loop:

- 49. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess.
- 50. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 51. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 52. Close valve MV21.
- 53. Close pneumatic valve PV21 at the master vacuum interlock box.
- 54. Turn off mechanical pump VP1 and vent it.
- 55. Remove mechanical pump VP1 and cap off the inlet to pneumatic valve PV21.

Fill target loop to one absolute atmosphere helium:

- 56. 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.
- 57. Close valves MV1A, MV1, MV30, MV46, MV32 and MV13.
- 58. Close hydrogen regulator R1 by turning its handle fully counterclockwise
- 59. Confirm that all final conditions for procedure F are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## F. Evacuation and flushing of target and filling lines with helium

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	0 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	0 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	open	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	open	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	0 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	0 psig
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	0 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	0 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	off
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**G. Filling and cooling the target with helium**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	0 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	0 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	open	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	open	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	0 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	0 psig
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	0 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	0 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	off
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**G. Filling and cooling the target with helium**

- 1. Evacuate and flush the target and filling lines with helium as described in section F.
- 2. Confirm that all initial conditions for section G are met. They are the same as the final conditions for section F.
- 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 40 psig.
- 10. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK. Install lock on MV29 to keep it open.
- 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 house helium 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 F for this procedure.
- 17. Confirm that all final conditions for procedure G are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**G. Filling and cooling the target with helium**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	10 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	40 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	10 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	10 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	10 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	off
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	open	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

## H. Replacing helium with hydrogen while the target is cold

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	10 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	40 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	10 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	10 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	10 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	off
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	open	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

## H. Replacing helium with hydrogen while the target is cold

- 1. The target is filled with circulating helium as described in section G.
- 2. Turn off the beam and set the interlock so beam may not be put on the target.  
At this point it will be necessary to enter Hall C. Install the target computer there.
- 3. Confirm that all initial conditions for procedure H are met. They are the same as the final conditions for section G.
- 4. Close gate valve XXX from the master vacuum interlock box.
- 5. Slowly close the target JT valve until the temperature of the coolant goes to 28 K. Helium will vent through SV13. Wait until the loop comes to 28 K.
- 6. Close valve MV30.
- 7. Close valve MV31.
- 8. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 9. Gradually open valve MV13. Gauge P3 will drop from 10 psig to 0 psig. Gauges P2, P5 and P10 will do the same.
- 10. Close valves MV2 and MV4.
- 11. Turn off the target loop pump.
- 12. Turn on mechanical pump VP1.
- 13. Open pneumatic valve PV21 at the master vacuum interlock box.
- 14. Open valves MV32, MV20 and MV21. Gauge P10 will go from 10 psig to 30 in. Hg.
- 15. Close valves MV12 and MV28.  
First evacuation of target loop
- 16. Gradually open valve MV4 to pump out the target loop and connecting lines. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.
- 17. Close valve MV4.
- 18. Install a hydrogen bottle at valve MV1A, if necessary.
- 19. Make sure the hydrogen bottle is closed, then open valve MV1A.

- 20. Open hydrogen regulator R1 by turning its handle fully clockwise.
- 21. Connect ballast hose to hydrogen tank, if necessary.
- 22. Open valve MV28.
- 23. Gradually open valves MV2 and MV1. Wait until VPI's thermocouple reaches 1 mtorr.
- 24. Open valve MV12.
- 25. Open valve MV4. Wait until VP1's thermocouple gauge reaches 20 mtorr.
- 26. Close helium regulator R6 by turning its handle fully counterclockwise.
- 27. Gradually open valve MV9. Gauge P6 will drop from 40 psig to 30 in. Hg.
- 28. Close valves MV22 and MV9.
- 29. Adjust helium regulator R6 to 0 psig.
- 30. Open valve MV22.
- 31. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 32. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 1 mtorr.
- 33. Close valves MV21 and MV1.
- 34. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
- 35. Open the hydrogen bottle and adjust its regulator R1 to 0 psig.  
First backfill of target loop with hydrogen:
- 36. 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.
- 37. Close valve MV1 when gauge P8 reaches 0 psid.
- 38. Open solenoid valve SV13 momentarily to introduce hydrogen to the space between it and check valve CV13. Push the switch next to SV13 to do this.  
Second evacuation of target loop:
- 39. Gradually open valve MV21 to evacuate the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.

- 40. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 41. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 42. Close valve MV21.

Second backfill of target loop:

- 43. 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.
- 44. Open solenoid valve SV13 momentarily to introduce hydrogen to the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 45. Close valve MV1 when gauge P8 reaches 0 psid.

Third evacuation of target loop:

- 46. Gradually open valve MV21 to evacuate the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.
- 47. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 48. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 49. Close valve MV21.

Third backfill of target loop:

- 50. 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.
- 51. Open solenoid valve SV13 momentarily to introduce hydrogen to the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 52. Close valves MV1 and MV32 when gauge P8 reaches 0 psid.
- 53. Close valves MV22 and MV29 after removing the lock from MV29.
- 54. Close valve MV13.
- 55. Open valve MV11.

- 56. Adjust helium regulator R6 to 15 psig.  
Fill helium cell to two absolute atmospheres helium:
- 57. Gradually open valve MV22 until gauge P5 increases from 0 to 15 psig. Gauge P8 will go from 0 psid to 15 psid helium excess.
- 58. Close valve MV22.
- 59. Increase the hydrogen regulator R1 to 15 psig.  
Fill target loop to two absolute atmospheres hydrogen:
- 60. Gradually open valve MV1 until gauge P8 is reduced from 15 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 61. Increase the helium regulator R6 to 20 psig.  
Fill helium cell to 2.3 absolute atmospheres helium:
- 62. Gradually open valve MV22 until gauge P5 increases from 15 to 20 psig. Gauge P8 will increase to 5 psid helium excess. Do not close MV22.
- 63. Increase the hydrogen regulator R1 to 20 psig.  
Fill target loop to 2.3 absolute atmospheres hydrogen:
- 64. Gradually open valve MV1 until gauge P8 is reduced from 5 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 65. Close valve MV20.
- 66. Turn on the target loop pump.
- 67. Close valve MV11.
- 68. Increase the helium regulator R6 to 40 psig.
- 69. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK. Install lock on MV29 to keep it open.
- 70. Open valve MV31.
- 71. Set target helium regulator R30 to 45 psig.
- 72. Open valve MV46.
- 73. Close valve MV28.

- 74. Open valve MV57.
- 75. Gradually open valve MV28. This will equalize the hydrogen pressures in the target loop and the ballast tank.
- 76. Close valves MV2, MV4, and MV7.

Resume cooling the target loop:

- 77. Ask the cryo group to provide coolant to the target. As the loop cools, hydrogen will be drawn from the ballast tank.
- 78. Close pneumatic valve PV21.
- 79. Turn off mechanical pump VP1 and vent it.
- 80. Remove pump VP1 and cap off the inlet to pneumatic valve PV21.

After the loop is filled with liquid hydrogen:

- 81. Open pneumatic valve PV12 at the master vacuum interlock box.
- 82. Close valve MV12.
- 83. Close valve MV1A and the hydrogen bottle valve.
- 84. Close the hydrogen regulator R1 by turning its handle fully counterclockwise.
- 85. Open gate valve XXX before putting beam on the target and enable the target heater.
- 86. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section C for this procedure.
- 87. Confirm that all final conditions for procedure H are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## H. Replacing helium with hydrogen while the target is cold

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

## I. Replacing hydrogen with helium while the target is cold

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**I. Replacing hydrogen with helium while the target is cold.**

- 1. The target is filled with circulating liquid hydrogen as described in section B or H.
- 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 Hall C. Install the target computer there.

