LIGO-E940024-01-B

* * * FACSIMILE MESSAGE * * *

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FAX NUMBER IS: 815 439 6011
VERIFY NUMBER IS: 815 439 6322

PAGE: 1 **OF:** 15

DATE: July 22, 1994

TO: Larry Jones
Caltech

FAX NO.: 818/304-9834

FROM: Warren A. Carpenter
Process Engineering Department
CBI Technical Services Co.

RE: QUAL. TEST PROCEDURE
LIGO QUALIFICATION TEST
FACILITY
930212 File # 2.2.5

Attached is the qualification test procedure for pump down and outgassing testing. Please review and let me know if you have any comments. Minor comments may be changed prior to our meeting next week but major changes will probably need to be completed after the meeting.

Regards,

Warren A. Carpenter
Senior Engineer

FAX CC TO: Rai Weiss - MIT 617/253-7014

CBI	CBI PROPRIETARY	IDENTIFICATION OUTGAS			
TITLE	QUALIFICATION TEST PUMPDOWN AND OUTGASSING TEST PROCEDURE	REFERENCE NO. 930212		SHT 1 OF 14	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WAC	CHKD BY MLT	MADE BY WAC	CHKD BY PM
		DATE 3/14/94	DATE 3/14/94	DATE 7/22/94	DATE 7/22/94

QUALIFICATION TEST
PUMP DOWN AND OUTGASSING TESTS

1.0 RECORD KEEPING

All operating data taken, the time, the date, all physical actions (such as opening or closing a valve) and all mental impressions, visual evidence or unusual occurrences (such as how fast the system is pumping down or that the power is fluctuating) shall be recorded in the lab notebook and the appropriate computer. Operating data shall include pressures, piping, and tube temperatures, bake-out durations etc. The operator shall initial each page of the lab notebook. All RGA data will be automatically recorded on the RGA computer.

Each log entry in the computer shall include the system state vector as well as a discussion of the changes made or the operations performed. The system state vector shall list the critical valves, and cold traps and the state of each valve or cold trap. The state vector shall signify an open or operating condition by recording a one. The state vector shall signify a closed or non operating condition by recording a zero. Examples of the system state vector are shown through out this procedure.

2.0 PREPARATION

It is assumed that the system is in all respects ready for evacuation and bake out with the exception that the insulation shall not be installed. The system (including the tube sections, ports and all weld seams) shall have been preliminarily leak tested in accordance with procedures LIGOTPQT, HMST1QT, HMST2QT . The system including the beam tube and all piping and fittings has been cleaned in accordance with project procedures CL1QT, CL2QT, CL3QT and CRWAQT. It is also assumed that the pump out and outgassing measurement system has been operated, baked out and calibrated such that the background outgassing levels are known and acceptable.

The facility shall be inspected to ensure that the utilities are available. Electrical breakers are turned on, water and air are available, nitrogen and helium bottles are available in sufficient quantities for the test.

2.1 Apparel

Test personnel shall wear, as a minimum, the following protective clothing:

1. Lab coat

2. Clean room gloves
3. Clean room hat
4. Clean room shoe covers

3.0 EVACUATION

3.1 Pre evacuation check list

1. Visually check that all ports are closed
2. Confirm that all utilities such as electricity, nitrogen, helium, etc. are available and operating
3. Confirm that all of the pumping system has been leak tested and all leaks have been repaired and confirmed leak tight.
4. The pirani gaging systems are turned on and operating
5. Activate the data acquisition system and start recording the temperature and pressure data. The data will be recorded for the duration of the qualification test. Each day, the data shall be copied to a separate file and sent to Caltech and MIT. Temperature data will include the 26 thermocouples which are located in the following locations:
   - 2 at one fixed support
   - 2 on each end cap
   - 3 at each power tie-in
   - 4 around the bellows
   - 2 at the guided support
   - 4 around at two locations on the tube

   Vacuum gages to be recorded are P1, CC1, CC2 and CC3. These gages shall be recorded at all times except during RGA measurements. All gages shall be turned off during RGA measurements.
6. Visually confirm that all structural elements have been installed.
7. Confirm that the I^2R bake out wiring is in place and has been tested
8. Confirm that the leak testing equipment such as the helium leak detector has been installed in accordance with HMST4QT
9. Confirm that valves, rotating equipment, cold traps and vacuum gages are tagged
10. Confirm that viscous inbleed valves (V-23 & 24) for the roughing pumps have been adjusted to maintain the roughing system within the viscous flow regime.
11. Confirm that V-14, the repressurization valve, is closed
12. Record the size of all calibrated leaks in the log book file for future reference

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3.2 Pump Down Procedure

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	0	1	1	1	0	0	0	0	0	0	0	0	0	0

Start roughing pump RP-1 and allow the unit to warm up for 10 minutes. Slowly open valve V-7 and V-9. The beam tube and pumping system shall be evacuated until the pressure reaches 0.1 torr. The high vacuum turbomolecular pump (TMP-1) shall now be started.

