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# Special Hydrogen Target (Prop. 210)

# Guide to the Electrical Control and Automatic Vacuum Systems

C E Halliday

November 1979

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# SPECIAL HYDROGEN TARGET (PROP. 210)
# GUIDE TO THE ELECTRICAL CONTROL & AUTOMATIC VACUUM SYSTEMS

ABSTRACT

This guide contains a description of the electrical control and automatic vacuum systems. It should be used in conjunction with the flow diagram 1R 156151 and the mimic diagram 1R 156152.

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## 1. GENERAL OPERATION

The control system is designed to be operated remote from the target area once the system has been purged.

All electrical controls are housed in racks situated in the control room.

The mimic control panel is designed such that in normal operation only red or green lamps are illuminated. Fault conditions are indicated by amber lamps.

An integral alarm system gives an audible and visual indication of a fault condition in the target. It is possible to cancel the audible alarm but the visual indication will remain until the fault is cleared.

The vacuum system is of an automatic sequence controlled type. Provision is made by means of a selector switch (SW 1) to override the auto control.

This facility is provided for diagnostic and commissioning use only. In normal operation, the selector switch should always be in the auto mode.

## 2. NORMAL RUNNING CONDITIONS

Target cooled down and filled with liquid hydrogen.

Vacuum system operating on automatic control, vacuum vessel being pumped continuously. Systems pressures better than $2 \times 10^{-5}$ and $2 \times 10^{-1}$ torr on gauges G107 and G109 respectively.

Heater 4 in auto mode (SW 2)

Compressed air supply at 65 psig on G114.

Emergency $N_2$ gas pressure greater than 150 psig on G116 and at 65 psig on G115.

Target vessel pressure within the limits 740-796 torr on G122.

Water flow to diffusion pump and peltier baffle greater than 150 $Lh^{-1}$ (FM4).

Purge gas flow greater than 0.5 $Lm^{-1}$ (FM6).

3. PRE-COMMISSIONING

1) Ensure that $N_2$ gas bottles are connected and pressures are correct.

| | | |
|---|---|---|
| G116 | | >150 psig |
| G117 | | >150 psig |
| G115 | = | 65 psig |
| G118 | = | 3 psig |
| G119 | = | 1 psig |

2) Check compressed air supply is functional.

G114 = 65 psig

3) Check water flow to diffusion pump and peltier baffle is greater than 150 $Lh^{-1}$ (FM4).

4) Check purge gas supply is functional

G118 = 1 psig and FM6 0.5 $Lm^{-1}$

G119 = 3 psig.

5) Check that V5, V18, V10, V11 and V38 are closed

6) If necessary purge RP1 and RP2 with $N_2$ gas via NRV's 10 and 11.

7) Select manual position on Auto/Man vac selector (SW 1).

8) Select manual position on Auto/Man heater 4 selector (SW 2).

9) Set switches V1, V2, V3, V4, V6 and V8 in closed position.

10) The system is now ready for pumping down.

## 4. AUTOMATIC PUMPING SYSTEM

The vacuum system is an automatic sequence control type utilizing two rotary pumps (type EDM20), one water cooled diffusion pump (type E06) and a peltier baffle.

The control valves are air operated Worcester valves controlled by electrical solenoids mounted in rack No. 3.

RP1 is used for roughing/backing the insulating vacuum system and RP2 is primarily intended for auxiliary operations, purging etc.

However it is possible by manipulating valves V1, V2, and V38 to interchange these functions should either pump need to be stopped for servicing.

No useful function is served by operating RP1 and RP2 in parallel via V38 as their pumping speeds are limited by the size of the connecting pipework.

RP1 is wired into the auto control system and will re-start automatically when the electrical supply is restored after failure.

RP2 is on manual control at all times.

### 4.1 Establishing Insulation Vacuum

1) Select man position on insulating vacuum control mode and heater 4 control mode switches SW 1 and SW 2 respectively.

2) Start RP1 and check that its ultimate pressure is better than $5 \times 10^{-2}$ torr on G101.