- 5. Confirm that all initial conditions for procedure I are met. They are the same as the final conditions for section B or H.
- 6. Close gate valve XXX from the master vacuum interlock box.
- 7. Slowly close the target JT valve until the temperature of the coolant gets to 28K. Wait until the loop comes to 28K.
- 8. Once all liquid has boiled away, the target will slowly warm up.
- 9. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section D to change the helium bottle).

NOTE: 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.

- 10. Close valve MV57.
- 11. Open valve MV7.
- 12. Gradually open valves MV2 and MV4, making sure gauge P8 doesn't go to hydrogen excess.
- 13. Slightly crack open valve MV13. Gauge P3 will drop from 10 psig to 0 psig.
- 14. Open valve MV13 fully.
- 15. Close pneumatic valve PV12.
- 16. Re-install pump VP1 and turn it on.
- 17. Open valve PV21 at the master vacuum interlock box.
- 18. Close valves MV2, MV4 and MV7.

- 19. Turn off the loop pump.
- 20. Make sure the hydrogen bottle is closed, then open valves MV21, MV1, MV1A, MV20 and MV12.
- 21. Gradually open valve MV2.
- 22. Wait until the pressure at gauge P1 has dropped to 0 psig, then open hydrogen regulator R1 by turning its handle fully clockwise.
- 23. Wait until the thermocouple gauge for pump VP1 has reached 100 mtorr, then close valve MV2.
- 24. Close valves MV46 and MV31.
- 25. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 26. Momentarily crack open valve MV45 to bleed P30 down to 0 psig, and then close MV45.  
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, MV32, MV7 and MV2.
- 29. Open target helium regulator R30 by turning its handle fully clockwise.
- 30. Open solenoid valve SV13 for several seconds to evacuate the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 31. Pump until the thermocouple gauge for pump VP1 reads 100 mtorr, then close valve MV21.
- 32. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 33. Close valve MV30.
- 34. Open valve MV31 and set its regulator R30 to 0 psig.  
First backfill of target loop with helium:
- 35. 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.
- 36. Open solenoid valve SV13 momentarily to introduce helium into the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 37. Close valve MV30.

Second evacuation of target loop:

- 38. 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.
- 39. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
- 40. Close valve MV21.

Second backfill of target loop with helium:

- 41. 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.
- 42. Close valve MV30.

Third evacuation of target loop:

- 43. 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.
- 44. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
- 45. Close valve MV21.

Third backfill of target loop with helium:

- 46. Open valve MV30 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 47. Close valves MV30, MV13, and MV32.
- 48. Close valves MV1 and MV1A.
- 49. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
- 50. Close valve MV22.
- 51. Gradually open valve MV11 to bleed gauge P4 down to 0 psig.
- 52. Remove the lock from valve MV29 and close it.
- 53. Gradually crack open valve MV22 until gauge P8 reads 15 psid helium excess, then close valve MV22.
- 54. Close valve MV11.
- 55. Set target helium regulator R30 to 10 psig.

- 56. 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.
- 57. Open valve MV29. Gauge P8 will go to 0 psid. Install lock on MV29 to keep it open.
- 58. Open valve MV22.
- 59. Close valve MV20.
- 60. Close pneumatic valve PV21.
- 61. Turn on the target loop pump.  
Resume cooling the target loop:
- 62. Ask the cryo group to resume cooling the loop to 20K. As the loop cools, gauge P9A will rise very slowly.
- 63. Turn off mechanical pump VP1 and remove it. Cap the inlet to pneumatic valve PV21.
- 64. Open gate valve XXX before putting beam on the target.
- 65. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.
- 66. Confirm that all final conditions for procedure I are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## I. Replacing hydrogen with helium while the target is cold

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	10 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	40 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	10 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	10 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	10 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	open	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**J. Warming the helium-filled target to room temperature**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	10 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	40 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	10 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	10 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	10 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	open	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	$< 10^{-4}$ torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

## J. Warming the helium-filled target to room temperature

- 1. The target is filled with circulating helium as described in section G or I.
- 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 the Hall. Install the target computer there.

- 4. Confirm that all initial conditions for procedure J are met. They are the same as the final conditions for section G or I.
- 5. Close gate valve XXX from the master vacuum interlock box.
- 6. Slowly close the JT valve until the temperature of the coolant goes to 80K. Helium will vent through solenoid valve SV13. Wait until the loop comes up to 80K.

NOTE: 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 CCG 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.
- 8. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section F to change the helium bottle).
- 9. Once the target has reached 40 K, the cryo group can remove the coolant.
- 10. Turn off the target loop pump.
- 11. Close valve MV30.
- 12. Open valve MV13. Gauge P3 will drop from 10 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 valves MV31, MV5C and MV5D.

18. Confirm that all final conditions for procedure J are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**J. Warming the helium-filled target to room temperature**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	0 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	0 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	closed	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	open	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	not in use
<input type="checkbox"/> MV11.....	open	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	open	<input type="checkbox"/> Helium bottles.....	both closed
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	closed
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	not in use
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	closed
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	not in use
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	closed	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	$< 10^{-4}$ torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank or deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**K. Evacuation and flushing of the target and filling lines with deuterium**

Initial state:

<input type="checkbox"/>	MV1.....	closed	<input type="checkbox"/>	P2.....	not in use
<input type="checkbox"/>	MV1A.....	closed	<input type="checkbox"/>	P3.....	not in use
<input type="checkbox"/>	MV2.....	closed	<input type="checkbox"/>	P4.....	not in use
<input type="checkbox"/>	MV4.....	closed	<input type="checkbox"/>	P5.....	not in use
<input type="checkbox"/>	MV5A.....	closed	<input type="checkbox"/>	P7.....	20 psig
<input type="checkbox"/>	MV5B.....	closed	<input type="checkbox"/>	P76.....	20 psig
<input type="checkbox"/>	MV5C.....	closed	<input type="checkbox"/>	P77.....	not in use
<input type="checkbox"/>	MV5D.....	closed	<input type="checkbox"/>	P8.....	not in use
<input type="checkbox"/>	MV7.....	closed	<input type="checkbox"/>	P9.....	not in use
<input type="checkbox"/>	MV9.....	closed	<input type="checkbox"/>	P10.....	not in use
<input type="checkbox"/>	MV10.....	closed	<input type="checkbox"/>	P11.....	not in use
<input type="checkbox"/>	MV11.....	closed	<input type="checkbox"/>	P12.....	not in use
<input type="checkbox"/>	PV12.....	closed	<input type="checkbox"/>	Hydrogen bottle.....	not in use
<input type="checkbox"/>	MV12.....	closed	<input type="checkbox"/>	Deuterium bottle.....	closed
<input type="checkbox"/>	SV13.....	closed	<input type="checkbox"/>	R1.....	closed
<input type="checkbox"/>	MV13.....	closed	<input type="checkbox"/>	P1.....	not in use
<input type="checkbox"/>	MV20.....	closed	<input type="checkbox"/>	Helium bottles.....	both closed
<input type="checkbox"/>	MV21.....	closed	<input type="checkbox"/>	R6.....	closed
<input type="checkbox"/>	PV21.....	closed	<input type="checkbox"/>	P6.....	not in use
<input type="checkbox"/>	MV22.....	closed	<input type="checkbox"/>	R30.....	closed
<input type="checkbox"/>	MV24.....	closed	<input type="checkbox"/>	P30.....	closed
<input type="checkbox"/>	MV28.....	closed	<input type="checkbox"/>	VP1.....	not in use
<input type="checkbox"/>	MV29.....	closed	<input type="checkbox"/>	TC for VP1.....	not in use
<input type="checkbox"/>	MV30.....	closed	<input type="checkbox"/>	VP3.....	not in use
<input type="checkbox"/>	MV31.....	closed	<input type="checkbox"/>	TC for VP3.....	not in use
<input type="checkbox"/>	MV32.....	closed	<input type="checkbox"/>	VP5.....	not in use
<input type="checkbox"/>	MV45.....	closed	<input type="checkbox"/>	TC for VP5.....	not in use
<input type="checkbox"/>	MV46.....	closed	<input type="checkbox"/>	CCG.....	$< 10^{-4}$ torr
<input type="checkbox"/>	MV57.....	closed	<input type="checkbox"/>	Target loop pump.....	not in use
<input type="checkbox"/>	MV77.....	closed	<input type="checkbox"/>	TC3.....	not in use
<input type="checkbox"/>	MV78.....	closed	<input type="checkbox"/>	Ballast hose.....	Deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**K. Evacuation and flushing of the target and filling lines with deuterium**