The cold cathode gage CC1 will be automatically activated by a set point from pirani gage P1, however, the other cold cathode gages must be started manually. Gage CC2 may be manually operated only when CC1 operates. CC3 may be operated only when TMP-3 is at full speed. CC4 may be operated only when TMP-2 is running at full speed. CC5 may be operated only when V-4 is open and CC1 is operating. CC6 may be operated only if V-4 is open and CC1 is operating or if V-15 is open and CC3 is operating. These cold cathode gages cannot be automatically operated because there is not a pirani gage at each cold cathode gage location.

During the pump down, the system shall be monitored to ensure that the pump down is proceeding in accordance with the estimated pump down curves. The system shall be leak tested in accordance with the leak test procedure HMST4QT and any leaks found will be repaired and retested. The system will not be leak tested until after the pump down curve starts to level off. This should be at a pressure below 1×10^{-5} torr if the system leak rate is low.

NOTE: (this note applies to any section of the procedure)
Ion or Cold Cathode vacuum gaging shall be shut off prior to any RGA measurement.

During the pump down, start roughing pump RP-2. Allow the pump to warm up for 5 minutes and then open valve V-10 and slowly open V-11. Evacuate the auxiliary pump system until the pirani gage indicates a vacuum of .1 torr. Turn on the turbomolecular pump TMP-3. Activate the RGA in the faraday cup mode after the auxiliary pumping system has evacuated the RGA to below $1\text{X}10^{-5}$ torr.

After the beam tube has pumped down below 1×10^{-5} torr, open V-2, shut off all high vacuum gages and record a sweep of the full RGA range. The pump system cold trap shall then be activated.

The RGA shall be set to record a full RGA scan every 15 minutes as a default setting during periods of time when specific RGA measurements are not being conducted

4.0 WATER OUTGASSING RATE TEST

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	1	1	1	0	1	1	1	0	1	0	1	0	0	0

The RGA will be set up to monitor the 16, 17 and 18 AMU peaks. Close V-1 and allow the system pressure and RGA partial pressures to stabilize (P_s). Measure the three AMU partial pressures. Open valve V-1 and allow the pressure to stabilize and record the partial pressure resulting from the sum of the beam tube outgassing and the pumping system piping outgassing (P_t+P_s). Record the three AMU partial pressures. Typically, only the 18 AMU peak will be used to evaluate the water partial pressure but all three peaks will be recorded and evaluated to confirm that the ratio of the three peak heights remains stable. Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

Subtract the average of the two measurements for mass number 18 to determine the beam tube water measurement $(P_t+P_s)_{ave} - (P_s)_{ave} = (P_t)_{ave}$. The subtraction need not be accomplished if the system partial pressure measurement is at least an order of magnitude below the beam tube measurement.

4.1 Water Vapor Outgassing Rate Calibration

Change the RGA to record the 28 AMU peak. Close V-1 and open the nitrogen calibrated leak isolation valve (V-29) and allow the system partial pressure to stabilize. Record the nitrogen partial pressure (P_l+P_s). Shut the calibrated leak isolation valve (V-29) and again allow the system partial pressure to stabilize. Measure the nitrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other. Subtract the average of the two measurements to determine (P_l) if P_s is in the same order of magnitude as P_l.

The beam tube water flow rate (Q_t) is then calculated by multiplying the nitrogen calibrated leak flow rate(Q_l) by the ratio of the partial pressures (P_t/P_l). The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

5.0 HYDROGEN OUTGASSING RATE MEASUREMENT

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	1	1	1	0	1	0	1	0	0	0	0	0	0	0

Activate the pumping system and calibrated leak manifold cold traps (LNT-1 & 3) and allow the pressures to stabilize. Set up the RGA to monitor the 2 AMU peak. Record the hydrogen partial pressure (P_t+P_s). Close valve V-1 and allow the hydrogen partial pressure to stabilize and record the hydrogen partial pressure (P_s). Reopen valve V-2. Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

Subtract the average of the two measurements to determine the beam tube hydrogen measurement (P_t). The subtraction need not be accomplished if the system partial pressure measurement is at least an order of magnitude below the beam tube measurement.