3) Select auto position on SW 1. The system will now operate in automatic mode as follows:-

## 4.2 Auto Sequence

Operation is controlled by the Hastings thermocouple gauges G103, G108 and G109 in the following sequence -

1) V1 opens and evacuates line to V3 and V4.

2) G108 reads better than $1 \times 10^{-1}$ torr, V4 opens and evacuates diffusion pump.

3) G109 reads better than $1 \times 10^{-1}$ torr, diffusion pump heater switches on, V4 closes, V3 opens and evacuation of main vessel commences. At this stage V3 and V4 keep closing and opening as G109 goes above and below its set position due to the diffusion pump oil vapourising and being pumped out.

4) G103 and G104 read better than $1 \times 10^{-1}$ torr, V3 closes and V4 opens.

5) G109 reads better than $1 \times 10^{-2}$ torr, V6 opens and diffusion pump starts to evacuate the main vessel. At this stage V6 and possibly V4 will close and open as G109 and G108 go above and below their set positions.

6) The system will settle down and the main vessel pressure will be indicated on the Penning Gauges G105, G106 and G107.

NB. Although these three gauges are looking at the same pressure they will not necessarily be in agreement. This is because each gauge has been set to read accurately at its designated alarm trip point

ie. G105 ... $1 \times 10^{-4}$ torr
G106 ... $5 \times 10^{-3}$ torr
G107 ... $2 \times 10^{-5}$ torr.

The most accurate indication of pressure will, under normal conditions be indicated by G107.

It is possible to pump the system down faster by selecting manual position on SW 1 and isolating certain gauges etc, but this will ultimately impair the performance of the pumps and degrade the whole system.

5. ALARM SYSTEM

If a fault develops in the control system an audible warning will sound and the large amber alarm lamp (LP53) will light.

Should this occur, the audible warning can be silenced by pressing the alarm cancel button on the left of the alarm lamp.

The mimic panel should then be examined to determine where the fault lies (look for an amber lamp).

Most likely causes will be:-

| | | |
|---|---|---|
| 1) | G106, G107 | Failure of main vacuum. |
| 2) | FM4 | Water flow insufficient to diffusion pump. |
| 3) | PS2 | Compressed air failure. |
| 4) | PS3,PS4 | $N_2$ gas supply pressure low |

Important: It is bad practice at any time, and positively dangerous when hydrogen is in the system to disable or reduce the intensity of the audible warning in any way. In particular, the practice of wedging the cancel button should not be permitted.

6. NITROGEN FILLING SYSTEM FOR THE SiLi DETECTOR

The liquid nitrogen level of the SiLi Detector is controlled via V7 by a modified Thor Cyrogenics Auto Fill Control Box.

V7 is interlocked with Hastings gauges 103 and 104 such that V7

can only be opened if the insulating vacuum pressure is better than $1 \times 10^{-1}$ torr.

This is done to prevent any possibility of the $N_2$ storage dewar being over-pressured via its transfer line in the event of a large pressure rise in the main vessel.

However, should it be necessary to fill the detector with liquid nitrogen when the insulating vacuum is worse than $1 \times 10^{-1}$ torr, (eg. during storage or shut down periods) V7 can be enabled by using the V7 override keyswitch SW3.

This will illuminate the override alarm lamp LP59.

NB. THIS SWITCH MUST NOT BE USED IF CRYOGENIC FLUIDS ARE PRESENT IN THE TARGET VESSEL OR THE HELIUM BATH.

7. SiLi DETECTOR POWER SUPPLY

The SiLi Power Supply is interlocked with Pennings G106 and G107.

Should the main vessel pressure rise above G106 or G107's set points the alarm will sound at once and in the case of G106 ($p<1 \times 10^{-4}$ torr) the SiLi power supply will be disabled immediately. Operation of G107's trip will start a timer control sequence which will disable the power supply after a period of five minutes, if the pressure has not been restored to better than $2 \times 10^{-5}$ torr during that time.