- 1. Confirm that all initial conditions for procedure K are met.
- 2. The vacuum chamber must be under vacuum before proceeding. DO NOT pump on the target unless the chamber is at a pressure of  $10^{-4}$  torr or less as read on cold cathode gauge CCG.
- 3. Turn on mechanical pump VP1.
- 4. Open pneumatic valve PV21 at the master vacuum interlock box.
- 5. Open valves MV46, MV1, MV30, MV13, MV20, MV32 and MV29.
- 6. Make sure the deuterium bottle is closed, then open valve MV1A.
- 7. Open valve MV77.
- 8. Open valve MV21. Gauge P10 will drop from 0 psig to 30 in. Hg.
- 9. Gradually open valve MV2.
- 10. Gradually open target helium regulator R30 by turning its handle fully clockwise.
- 11. Gradually open deuterium regulator R1 by turning its handle fully clockwise. Wait until VP1's thermocouple gauge reaches 100 mtorr.

First evacuation of target loop:

- 12. Gradually open valve MV4 to evacuate the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.
- 13. Open valves MV7, MV28 and MV12
- 14. Open valves MV10 and MV11.

First evacuation of helium cell:

- 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 valves MV5C and MV5D.
- 24. Open both helium bottle valves and adjust their regulator R6 to 0 psig.
- 25. Close valve MV5D and the helium bottle connected to it.

First backfill of helium cell with helium:

- 26. 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.
- 27. Close valve MV22.

Second 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.

Second backfill of helium cell with helium:

- 30. Gradually open valve MV22 to fill the helium cell with helium. Gauge P8 will go from 0 psid to full scale helium excess.
- 31. Close valve MV22.

Third evacuation of helium cell:

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

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

Third backfill of helium cell with helium:

- 34. Gradually open valve MV22 to fill the helium cell with helium. Gauge P8 will go from 0 psid to full scale helium excess.
- 35. Close valve MV22.
- 36. Close valves MV21 and MV30.
- 37. Close target helium regulator R30 by turning its handle fully counterclockwise.
- 38. Open valve MV31 and adjust its regulator R30 to 0 psig.
- 39. Open valves MV2 and MV4.

Backfill of target loop with helium:

- 40. 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.
- 41. Close valves MV46 and MV30 when gauge P8 reaches 0 psid.
- 42. Close valve MV31 and its regulator R30.
- 43. 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.

Second evacuation of target loop:

- 44. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid 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 deuterium regulator R1 by turning its handle fully counterclockwise.

- 49. Open the deuterium bottle valve and adjust its regulator R1 to 0 psig.

First backfill of target loop with deuterium:

- 50. Gradually open valve MV1 to fill the target loop with deuterium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 51. Close valve MV1 when gauge P8 reaches 0 psid.
- 52. Open solenoid valve SV13 momentarily to introduce deuterium to the space between it and check valve CV13. Push the button next to SV13 to do this.

Third evacuation of target loop:

- 53. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess.
- 54. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 55. 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.
- 56. Close valve MV21.

Second backfill of target loop with deuterium:

- 57. Gradually open valve MV1 to fill the target loop with deuterium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 58. Close valve MV1 when gauge P8 reaches 0 psid.
- 59. Open solenoid valve SV13 momentarily to introduce deuterium to the space between it and check valve CV13. Push the button next to SV13 to do this.

Fourth evacuation of target loop:

- 60. Gradually open valve MV21 to pump out the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess.
- 61. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 62. Confirm that all final conditions for procedure K are met.

63. Go to Section L to fill and cool the target.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**K. Evacuation and flushing of the target and filling lines with deuterium**

Final state:

<input type="checkbox"/>	MV1.....	closed	<input type="checkbox"/>	P2.....	30 in. Hg
<input type="checkbox"/>	MV1A.....	open	<input type="checkbox"/>	P3.....	30 in. Hg
<input type="checkbox"/>	MV2.....	open	<input type="checkbox"/>	P4.....	0 psig
<input type="checkbox"/>	MV4.....	open	<input type="checkbox"/>	P5.....	0 psig
<input type="checkbox"/>	MV5A.....	closed	<input type="checkbox"/>	P7.....	20 psig
<input type="checkbox"/>	MV5B.....	closed	<input type="checkbox"/>	P76.....	20 psig
<input type="checkbox"/>	MV5C.....	open	<input type="checkbox"/>	P77.....	30 in. Hg
<input type="checkbox"/>	MV5D.....	closed	<input type="checkbox"/>	P8.....	15 psid He excess
<input type="checkbox"/>	MV7.....	open	<input type="checkbox"/>	P9.....	0 psid
<input type="checkbox"/>	MV9.....	closed	<input type="checkbox"/>	P10.....	30 in. Hg
<input type="checkbox"/>	MV10.....	open	<input type="checkbox"/>	P11.....	> 200 psig
<input type="checkbox"/>	MV11.....	open	<input type="checkbox"/>	P12.....	> 200 psig
<input type="checkbox"/>	PV12.....	closed	<input type="checkbox"/>	Hydrogen bottle.....	not in use
<input type="checkbox"/>	MV12.....	open	<input type="checkbox"/>	Deuterium bottle.....	open
<input type="checkbox"/>	SV13.....	closed	<input type="checkbox"/>	R1.....	0 psig
<input type="checkbox"/>	MV13.....	open	<input type="checkbox"/>	P1.....	0 psig
<input type="checkbox"/>	MV20.....	open	<input type="checkbox"/>	Helium bottles.....	one open
<input type="checkbox"/>	MV21.....	open	<input type="checkbox"/>	R6.....	0 psig
<input type="checkbox"/>	PV21.....	open	<input type="checkbox"/>	P6.....	0 psig
<input type="checkbox"/>	MV22.....	closed	<input type="checkbox"/>	R30.....	closed
<input type="checkbox"/>	MV24.....	closed	<input type="checkbox"/>	P30.....	not in use
<input type="checkbox"/>	MV28.....	open	<input type="checkbox"/>	VP1.....	on
<input type="checkbox"/>	MV29.....	open	<input type="checkbox"/>	TC for VP1.....	< 100 mtorr
<input type="checkbox"/>	MV30.....	closed	<input type="checkbox"/>	VP3.....	not in use
<input type="checkbox"/>	MV31.....	closed	<input type="checkbox"/>	TC for VP3.....	not in use
<input type="checkbox"/>	MV32.....	open	<input type="checkbox"/>	VP5.....	not in use
<input type="checkbox"/>	MV45.....	closed	<input type="checkbox"/>	TC for VP5.....	not in use
<input type="checkbox"/>	MV46.....	closed	<input type="checkbox"/>	CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/>	MV57.....	closed	<input type="checkbox"/>	Target loop pump.....	off
<input type="checkbox"/>	MV77.....	open	<input type="checkbox"/>	TC3.....	not in use
<input type="checkbox"/>	MV78.....	closed	<input type="checkbox"/>	Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### L. Filling and cooling the target with deuterium