5.1 Hydrogen Outgassing Rate Calibration

Open the hydrogen calibrated leak isolation valve V-26 and close V-1. Allow the hydrogen partial pressure to stabilize. Record the hydrogen partial pressure (P_l+P_s). Close valve V-26 and allow the partial pressure to stabilize. Record the hydrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

Subtract the average of the two measurements to determine the hydrogen calibrated leak measurement (P_l). The subtraction need not be accomplished if the system partial pressure measurement is at least an order of magnitude below the calibrated leak measurement.

The beam tube hydrogen flow rate (Q_t) is then calculated by multiplying the calibrated leak flow rate(Q_l) by the ratio of the partial pressures (P_t/P_l). The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

6.0 AIR SIGNATURE TEST

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	1	1	1	0	1	0	1	0	1	1	1	0	0	0

The RGA shall be set in a table mode using the mass numbers agreed by CBI and Caltech. Currently these mass numbers are 2, 12, 14, 15, 16, 17, 18, 28, 32, 39, 40, 41, 42, 43, 44, 51, 52, 55 and 57. RGA measurements (in the faraday cup mode) shall be evaluated for an air signature which indicates a leak larger than 1×10^{-5} torr liters per second.

If the air signature indicates leakage, the system will be re leak tested, repaired and reevaluated until no leakage is detectable. The water and hydrogen outgassing test measurements shall then be redone. If no leakage is indicated by the air signature evaluation, the tube shall be connected to the bake out power supplies and insulated.

6.1 Air Signature Calibration

Slowly open the precision variable leak valve until a strong signal is achieved on the RGA (at least one order of magnitude larger than the background). Record a full RGA scan and also record a table of the mass numbers specified above. Utilize the air leak to determine the initial fractionation patterns for use in the air signature program.

Close V-1 and open the nitrogen calibrated leak isolation valve (V-29) and allow the system partial pressure to stabilize. Record the nitrogen partial pressure (P_l+P_s). Shut the calibrated leak isolation valve (V-29) and again allow the system partial pressure to stabilize. Measure the nitrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other. Subtract the average of the two measurements to determine (P_l).

The beam tube air flow rate (Q_t) is then calculated by multiplying the calibrated leak flow rate(Q_l) by the ratio of the partial pressures (P_t/P_l) and dividing by 0.79 which is the amount of nitrogen in air. The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

7.0 BAKE OUT

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	0	1	1	1	1	0	1	1	1	0	1	1	1	1

The system is now ready for bake out with the exception of the insulation installation. CBI and Caltech shall both confirm that the beam tube is now ready for bake out.

The beam tube may be insulated after the air signature test has confirmed that there are no detectable leaks in the system. Prior to the start of the bake out, piston the liquid out of LNT-2 and allow the trap to warm up. Evacuation will continue until the system has been evacuated to 1 X 10^{-6} torr or lower. The bake out heaters may then be activated. The heaters shall be controlled such that the system pressure does not go above 1 X 10^{-5} torr. Heater set point will be 140°C. The bake out will continue for 30 days after the tube temperature reaches 140°C.

8.0 BAKE OUT OUTGASSING TESTS

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	1	1	1	0	1	0	1	1	1	0	1	0	0	0

The full scans shall be automatically recorded every 15 minutes through out the duration of the heat up, bake out and cool down. Once per day, the system shall be calibrated for nitrogen and hydrogen.

Nitrogen calibration for water vapor shall be accomplished by closing V-1, opening the nitrogen calibrated leak isolation valve (V-29) and allowing the system partial pressure to stabilize. Record the nitrogen partial pressure (P_l+P_s). Shut the calibrated leak isolation valve (V-29) and again allow the system partial pressure to stabilize. Measure the nitrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

Subtract the average of the two nitrogen measurements to determine (P_l). The subtraction need not be accomplished if the system partial pressure measurement is at least an order of magnitude below the calibrated leak measurement.