In both cases, a remote alarm lamp (adjacent to the $N_2$ control box) will illuminate. In order to protect the detector, the power supply will remain disabled until a reset button (adjacent to the remote alarm lamp) is operated.

Before operating this reset, the operator should satisfy himself that it is safe to do so, and that any necessary adjustments have been made to the power supply.

8. HEATERS 1 - 5

There are four electrical heaters in the cryostat (T1-T4) and one (T5) is situated on the SiLi Detector Probe. T5 is controlled automatically from the user's rack and does not come within the scope of these notes, except to record that it is controlled via PS5 and so cannot be energised if the insulating vessel pressure is greater than 30 torr. (See Safety Devices page 9 ).

Heaters 1-4 are controlled via Hastings 103 and 104. If the main insulating vessel pressure is greater than $1 \times 10^{-1}$ torr, they are disabled and their outputs open circuited and crowbarred.

In normal operation the output of heaters 1-3 can be varied up to their maximum powers which are as follows:-

Heater 1 .... 10 watts

Heater 2 .... 10 watts

Heater 3 .... 1 watt

The output of Heater 4 can also be varied up to its maximum power of 1 watt when the selector switch SW2 is in manual position. With SW2 in its normal operating mode (AUTO) Heater 4 is controlled automatically by the transducer such that it will be switched on to its full output (irrespective of the control setting) if the target vessel pressure falls below 740 torr. It will remain on until the safe working pressure has been restored.

9. TEMPERATURE MEASUREMENT

There are five temperature monitor probes in the cryostat, T1-T5, their positions are as follows:-

T1 ... Upper heat exchanger
T2 ... Lower heat exchanger
T3 ... Target vessel top plate
T4 ... Radiation shield
T5 ... SiLi Detector heat shield.

T1 and T2 utilise silicon diodes and have analogue indication. T3, T4 and T5 are iron/gold thermocouples and have digital indication.

The thermocouple monitors are compensated by a platinum resistance thermometer. For safety reasons it is necessary to disable this module if the insulating vacuum pressure exceeds 30 torr.

However, so that all temperature indication is not lost at what may be a critical time, it is arranged that the monitors will still read, albeit inaccurately. This state will be indicated by an illuminated 'UNCALIBRATED' sign appearing adjacent to the digital displays.

All five temperatures are continuously recorded on a Kent 6 channel chart recorder, and all monitors have a dual range facility. T1 and T2 have a high and low range which reads as follows:-

High range: $273^{o}K$ at 0 to $77^{o}K$ at 150

Low range: $77^{o}K$ at 0 to $20^{o}K$ at 50

below $20^{o}K$ the system is unstable.

T3, T4 and T5 are indicated digitally from $400^{o}K$ to $1^{o}K$ with an accuracy of $\pm 0.5^{o}K$. In addition each output has a high and low sensitivity switch which selects the output to the chart recorder.

Low sensitivity .... $3^{o}K/mV$

High sensitivity .... $1^{o}K/mV$.

10. LIQUID $He^{4}$ LEVEL INDICATION

Liquid level in the $He^{4}$ bath is indicated by a modified Oxford Instruments Level Gauge type HLM2.

The instrument utilises a superconducting wire probe and indicates depth as a percentage of total capacity.

It has facility for high and low level alarms and a variable sample

rate. To avoid unnecessary heat input to the $He^4$ bath, it should be operated in the low sample rate mode whenever possible.

This instrument, in common with Heater 5 power supply and the temperature conditioning module is controlled by PS5 and so will be inoperative at a pressure greater than 30 torr in the insulating vacuum vessel.

11. SAFETY DEVICES

There are a number of safety devices built into the system in order to minimise the possibility of an explosion when using hydrogen.

The most likely hazard would be if the target vessel or its Be. window should rupture whilst containing liquid hydrogen. The hydrogen would then vapourise and fill the vacuum insulating vessel with hydrogen gas.

For an explosion to occur there would then have to be (a) a source of ignition with an energy content of more than 19 μJoules and (b) a minimum of 4% oxygen in the gas mixture.