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	30 in. Hg
<input type="checkbox"/> MV1A.....	open	<input type="checkbox"/> P3.....	30 in. Hg
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	0 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	30 in. Hg
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	15 psid He excess
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	30 in. Hg
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	open	<input type="checkbox"/> P12.....	> 200 psig
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	open
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	0 psig
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	0 psig
<input type="checkbox"/> MV20.....	open	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	open	<input type="checkbox"/> R6.....	0 psig
<input type="checkbox"/> PV21.....	open	<input type="checkbox"/> P6.....	0 psig
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	closed
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	not in use
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	on
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	< 100 mtorr
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	closed	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	open	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**L. Filling and cooling the target with deuterium**

- 1. Evacuate and flush the target and filling lines as described in section K.
- 2. Confirm that all initial conditions for section L are met. They are the same as the final conditions for section K.
- 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.  
Fill target loop to one absolute atmosphere deuterium:
- 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, MV32 and MV13.
- 9. Increase the helium regulator R6 to 15 psig.
- 10. Close valve MV29.  
Fill helium cell to two absolute atmospheres helium:
- 11. Gradually open valve MV22 until gauge P5 increases from 0 psid to 15 psig. Gauge P8 will increase to 15 psid helium excess.
- 12. Close valve MV22.
- 13. Increase the deuterium regulator R1 to 15 psig.  
Fill target loop to two absolute atmospheres deuterium:
- 14. Gradually open valve MV1 until gauge P8 is reduced from 15 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 15. Increase the helium regulator R6 to 20 psig.  
Fill helium cell to 2.3 absolute atmospheres helium:
- 16. Gradually open valve MV22 until gauge P5 increases from 15 to 20 psig. Gauge P8 will increase to 5 psid helium excess. Do not close MV22.
- 17. Increase the deuterium regulator R1 to 20 psig.

Fill target loop to 2.3 absolute atmospheres deuterium:

- 18. Gradually open valve MV1 until gauge P8 is reduced from 5 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 19. Close valve MV11.
- 20. Increase the helium regulator R6 to 40 psig.
- 21. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK. Install lock on MV29 to keep it open.
- 22. Open valve MV31.
- 23. Set target helium regulator R30 to 45 psig.
- 24. Open valve MV46.
- 25. Close valves MV20 and MV28.
- 26. Open valve MV78.
- 27. Gradually open valve MV28. This will equalize the deuterium pressures in the target loop and the ballast tank.
- 28. Close valves MV2, MV4 and MV7.

Cooling the target loop:

- 29. Turn on the target loop pump. As the deuterium cools, gauge P9 will rise very slowly.
- 30. Ask the cryo group to provide coolant to the target. As the loop cools, deuterium will be drawn from the ballast tank.

After the loop is filled with liquid deuterium:

- 32. Open pneumatic valve PV12 at the master vacuum interlock box.
- 33. Close valve MV12.
- 34. Close valve MV1A and the deuterium bottle valve.
- 34. Close the deuterium regulator R1 by turning its handle fully counterclockwise.
- 35. Open gate valve XXX before putting beam on the target.
- 36. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section F for this procedure.

37. Confirm that all final conditions for procedure L are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## L. Filling and cooling the target with deuterium

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	10 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	10 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### M. Warming the deuterium-filled target to room temperature

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	10 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	10 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### M. Warming the deuterium-filled target to room temperature

- 1. The target is filled with circulating liquid deuterium as described in section L.
- 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 Hall C. Install the target computer there.

- 5. Confirm that all initial conditions for procedure M are met. They are the same as the final conditions for section L.
- 6. Close gate valve XXX from the master vacuum interlock box.

NOTE: 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 or at gauge P3 on the gas panel. As the target starts to boil, its pressure will increase and deuterium will go to the ballast tank through check valve CV12. If the target pressure reaches 22 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 20 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.
- 11. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section C to change the helium bottle).

NOTE: 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 cold cathode gauge CCG 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. Turn off the target loop pump.
- 13. Slightly crack open valve MV13. Gauge P3 will drop from ~20 psig to 0 psig.
- 14. Open valve MV13 fully.
- 15. Proceed to section N to purge deuterium from the target loop.
- 16. Confirm that all final conditions for procedure M are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

### M. Warming the deuterium-filled target to room temperature

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	20 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**N. Purging deuterium from the target loop.**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	20 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**N. Purging deuterium from the target loop**

- 1. The deuterium 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 M.
- 3. Confirm that all initial conditions for procedure N are met. They are the same as the final conditions for procedure M.
- 4. Re-install pump VP1 and turn it on.
- 5. Open valve PV21 at the master vacuum interlock box.
- 6. Close valves MV78 and MV77.
- 7. Make sure the deuterium bottle is closed, then open valves MV21, MV1, MV1A, MV32 and MV20. Gauge P10 will go to 30 in. Hg.
- 8. Gradually open valve MV12 to vent the line to the ballast tank to 0 psig.
- 9. Gradually open valve MV2.
- 10. Wait until the pressure at gauge P1 has dropped to 0 psig, then open deuterium regulator R1 by turning its handle fully clockwise.  
First evacuation of target loop:
- 11. 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.
- 12. 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.
- 13. Pump until VP1's thermocouple gauge reaches 100 mtorr.
- 14. Close valve MV31.
- 15. Open valve MV30.
- 16. Open target helium regulator R30 by turning its handle fully clockwise. Gauge P30 will drop to 30 in. Hg.
- 17. Close valve MV30.
- 18. Close target helium regulator R30 by turning its handle fully counterclockwise.

19. Open valve MV31 and adjust its regulator R30 to 0 psig.

20. Close valve MV21.

First backfill of target loop with helium:

21. 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.

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

23. Close valve MV30.

Second evacuation of target loop:

24. 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.

25. 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.

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

27. Close valve MV21.

Second backfill of target loop with helium:

28. 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.