The beam tube water flow rate (Q_t) is then calculated by multiplying the calibrated leak flow rate(Q_l) by the ratio of the partial pressures (P_t/P_l). The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

Hydrogen calibration is achieved by opening the hydrogen calibrated leak isolation valve V-26 and closing V-1. Allow the hydrogen partial pressure to stabilize. Record the hydrogen partial pressure (P_l+P_s). Close valve V-26 and allow the partial pressure to stabilize. Record the hydrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

Subtract the average of the two measurements to determine the hydrogen calibrated leak measurement (P_l). The subtraction need not be accomplished if the system partial pressure measurement is at least an order of magnitude below the calibrated leak measurement.

The beam tube hydrogen flow rate (Q_t) is then calculated by multiplying the calibrated leak flow rate(Q_l) by the ratio of the partial pressures (P_t/P_l). The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

9.0 AIR SIGNATURE OUTGASSING TEST

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	1	1	1	0	1	0	1	1	1	1	1	1	1	0

After completion of the bake, with the beam tube and systems at ambient temperature, open V-8, close V-7 and start TMP-2. The RGA will be activated in the electron multiplier mode and allowed to operate for a minimum of 30 minutes. Make sure that the hydrogen partial pressure has stabilized and the cold cathode gages are shut down. The RGA will then be activated to record the mass numbers 2, 12, 14, 15, 16, 17, 18, 28, 32, 39, 40, 41, 42, 43, 44, 51, 52, 55 and 57 ($P_t^m+P_s^m$) for each mass number (m). The RGA will be set with a long integration time constant on each mass number specified. V-1 will then be closed and the RGA will again record the specified mass numbers (P_s^m). Valve V-1 will then be reopened and both measurements will be taken until the values of each mass numbers of both of the measurements do not vary by more than 20 % for three consecutive times. The measured partial pressures for the tube will be determined by subtracting the average system partial pressures from the average total partial pressures ($P_t^m+P_s^m$)-(P_s^m)=(P_t^m) for each mass number

Minor components of the residual gas mixture may vary more than 20% due to the very low signal levels. The CBI vacuum engineer, along with a Caltech representative, if present, shall determine if it is possible to achieve the repeatability specified above for the minor components

If a leak is detected, the system will be leak tested (in accordance with the leak test procedures), repaired and retested for air signatures until the RGA shows no air signature above $1X10^{-10}$ std cc / sec. The system is now ready for formal after bake outgassing tests.

9.1 Air Signature Outgassing Calibration

Slowly open the precision variable leak valve (V-28) until a strong signal is achieved on the RGA (at least one order of magnitude larger than the background). Record a full RGA scan and also record a table of the mass numbers specified above. Utilize the air leak to determine the initial fractionation patterns for use in the air signature program.

Insert the measured gas partial pressures for the beam tube (P_t^m) into the air signature program to determine the measured air leak rate

Close V-1 and open the nitrogen calibrated leak isolation valve (V-29) and allow the system partial pressure to stabilize. Record the nitrogen partial pressure (P_l+P_s). Shut the calibrated leak isolation valve (V-29) and again allow the system partial pressure to stabilize. Measure the nitrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other. Subtract the average of the two measurements to determine (P_l).

The beam tube air flow rate (Q_t) is then calculated by multiplying the calibrated leak flow rate(Q_l) by the ratio of the air leak partial pressure, as calculated by the air signature program, to the measured nitrogen calibrated leak partial pressure (P_t/P_l) and dividing by 0.79 which is the amount of nitrogen in air. The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

The calibration of the air signature may be confirmed by accumulating the nitrogen leak and expanding the nitrogen into a known volume. The RGA will be used to measure the partial pressure spike which will allow calculation of the theoretical partial pressure. During this mode of operation, the RGA will be set to a minimum integration time constant. The ratio of the calculated partial pressure to the measured pressure provides the calibration factor for the air signature measurements.

The calibration of the air signature measurement may also be confirmed by establishing the calibration factor for the nitrogen calibrated leak and the RGA then developing the valve opening vs. flow rate chart for the precision variable leak valve V-28 using a nitrogen supply instead of air. The chart shall be made for valve opening as well as valve closing to account for valve hysteresis. The valve shall be checked at least three full cycles to confirm repeatability. The air leak can then be directly compared to the valve flow chart when a valve position is determined based on equal partial pressure measurements between the valve and the measured/calculated air signature.