1) A transducer continually monitors the pressure in the target vessel and by means of heater 4 and V8 maintains its pressure between safe limits of 740-796 torr. Should this system malfunction there are two further safeguards, a relief valve (RV3) and finally a bursting disc (BD2).

2) The insulating vacuum vessel is designed to contain the maximum pressure generated by the vapourization of the liquid content of the target vessel and the helium bath. Unless the casing of the insulating vessel is also ruptured, no oxygen can be present and the contents will remain below the flammability limits.

The insulating vessel is also provided with a bursting disc (BD1) and a non-return valve (NRV1) which will vent at less than

the safe working pressure of the vessel.

3) To ensure that the nitrogen storage dewar can not be over-pressured via its transfer line, should the insulating vessel be pressurised, the $N_2$ valve V7 is interlocked with vacuum gauges G103 and G104 and will remain closed at pressures in excess of $1 \times 10^{-1}$ torr.

4) Possible sources of electrical ignition as listed below are arranged to be disabled before the gas mixture in the insulating vessel can reach explosive proportions.

a) SiLi Detector Power Supply
This is controlled via Penning gauges G106 and G107. It will be isolated if the insulating vacuum deteriorates to worse than $5 \times 10^{-3}$ torr or $2 \times 10^{-5}$ torr (for more than 5 minutes) respectively.

b) Penning Gauge Head
These are electrically isolated at $1 \times 10^{-1}$ torr by two independant Hastings thermocouple gauges H103 and H104.

c) Electrical Heaters 1 - 4
These are electrically isolated at $1 \times 10^{-1}$ torr by H103 and H104 and are also crowbarred to prevent residual energy causing a spark.

d) $He^4$ Liquid Level Indicator
Heater 5
Conditioning Module for Temperature Measurement
These are electrically isolated by PS5 at a pressure of 30 torr. Should PS5 operate, T3, T4 and T5 will continue to digitally display their respective temperatures but their accuracy will be impaired. This is indicated by an illuminated 'UNCALIBRATED' sign.

## 12. CALIBRATION PROCEDURE FOR PENNING GAUGES

1) Check for physical damage

2) Connect 3 metres of cable (but not the head)

3) Connect Avo 8 to pin 16 on the McMurdo plug

4) Mains on (take care EHT present)

5) Adjust EHT (RV4) to approx 1.8Kv.

6) Remove Avo

7) Set zero on meter

8) Switch off mains, connect cable to head

9) Set vacuum to $10^{-2}$ torr

10) Adjust RV3 to $10^{-2}$ torr
NB. Head must be clean and have been on for 12 hours.

11) Check that lamps operate at trip points

12) Set required trip points (R1)

G105 ... $10^{-4}$ torr
G106 ... $5x10^{-3}$ torr
G107 ... $2x10^{-5}$ torr

13) Reset meter to read accurately at the selected trip point.
NB. Use a sub-standard gauge and control box such as VEECO or VARIAN for calibration.

## 13. CALIBRATION PROCEDURE FOR HASTINGS THERMOCOUPLE GAUGES

1) Check for physical damage

2) Ensure that gauge head is clean and correctly wired to drawing No.DNPL 01/1898.

3) Check that all cards are fitted internally.

4) Connect head to control unit, switch on and allow to stabilise for two hours.

5) Set gauge to read ATMOS, (red line on dial face) using R10 potentiometer.

6) Pump head down against a sub-standard gauge to $10^{-3}$ torr and calibrate using R15.

7) Raise pressure to 1 torr and re-set using R10.

8) Re-check $10^{-3}$ torr setting.