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

30. Close valves MV30, MV32 and MV46.

31. Close valve MV22.

32. Open valve MV9.

33. Open valve MV11.

34. Open valve MV7.

35. Close pneumatic valve PV21 at the master vacuum interlock box.

36. Close valves MV1 and MV1A.

- 37. Turn off mechanical pump VP1 and vent it.
- 38. Close deuterium regulator R1 by turning its handle fully counterclockwise.
- 39. Close the helium bottle valve and valve MV5C.
- 40. Close helium regulator R6 by turning its handle fully counterclockwise.
- 41. Close valve MV31.
- 42. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 43. Confirm that all final conditions for procedure N are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**N. Purging deuterium from the target loop.**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	0 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	0 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	0 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	0 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	closed	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	open	<input type="checkbox"/> P10.....	0 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	0 psig
<input type="checkbox"/> MV11.....	open	<input type="checkbox"/> P12.....	0 psig
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	open	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	open	<input type="checkbox"/> Helium bottles.....	both closed
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	closed
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	not in use
<input type="checkbox"/> MV22.....	closed	<input type="checkbox"/> R30.....	closed
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	not in use
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	off
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	closed	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	$< 10^{-4}$ torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	off
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### O. Replacing helium with deuterium while the target is cold

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	10 psig
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	open	<input type="checkbox"/> P4.....	40 psig
<input type="checkbox"/> MV4.....	open	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	open	<input type="checkbox"/> P9.....	0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	10 psig
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	closed	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	open	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	10 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	10 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	off
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	open	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	closed	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	deuterium tank or hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**O. Replacing helium with deuterium while the target is cold**

- 1. The target is filled with circulating helium as described in section G.
- 2. Turn off the beam and set the interlock so beam may not be put on the target.  
At this point it will be necessary to enter Hall C. Install the target computer there.
- 3. Confirm that all initial conditions for procedure O are met. They are the same as the final conditions for section G.
- 4. Close gate valve XXX from the master vacuum interlock box.
- 5. Slowly close the target JT valve until the temperature of the coolant goes to 28 K. Helium will vent through SV13. Wait until the loop comes to 28 K.
- 6. Close valve MV30.
- 7. Close valve MV31.
- 8. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 9. Gradually open valve MV13. Gauge P3 will drop from 10 psig to 0 psig. Gauges P2, P5 and P10 will do the same.
- 10. Close valves MV2 and MV4.
- 11. Turn off the target loop pump.
- 12. Turn on mechanical pump VP1.
- 13. Open pneumatic valve PV21 at the master vacuum interlock box.
- 14. Open valves MV20, MV32 and MV21. Gauge P10 will go from 10 psig to 30 in. Hg.
- 15. Close valves MV12 and MV28.  
First evacuation of target loop
- 16. Gradually open valve MV4 to pump out the target loop and connecting lines. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.
- 17. Close valve MV4.
- 18. Install a deuterium bottle at valve MV1A, if necessary.
- 19. Make sure the deuterium bottle is closed, then open valve MV1A.

- 20. Open deuterium regulator R1 by turning its handle fully clockwise.
- 21. Connect ballast hose to deuterium tank, if necessary.
- 22. Open valve MV77.
- 23. Open valve MV28.
- 24. Gradually open valves MV2 and MV1. Wait until VPI's thermocouple gauge reaches 1 mtorr.
- 25. Open valve MV12.
- 26. Open valve MV4. Wait until VP1's thermocouple gauge reaches 20 mtorr.
- 27. Close helium regulator R6 by turning its handle fully counterclockwise.
- 28. Gradually open valve MV9. Gauge P6 will drop from 40 psig to 30 in. Hg.
- 29. Close valves MV22 and MV9.
- 30. Adjust helium regulator R6 to 0 psig.
- 31. Open valve MV22.
- 32. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 33. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 1 mtorr.
- 34. Close valves MV21 and MV1.
- 35. Close deuterium regulator R1 by turning its handle fully counterclockwise.
- 36. Open the deuterium bottle and adjust its regulator R1 to 0 psig.  
First backfill of target loop with deuterium:
- 37. Gradually open valve MV1 to fill the target loop with deuterium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 38. Close valve MV1 when gauge P8 reaches 0 psid.
- 39. Open solenoid valve SV13 momentarily to introduce deuterium to the space between it and check valve CV13. Push the switch next to SV13 to do this.  
Second evacuation of target loop:

- 40. Gradually open valve MV21 to evacuate the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 to 30 in. Hg.
- 41. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 42. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 43. Close valve MV21.  
Second backfill of target loop:
- 44. Gradually open valve MV1 to fill the target loop with deuterium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 45. Open solenoid valve SV13 momentarily to introduce deuterium to the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 46. Close valve MV1 when gauge P8 reaches 0 psid.  
Third evacuation of target loop:
- 47. Gradually open valve MV21 to evacuate the target loop and plumbing. Gauge P8 will go from 0 psid to full scale helium excess. Gauge P3 will go from 0 psid to 30 in. Hg.
- 48. Open solenoid valve SV13 for several seconds to pump out the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 49. Continue pumping on the target loop and plumbing until VP1's thermocouple gauge reaches 100 mtorr.
- 50. Close valve MV21.  
Third backfill of target loop:
- 51. Gradually open valve MV1 to fill the target loop with deuterium. Gauge P8 will go from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 52. Open solenoid valve SV13 momentarily to introduce deuterium to the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 53. Close valves MV1 and MV32 when gauge P8 reaches 0 psid.
- 54. Close valves MV22 and MV29 after removing the lock from MV29.
- 55. Close valve MV13.

- 56. Open valve MV11.
- 57. Adjust helium regulator R6 to 15 psig.  
Fill helium cell to two absolute atmospheres helium:
- 58. Gradually open valve MV22 until gauge P5 increases from 0 to 15 psig. Gauge P8 will go from 0 psid to 15 psid helium excess.
- 59. Close valve MV22.
- 60. Increase the deuterium regulator R1 to 15 psig.  
Fill target loop to two absolute atmospheres deuterium:
- 61. Gradually open valve MV1 until gauge P8 is reduced from 15 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 62. Increase the helium regulator R6 to 20 psig.  
Fill helium cell to 2.3 absolute atmospheres helium:
- 63. Gradually open valve MV22 until gauge P5 increases from 15 to 20 psig. Gauge P8 will increase to 5 psid helium excess. Do not close MV22.
- 64. Increase the deuterium regulator R1 to 20 psig.  
Fill target loop to 2.3 absolute atmospheres deuterium:
- 65. Gradually open valve MV1 until gauge P8 is reduced from 5 psid to 0 psid helium excess, and then close MV1. DO NOT let gauge P8 go to hydrogen excess.
- 66. Close valve MV20.
- 67. Turn on the target loop pump.
- 68. Close valve MV11.
- 69. Increase the helium regulator R6 to 40 psig.
- 70. Gradually open valve MV29. You may hear some helium vent through check valve CV6. This is OK. Install lock on MV29 to keep it open.
- 71. Open valve MV31.
- 72. Set target helium regulator R30 to 45 psig.
- 73. Open valve MV46.

- 74. Close valve MV28.
- 75. Open valve MV78.
- 76. Gradually open valve MV28. This will equalize the deuterium pressures in the target loop and the ballast tank.
- 77. Close valves MV2, MV4, and MV7.

Resume cooling the target loop:

- 78. Ask the cryo group to provide coolant to the target. As the loop cools, deuterium will be drawn from the ballast tank.
- 79. Close pneumatic valve PV21.
- 80. Turn off mechanical pump VP1 and vent it.
- 81. Remove pump VP1 and cap off the inlet to pneumatic valve PV21.