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10.0 HYDROGEN OUTGAS TEST

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	1	1	1	0	0	1	1	1	1	1	1	1	1	1

The RGA will again be operated in the electron multiplier mode. Set up the RGA to monitor the 2 AMU peak. Record the hydrogen partial pressure (P_t+P_s). Close valve V-1 and allow the hydrogen partial pressure to stabilize and record the hydrogen partial pressure (P_s). Reopen valve V-2. Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

Subtract the average of the two measurements to determine the beam tube hydrogen measurement (P_t). The subtraction need not be accomplished if the system partial pressure measurement is at least an order of magnitude below the beam tube measurement.

10.1 Hydrogen Outgassing Rate Calibration

Open the hydrogen calibrated leak isolation valve V-26 and close V-1. Allow the hydrogen partial pressure to stabilize. Record the hydrogen partial pressure (P_l+P_s). Close valve V-26 and allow the partial pressure to stabilize. Record the hydrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

Subtract the average of the two measurements to determine the hydrogen calibrated leak measurement (P_l). The subtraction need not be accomplished if the system partial pressure measurement is at least an order of magnitude below the calibrated leak measurement.

The beam tube hydrogen flow rate (Q_t) is then calculated by multiplying the calibrated leak flow rate(Q_l) by the ratio of the partial pressures (P_t/P_l). The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

Hydrogen outgassing rate can be confirmed by accumulating the beam tube (close V-1) for a sufficient time to increase the hydrogen partial pressure in the system by at least two orders of magnitude. The beam tube isolation valve is then opened and the hydrogen partial pressure spike is recorded on the RGA with a minimum integration time constant. The hydrogen calibrated leak is then accumulated (close valve V-27) for a sufficient time to increase the hydrogen partial pressure to a level approximately equal to the accumulation partial pressure from the beam tube.

The outgassing rate of the beam tube is then the calibrated leak flow rate multiplied by the ratio of the accumulation times multiplied by the ratio of partial pressures and divided by the area of the beam tube.

11.0 WATER VAPOR OUTGAS TEST

Starting System State Vector

V-1	V-2	V-3	V-4	V-5	V-7	V-8	V-9	V-10	LNT1	LNT2	LNT3	CC1	CC2	CC3
1	1	1	0	0	0	1	1	1	1	0	0	0	0	0

The pumping, outgassing and calibrated leak systems shall be baked for a minimum of 24 hours at 250°C. The RGA cold trap (LNT-2) shall have been emptied of LN2 and baked along with the other systems. The water vapor partial pressure shall then be measured by the RGA. The RGA will be monitored until the water vapor partial pressure stabilizes (comes to equilibrium with the system surfaces under vacuum). During the measurement, V-5 will be closed and all cold cathode and ion gages will be shut off. This will ensure that all water vapor pumping is accomplished by the cold trap (LNT-1). The RGA cold trap shall not be filled with LN2 at any time during the water vapor outgas test.

The RGA will be set up to monitor the 16, 17 and 18 AMU peaks. Close V-1 and allow the system pressure and RGA partial pressures to stabilize (P_s). Measure the three AMU partial pressures. Open valve V-1 and allow the pressure to stabilize (P_s+P_t). Record the three AMU partial pressures. Typically, only the 18 AMU peak will be used to evaluate the water partial pressure but all three peaks will be recorded and evaluated to confirm that the ratio of the three peak heights remains stable. Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other.

11.1 Water Vapor Outgassing Rate Calibration

Change the RGA to record the 28 AMU peak. Close V-1 and open the nitrogen calibrated leak isolation valve (V-29) and allow the system partial pressure to stabilize. Record the nitrogen partial pressure (P_l+P_s). Shut the calibrated leak isolation valve (V-29) and again allow the system partial pressure to stabilize. Measure the nitrogen partial pressure (P_s). Repeat this procedure three times or until three partial pressure measurements stabilize to within 10% of each other. Subtract the average of the two measurements to determine (P_l).

The beam tube water flow rate (Q_t) is then calculated by multiplying the calibrated leak flow rate(Q_l) by the ratio of the partial pressures (P_t/P_l). The tube outgassing rate is then determined by dividing the tube flow (Q_t) by the tube surface area (A_t).

The water outgassing rate can be confirmed by accumulating the nitrogen calibrated leak and expanding into a known volume with the main pumping system operating. The accumulation will be of sufficient duration to increase the total pressure in the system after expansion by two orders of magnitude. The reduction in pressure per unit time multiplied by the known volume will determine the nitrogen pumping speed. The nitrogen pumping speed and also be confirmed by using an Ion gage for pressure measurements instead of an RGA.