9) Set required trip point on channel A or B card using R3.

| DRAWING NO. | TITLE | ISSUE NO | DATE |
|---|---|---|---|
| 1R 156151 | FLOW DIAGRAM | 1 | 3.10.79 |
| 1R 156152 | MIMIC PANEL MASK | 1 | 3.10.79 |
| 0R 156153 SHT 1+2 | ELECTRICAL SCHEMATIC SHT 1 | 1 | 3.10.79 |
| | ELECTRICAL SCHEMATIC SHT 2 | 2 | 12.11.79 |
| 0R 156154 SHT 1+2 | MIMIC RELAY UNIT | 1 | 3.10.79 |
| 0R 156155 | INTERCONNECTION DIAGRAM | 1 | 3.10.79 |
| 1R 156156 | TRANSDUCER CONTROL SYSTEM | 1 | 3.10.79 |
| 1R 156157 | HEATER POWER SUPPLY (1&3) | 1 | 3.10.79 |
| 1R 156158 | HEATER POWER SUPPLY (2&4) | 1 | 3.10.79 |
| 1R 156159 | TEMPERATURE MONITORS (T3,T4,T5) | A | 3.10.79 |
| 1R 156160 | SHELF UNIT 'C' | A | 3.10.79 |
| 1R 156161 | SHELF UNIT 'D' | A | 3.10.79 |
| 2R 156162 | POWER SUPPLY DETAIL | 1 | 3.10.79 |
| 2R 156163 | MIMIC RELAY LAYOUT | 1 | 3.10.79 |
| 2R 156164 | RELAY CHASSIS LAYOUT | 1 | 3.10.79 |
| 2R 156165 | UNIT DIAGRAM | 1 | 3.10.79 |
| DNPL 01/1898 | HASTINGS CONNECTION DIAGRAM | B | 13. 2.75 |
| DNPL 99/886 | HASTINGS SCHEMATIC DIAGRAM | D | 13. 2.75 |
| DNPL 99/693 | PENNING SCHEMATIC DIAGRAM | B | 3. 8.73 |