After the loop is filled with liquid deuterium:

- 82. Open pneumatic valve PV12 at the master vacuum interlock box.
- 83. Close valve MV12.
- 84. Close valve MV1A and the deuterium bottle valve.
- 85. Close the deuterium regulator R1 by turning its handle fully counterclockwise.
- 86. Open gate valve XXX before putting beam on the target and enable the target heater.
- 87. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.
- 88. Confirm that all final conditions for procedure O are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**O. Replacing helium with deuterium while the target is cold**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	10 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	10 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

### P. Replacing deuterium with helium while the target is cold

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	10 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	10 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**P. Replacing deuterium with helium while the target is cold.**

- 1. The target is filled with circulating liquid deuterium as described in section L 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 Hall C. 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 L or O.
- 6. Close gate valve XXX from the master vacuum interlock box.
- 7. Slowly close the target JT valve until the temperature of the coolant gets to 28K. Wait until the loop comes to 28K.
- 8. Once all liquid has boiled away, the target will slowly warm up.
- 9. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section D to change the helium bottle).

NOTE: 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.

- 10. Close valves MV77 and MV78.
- 11. Open valve MV7.
- 12. Gradually open valves MV2 and MV4, making sure gauge P8 doesn't go to hydrogen excess.
- 13. Slightly crack open valve MV13. Gauge P3 will drop from 10 psig to 0 psig.
- 14. Open valve MV13 fully.
- 15. Close pneumatic valve PV12.
- 16. Re-install pump VP1 and turn it on.
- 17. Open valve PV21 at the master vacuum interlock box.
- 18. Close valves MV2, MV4 and MV7.

- 19. Turn off the loop pump.
- 20. Make sure the deuterium bottle is closed, then open valves MV21, MV1, MV1A, MV20 and MV12.
- 21. Gradually open valve MV2.
- 22. Wait until the pressure at gauge P1 has dropped to 0 psig, then open deuterium regulator R1 by turning its handle fully clockwise.
- 23. Wait until the pressure at the gauge P2 has reached 100 mtorr, then close valve MV2.
- 24. Close valves MV46 and MV31.
- 25. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 26. Momentarily crack open valve MV45 to bleed P30 down to 0 psig, and then close MV45.  
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, MV32, MV7 and MV2.
- 29. Open target helium regulator R30 by turning its handle fully clockwise.
- 30. Open solenoid valve SV13 for several seconds to evacuate the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 31. Pump until the thermocouple gauge for pump VP1 reads 100 mtorr, then close valve MV21.
- 32. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 33. Close valve MV30.
- 34. Open valve MV31 and set its regulator R30 to 0 psig.  
First backfill of target loop with helium:
- 35. 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.
- 36. Open solenoid valve SV13 momentarily to introduce helium into the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 37. Close valve MV30.

Second evacuation of target loop:

- 38. 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.
- 39. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
- 40. Close valve MV21.

Second backfill of target loop with helium:

- 41. 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.
- 42. Close valve MV30.

Third evacuation of target loop:

- 43. 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.
- 44. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
- 45. Close valve MV21.

Third backfill of target loop with helium:

- 46. Open valve MV30 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 47. Close valves MV30, MV13, and MV32.
- 48. Close valves MV1 and MV1A.
- 49. Close deuterium regulator R1 by turning its handle fully counterclockwise.
- 50. Close valve MV22.
- 51. Gradually open valve MV11 to bleed gauge P4 down to 0 psig.
- 52. Remove the lock from valve MV29 and close it.
- 53. Gradually crack open valve MV22 until gauge P8 reads 15 psid helium excess, then close valve MV22.
- 54. Close valve MV11.
- 55. Set target helium regulator R30 to 10 psig.

- 56. 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.
- 57. Open valve MV29. Gauge P8 will go to 0 psid. Install lock on MV29 to keep it open.
- 58. Open valve MV22.
- 59. Close valve MV20.
- 60. Close pneumatic valve PV21.
- 61. Turn on the target loop pump.  
Resume cooling the target loop:
- 62. Ask the cryo group to resume cooling the loop to 20K. As the loop cools, gauge P9A will rise very slowly.
- 63. Turn off mechanical pump VP1 and remove it. Cap the inlet to pneumatic valve PV21.
- 64. Open gate valve XXX before putting beam on the target.
- 65. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.
- 66. Confirm that all final conditions for procedure P are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

### P. Replacing deuterium with helium while the target is cold

Final state:

<input type="checkbox"/>	MV1.....	closed	<input type="checkbox"/>	P2.....	10 psig
<input type="checkbox"/>	MV1A.....	closed	<input type="checkbox"/>	P3.....	10 psig
<input type="checkbox"/>	MV2.....	open	<input type="checkbox"/>	P4.....	40 psig
<input type="checkbox"/>	MV4.....	open	<input type="checkbox"/>	P5.....	10 psig
<input type="checkbox"/>	MV5A.....	closed	<input type="checkbox"/>	P7.....	20 psig
<input type="checkbox"/>	MV5B.....	closed	<input type="checkbox"/>	P76.....	20 psig
<input type="checkbox"/>	MV5C.....	open	<input type="checkbox"/>	P77.....	not in use
<input type="checkbox"/>	MV5D.....	closed	<input type="checkbox"/>	P8.....	0 psid
<input type="checkbox"/>	MV7.....	open	<input type="checkbox"/>	P9.....	0 psid
<input type="checkbox"/>	MV9.....	closed	<input type="checkbox"/>	P10.....	10 psig
<input type="checkbox"/>	MV10.....	open	<input type="checkbox"/>	P11.....	> 200 psig
<input type="checkbox"/>	MV11.....	closed	<input type="checkbox"/>	P12.....	not in use
<input type="checkbox"/>	PV12.....	closed	<input type="checkbox"/>	Hydrogen bottle.....	not in use
<input type="checkbox"/>	MV12.....	open	<input type="checkbox"/>	Deuterium bottle.....	closed
<input type="checkbox"/>	SV13.....	closed	<input type="checkbox"/>	R1.....	closed
<input type="checkbox"/>	MV13.....	closed	<input type="checkbox"/>	P1.....	not in use
<input type="checkbox"/>	MV20.....	closed	<input type="checkbox"/>	Helium bottles.....	one open
<input type="checkbox"/>	MV21.....	closed	<input type="checkbox"/>	R6.....	40 psig
<input type="checkbox"/>	PV21.....	closed	<input type="checkbox"/>	P6.....	40 psig
<input type="checkbox"/>	MV22.....	open	<input type="checkbox"/>	R30.....	10 psig
<input type="checkbox"/>	MV24.....	closed	<input type="checkbox"/>	P30.....	10 psig
<input type="checkbox"/>	MV28.....	open	<input type="checkbox"/>	VP1.....	off
<input type="checkbox"/>	MV29.....	locked open	<input type="checkbox"/>	TC for VP1.....	not in use
<input type="checkbox"/>	MV30.....	open	<input type="checkbox"/>	VP3.....	not in use
<input type="checkbox"/>	MV31.....	open	<input type="checkbox"/>	TC for VP3.....	not in use
<input type="checkbox"/>	MV32.....	closed	<input type="checkbox"/>	VP5.....	not in use
<input type="checkbox"/>	MV45.....	closed	<input type="checkbox"/>	TC for VP5.....	not in use
<input type="checkbox"/>	MV46.....	closed	<input type="checkbox"/>	CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/>	MV57.....	closed	<input type="checkbox"/>	Target loop pump.....	on
<input type="checkbox"/>	MV77.....	closed	<input type="checkbox"/>	TC3.....	not in use
<input type="checkbox"/>	MV78.....	closed	<input type="checkbox"/>	Ballast hose.....	Deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**Q. Replacing hydrogen with deuterium while the target is cold**

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	not in use
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**Q. Replacing hydrogen with deuterium while the target is cold.**

- 1. The target is filled with circulating liquid hydrogen as described in section B or H.
- 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 Hall C. Install the target computer there.