The nitrogen pumping speed may then be used to determine a calibration factor for the RGA. The calibration factor is determined by opening the nitrogen calibrated leak and determining the theoretical nitrogen partial pressure by dividing the nitrogen calibrated leak flow by the calculated nitrogen pumping speed. The calibration factor is then the ratio of the calculated theoretical partial pressure to the measured partial pressure. The calibration factors for nitrogen and water vapor are assumed to be the same and the pumping speed for water vapor is 600 L/S. The water outgassing rate can then be measured by multiplying the RGA measured water partial pressure by the water pumping speed and multiplying by the calibration factor.

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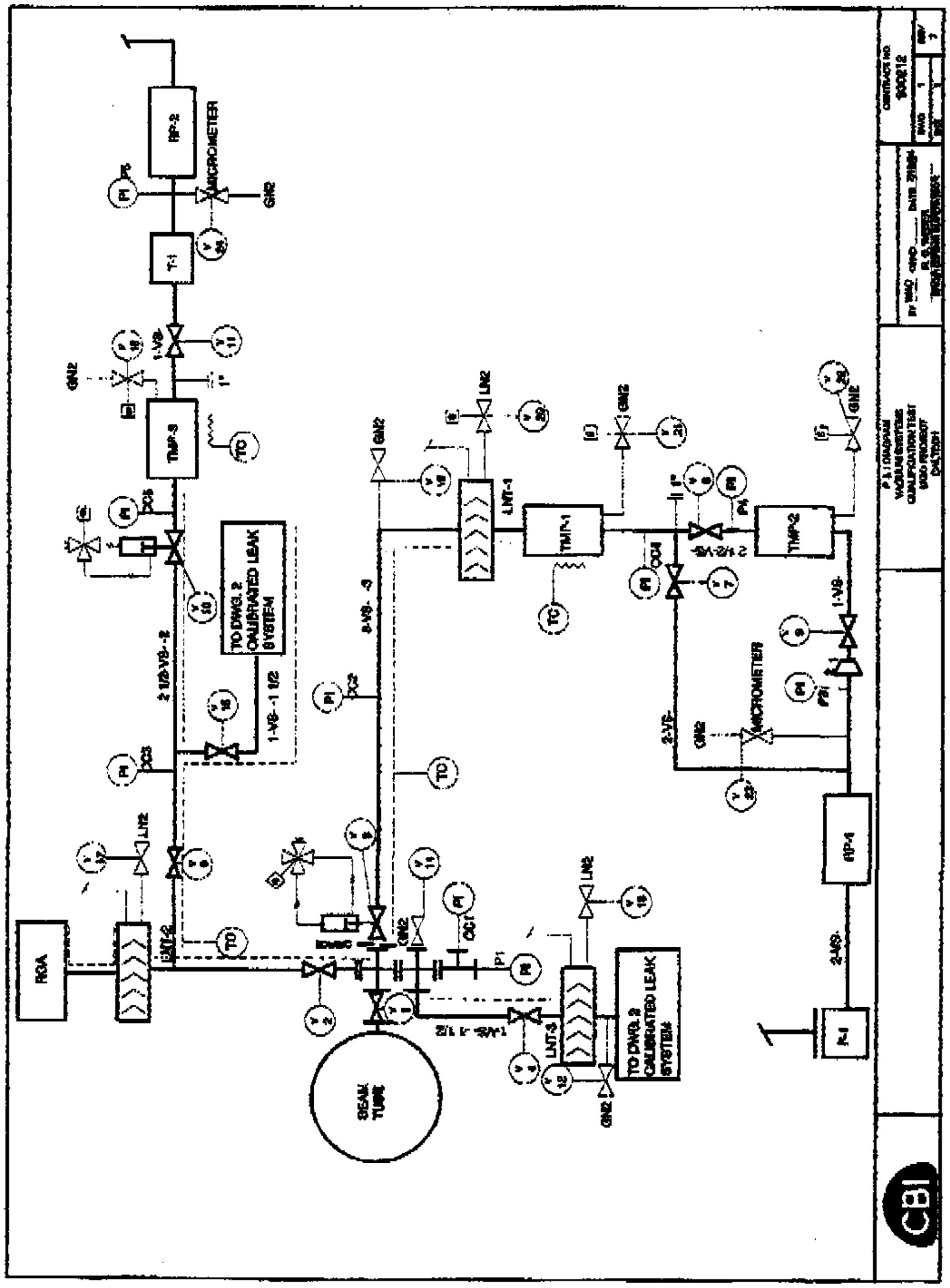

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