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PROJECTION

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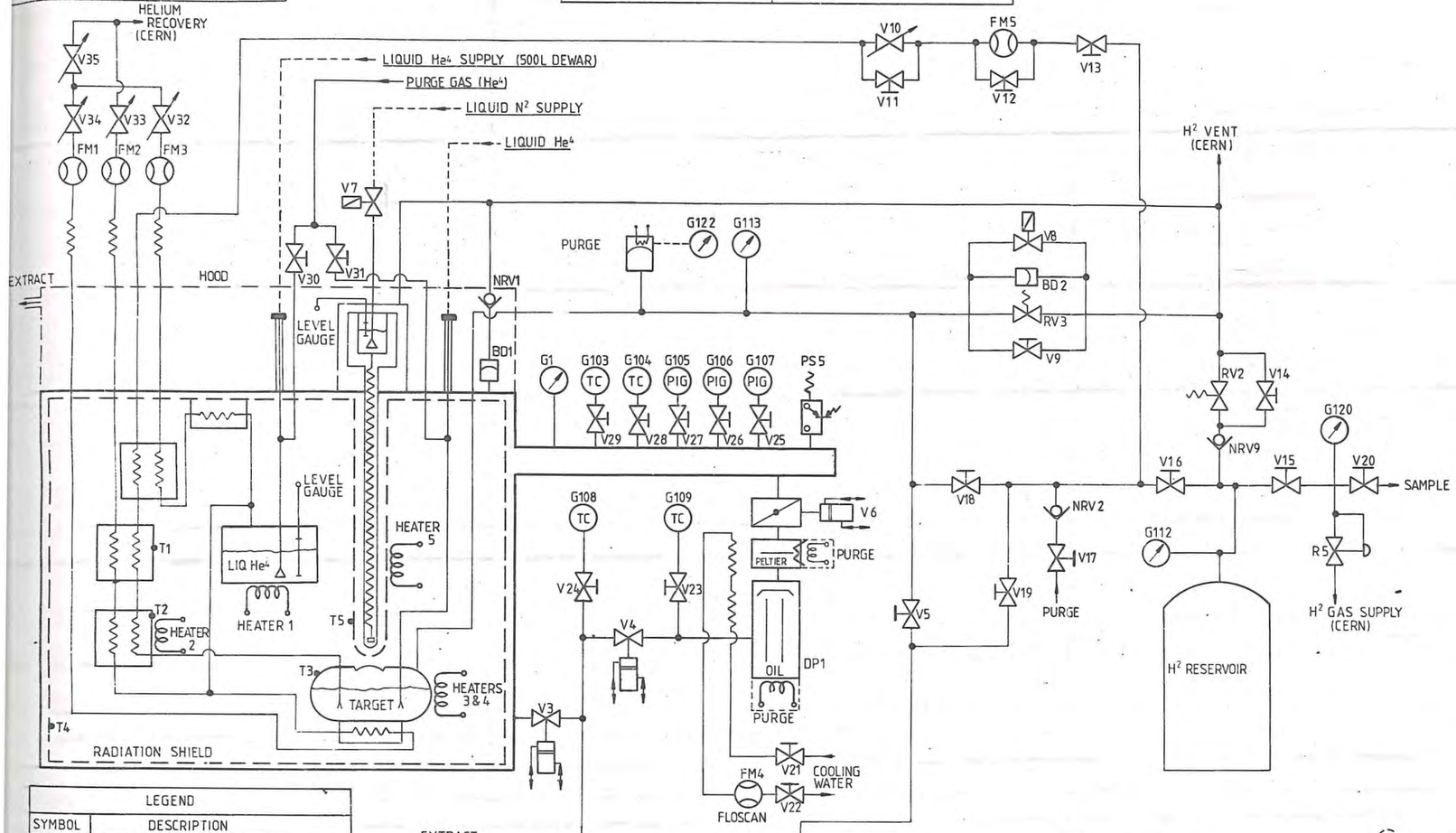
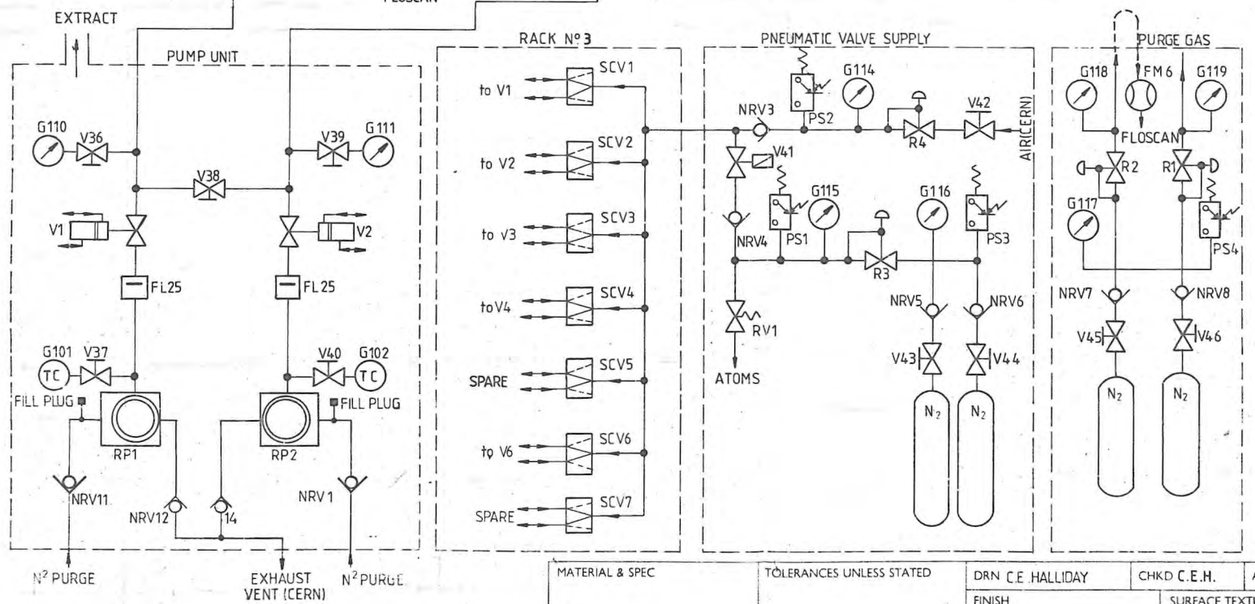