- 5. Confirm that all initial conditions for procedure Q are met. They are the same as the final conditions for section B or H.
- 6. Close gate valve XXX from the master vacuum interlock box.
- 7. Slowly close the target JT valve until the temperature of the coolant gets to 28K. Wait until the loop comes to 28K.
- 8. Once all liquid has boiled away, the target will slowly warm up.
- 9. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section D to change the helium bottle).

NOTE: 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.

- 10. Close valve MV57.
- 11. Replace the hydrogen bottle with a deuterium bottle.
- 12. Open valve MV7.
- 13. Gradually open valves MV2 and MV4, making sure gauge P8 doesn't go to hydrogen excess.
- 14. Slightly crack open valve MV13. Gauge P3 will drop from 10 psig to 0 psig.
- 15. Open valve MV13 fully.
- 16. Close pneumatic valve PV12.
- 17. Re-install pump VP1 and turn it on.
- 18. Open valve PV21 at the master vacuum interlock box.

- 19. Close valves MV2, MV4 and MV7.
- 20. Turn off the loop pump.
- 21. Make sure the deuterium bottle is closed, then open valves MV21, MV1, MV1A, MV20 and MV12.
- 22. Gradually open valve MV2.
- 23. Open deuterium regulator R1 by turning its handle fully clockwise.
- 24. Wait until the thermocouple gauge for pump VP1 has reached 100 mtorr, then close valve MV2.
- 25. Close valves MV46 and MV31.
- 26. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 27. Momentarily crack open valve MV45 to bleed P30 down to 0 psig, and then close it.  
First evacuation of target loop:
- 28. 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.
- 29. Open valves MV30, MV32, MV7 and MV2.
- 30. Open target helium regulator R30 by turning its handle fully clockwise.
- 31. Open solenoid valve SV13 for several seconds to evacuate the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 32. Pump until the thermocouple gauge for pump VP1 reads 100 mtorr, then close valve MV21.
- 33. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 34. Close valve MV30.
- 35. Open valve MV31 and set its regulator R30 to 0 psig.  
First backfill of target loop with helium:
- 36. 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.
- 37. Open solenoid valve SV13 momentarily to introduce helium into the space between it and check valve CV13. Push the switch next to SV13 to do this.

- 38. Close valve MV30.
- 39. Close valve MV28.
- 40. Change the ballast hose over to the deuterium tank.
- 41. Close valves MV4 and MV12.
- 42. Open valve MV28.

Second evacuation of target loop:

- 43. Gradually open valve MV21 to evacuate the target loop through check valve CV12. Gauge P3 will go from 0 psig to 30 in. Hg. Gauge P8 will go from 0 psid to full scale helium excess. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 1 mtorr.
- 44. Open valve MV77.
- 45. Open valves MV4 and MV12.
- 46. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 1 mtorr.
- 47. Close valve MV21.
- 48. Close valve MV1.
- 49. Close deuterium regulator R1 by turning its handle fully counterclockwise.
- 50. Open the deuterium bottle valve and adjust its regulator to 0 psi.

First backfill of target loop with deuterium:

- 51. Gradually open valve MV1 until gauge P8 goes from full scale helium excess to 0 psid helium excess. DO NOT let gauge P8 go to hydrogen excess.
- 52. Close valve MV1.

Third evacuation of target loop:

- 53. 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.
- 54. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
- 55. Close valve MV21.

Second backfill of target loop with deuterium:

56. Open valve MV1 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

57. Close valve MV1.

Fourth evacuation of target loop:

58. 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.

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

60. Close valve MV21.

Third backfill of target loop with deuterium:

61. Open valve MV1 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

62. Close valve MV1.

63. Close valves MV13 and MV32.

64. Close valve MV1A.

65. Close deuterium regulator R1 by turning its handle fully counterclockwise.

66. Close the deuterium bottle.

67. Close valve MV28.

68. Open valve MV78.

69. Crack open valve MV28 to equalize the pressure in the target loop with the deuterium ballast. The helium cell pressure will track with it. Make sure gauge P8 stays at 0 psid. The equalized target pressure will be 20 psig.

70. Open valve MV28 fully.

71. Close valves MV2, MV4 and MV7.

72. Set target helium regulator R30 to 45 psig.

73. Open valve MV46.

74. Close valve MV20.

75. Close pneumatic valve PV21.

- 76. Turn on the target loop pump.

Resume cooling the target loop:

- 77. Ask the cryo group to resume cooling the loop. As the loop cools, gauge P9A will rise very slowly.
- 78. Turn off mechanical pump VP1 and remove it. Cap the inlet to pneumatic valve PV21.  
After the loop is filled with liquid deuterium:
- 79. Open pneumatic valve PV12 at the master vacuum interlock box.
- 80. Close valve MV12.
- 81. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section C for this procedure.
- 82. Open gate valve XXX before putting beam on the target.
- 83. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section G for this procedure.
- 84. Confirm that all final conditions for procedure Q are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**Q. Replacing hydrogen with deuterium while the target is cold**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	10 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	10 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

## R. Replacing deuterium with hydrogen while the target is cold

Initial state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	20 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	10 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	10 psig
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	not in use
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	closed
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	closed	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	open	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	open	<input type="checkbox"/> Ballast hose.....	deuterium tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**R. Replacing deuterium with hydrogen while the target is cold.**

- 1. The target is filled with circulating liquid deuterium as described in section L, O or Q.
- 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 Hall C. Install the target computer there.

- 5. Confirm that all initial conditions for procedure R are met. They are the same as the final conditions for section L, O or Q.
- 6. Close gate valve XXX from the master vacuum interlock box.
- 7. Slowly close the target JT valve until the temperature of the coolant gets to 28K. Wait until the loop comes to 28K.
- 8. Once all liquid has boiled away, the target will slowly warm up.
- 9. Change the helium bottle going to the helium cell if the bottle pressure drops below 200 psig (see section D to change the helium bottle).  
NOTE: 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.
- 10. Close valves MV77 and MV78.
- 11. Replace the deuterium bottle with a hydrogen bottle.
- 12. Open valve MV7.
- 13. Gradually open valves MV2 and MV4, making sure gauge P8 doesn't go to hydrogen excess.
- 14. Slightly crack open valve MV13. Gauge P3 will drop from 10 psig to 0 psig.
- 15. Open valve MV13 fully.
- 16. Close pneumatic valve PV12.
- 17. Re-install pump VP1 and turn it on.
- 18. Open valve PV21 at the master vacuum interlock box.

- 19. Close valves MV2, MV4 and MV7.
- 20. Turn off the loop pump.
- 21. Make sure the hydrogen bottle is closed, then open valves MV21, MV1, MV1A, MV20 and MV12.
- 22. Gradually open valve MV2.
- 23. Wait until the pressure at gauge P1 has dropped to 0 psig, then open hydrogen regulator R1 by turning its handle fully clockwise.
- 24. Wait until the thermocouple gauge for pump VP1 has reached 100 mtorr, then close valve MV2.
- 25. Close valves MV46 and MV31.
- 26. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 27. Momentarily crack open valve MV45 to bleed P30 down to 0 psig, and then close it.  
First evacuation of target loop:
- 28. 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.
- 29. Open valves MV30, MV32, MV7 and MV2.
- 30. Open target helium regulator R30 by turning its handle fully clockwise.
- 31. Open solenoid valve SV13 for several seconds to evacuate the space between it and check valve CV13. Push the switch next to SV13 to do this.
- 32. Pump until the thermocouple gauge for pump VP1 reads 100 mtorr, then close valve MV21.
- 33. Close the target helium regulator R30 by turning its handle fully counterclockwise.
- 34. Close valve MV30.
- 35. Open valve MV31 and set its regulator R30 to 0 psig.  
First backfill of target loop with helium:
- 36. 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.
- 37. Open solenoid valve SV13 momentarily to introduce helium into the space between it and check valve CV13. Push the switch next to SV13 to do this.

- 38. Close valve MV30.
- 39. Close valve MV28.
- 40. Change the ballast hose over to the hydrogen tank.
- 41. Close valves MV4 and MV12.
- 42. Open valve MV28.

Second evacuation of target loop:

- 43. Gradually open valve MV21 to evacuate the target loop through check valve CV12. Gauge P3 will go from 0 psig to 30 in. Hg. Gauge P8 will go from 0 psid to full scale helium excess. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 1 mtorr.
- 44. Open valves MV4 and MV12.
- 45. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 1 mtorr.
- 46. Close valve MV21.
- 47. Close valve MV1.
- 48. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
- 49. Open the hydrogen bottle valve and adjust its regulator R1 to 0 psi.

First backfill of target loop with hydrogen:

- 50. Gradually open valve MV1 until gauge P8 goes from full scale helium excess to 0 psid helium excess. DO NOT let gauge P8 go to hydrogen excess.
- 51. Close valve MV1.

Third evacuation of target loop:

- 52. 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.
- 53. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
- 54. Close valve MV21.

Second backfill of target loop with hydrogen:

- 55. Open valve MV1 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.

- 56. Close valve MV1.

Fourth evacuation of target loop:

- 57. 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.
- 58. Wait until the pressure at the thermocouple gauge for pump VP1 has reached 100 mtorr.
- 59. Close valve MV21.

Third backfill of target loop with hydrogen:

- 60. Open valve MV1 until gauge P8 goes from full scale helium excess to 0 psid. DO NOT let gauge P8 go to hydrogen excess.
- 61. Close valve MV1.
- 62. Close valves MV13 and MV32.
- 63. Close valve MV1A.
- 64. Close hydrogen regulator R1 by turning its handle fully counterclockwise.
- 65. Close the hydrogen bottle.
- 66. Close valve MV28.
- 67. Open valve MV57.
- 68. Crack open valve MV28 to equalize the pressure in the target loop with the hydrogen ballast. The helium cell pressure will track with it. Make sure gauge P8 stays at 0 psid. The equalized pressure will be 20 psig.
- 69. Open valve MV28 fully.
- 70. Close valves MV2, MV4 and MV7.
- 71. Set target helium regulator R30 to 45 psig.
- 72. Open valve MV46.
- 73. Close valve MV20.
- 74. Close pneumatic valve PV21.
- 75. Turn on the target loop pump.

Resume cooling the target loop:

- 76. Ask the cryo group to resume cooling the loop to 20K. As the loop cools, gauge P9A will rise very slowly.
- 77. Turn off mechanical pump VP1 and remove it. Cap the inlet to pneumatic valve PV21.  
After the loop is filled with liquid hydrogen:
- 78. Open pneumatic valve PV12 at the master vacuum interlock box.
- 79. Close valve MV12.
- 80. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psi. See section E for this procedure.
- 81. Open gate valve XXX before putting beam on the target.
- 82. Continue to monitor the helium bottle. Replace it when its pressure falls below 200 psig. See section C for this procedure.
- 83. Confirm that all final conditions for procedure R are met.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**R. Replacing deuterium with hydrogen while the target is cold**

Final state:

<input type="checkbox"/> MV1.....	closed	<input type="checkbox"/> P2.....	not in use
<input type="checkbox"/> MV1A.....	closed	<input type="checkbox"/> P3.....	10 psig
<input type="checkbox"/> MV2.....	closed	<input type="checkbox"/> P4.....	45 psig
<input type="checkbox"/> MV4.....	closed	<input type="checkbox"/> P5.....	10 psig
<input type="checkbox"/> MV5A.....	closed	<input type="checkbox"/> P7.....	10 psig
<input type="checkbox"/> MV5B.....	closed	<input type="checkbox"/> P76.....	20 psig
<input type="checkbox"/> MV5C.....	open	<input type="checkbox"/> P77.....	not in use
<input type="checkbox"/> MV5D.....	closed	<input type="checkbox"/> P8.....	0 psid
<input type="checkbox"/> MV7.....	closed	<input type="checkbox"/> P9.....	> 0 psid
<input type="checkbox"/> MV9.....	closed	<input type="checkbox"/> P10.....	not in use
<input type="checkbox"/> MV10.....	open	<input type="checkbox"/> P11.....	> 200 psig
<input type="checkbox"/> MV11.....	closed	<input type="checkbox"/> P12.....	not in use
<input type="checkbox"/> PV12.....	open	<input type="checkbox"/> Hydrogen bottle.....	closed
<input type="checkbox"/> MV12.....	closed	<input type="checkbox"/> Deuterium bottle.....	not in use
<input type="checkbox"/> SV13.....	closed	<input type="checkbox"/> R1.....	closed
<input type="checkbox"/> MV13.....	closed	<input type="checkbox"/> P1.....	not in use
<input type="checkbox"/> MV20.....	closed	<input type="checkbox"/> Helium bottles.....	one open
<input type="checkbox"/> MV21.....	closed	<input type="checkbox"/> R6.....	40 psig
<input type="checkbox"/> PV21.....	closed	<input type="checkbox"/> P6.....	40 psig
<input type="checkbox"/> MV22.....	open	<input type="checkbox"/> R30.....	45 psig
<input type="checkbox"/> MV24.....	closed	<input type="checkbox"/> P30.....	45 psig
<input type="checkbox"/> MV28.....	open	<input type="checkbox"/> VP1.....	not in use
<input type="checkbox"/> MV29.....	locked open	<input type="checkbox"/> TC for VP1.....	not in use
<input type="checkbox"/> MV30.....	closed	<input type="checkbox"/> VP3.....	not in use
<input type="checkbox"/> MV31.....	open	<input type="checkbox"/> TC for VP3.....	not in use
<input type="checkbox"/> MV32.....	closed	<input type="checkbox"/> VP5.....	not in use
<input type="checkbox"/> MV45.....	closed	<input type="checkbox"/> TC for VP5.....	not in use
<input type="checkbox"/> MV46.....	open	<input type="checkbox"/> CCG.....	< 10 <sup>-4</sup> torr
<input type="checkbox"/> MV57.....	open	<input type="checkbox"/> Target loop pump.....	on
<input type="checkbox"/> MV77.....	closed	<input type="checkbox"/> TC3.....	not in use
<input type="checkbox"/> MV78.....	closed	<input type="checkbox"/> Ballast hose.....	Hydrogen tank

Name: \_\_\_\_\_

Date: \_\_\_\_\_