| LEGEND | |
|---|---|
| SYMBOL | DESCRIPTION |
| | TWO STAGE ROTARY VACUUM PUMP |
| | DIFFUSION VACUUM PUMP |
| | MANUALLY OPERATED VALVE |
| | SOLENOID OPERATED VALVE |
| | PNEUMATICALLY OPERATED VALVE |
| | MANUAL REGULATING VALVE |
| | BUTTERFLY VALVE |
| | NON RETURN VALVE |
| | PRESSURE RELIEF VALVE |
| | PNEUMATIC CONTROL VALVE SOLENOID OPERATED |
| | PRESSURE REGULATOR |
| | PRESSURE SWITCH |
| | BURSTING DISC |
| | FLOW METER |
| | PRESSURE GAUGE |
| TC | VACUUM GAUGE - THERMAL CONDUCTIVITY |
| PIG | VACUUM GAUGE - IONISATION |
| | COOLED BAFFLE |
| | ELECTRICAL HEATERS / TERMINALS |
| | HEAT EXCHANGER |




| ITEM N° | DRG LOCAN | PHYSICAL LOCAN |
|---|---|---|
| V1 | H4 | PUMP UNIT |
| V2 | H5 | " " |
| V3 | F4 | ADJACENT TO DIFF PUMP |
| V4 | E5 | " " " " |
| V5 | E7 | CONTROL PANEL |
| V6 | D6 | ABOVE DIFF PUMP |
| V7 | B3 | ABOVE HOOD |
| V8 | B8 | CONTROL PANEL |
| V9 | C8 | " " |
| V10 | A7 | " " |
| V11 | A7 | " " |
| V12 | A7 | " " |
| V13 | A8 | " " |
| V14 | C9 | " " |
| V15 | D9 | " " |
| V16 | D9 | " " |
| V17 | E8 | " " |
| V18 | D7 | " " |
| V19 | E8 | " " |
| V20 | D10 | " " |
| V21 | F6 | H² TARGET AREA |
| V22 | F6 | PURGE PANEL |
| V23 | E5 | ADJACENT TO DIFF PUMP |
| V24 | E5 | " " " " |
| V25 | D6 | TOP OF PUMPING TEE |
| V26 | D6 | " " " " |
| V27 | D5 | " " " " |
| V28 | D5 | " " " " |
| V29 | D5 | " " " " |
| V30 | C3 | PRESSURE VESSEL TOP PLATE |
| V31 | C3 | " " " " |
| V32 | B2 | CONTROL PANEL |
| V33 | B1 | " " |
| V34 | B1 | " " |
| V35 | A1 | " " |
| V36 | G4 | PUMP UNIT |
| V37 | J4 | " " |
| V38 | H4 | " " |
| V39 | G5 | " " |
| V40 | J5 | " " |
| V41 | G8 | PNEUMATIC PANEL |
| V42 | G9 | BRIDGE: NEAR HOIST |
| V43 | H9 | N² CYLINDERS ON BRIDGE |
| V44 | H9 | " " " " |
| V45 | H10 | " " " " |
| V46 | H10 | " " " " |
| NRV1 | C4 | TOP OF PRESSURE VESSEL |
| NRV2 | D8 | CONTROL PANEL |
| NRV3 | G8 | PNEUMATIC PANEL |
| NRV4 | H8 | " " |
| NRV5 | H9 | " " |
| NRV6 | H9 | " " |
| NRV7 | H10 | PURGE PANEL |
| NRV8 | H10 | " " |
| NRV9 | D9 | CONTROL PANEL |
| NRV10 | J5 | PUMP UNIT |
| NRV11 | J4 | " " |
| NRV12 | J4 | " " |
| NRV14 | J4 | " " |
| RV1 | H8 | PNEUMATIC PANEL |
| RV2 | C9 | CONTROL PANEL |
| RV3 | C8 | " " |

| ITEM N° | DRG LOCAN | PHYSICAL LOCAN |
|---|---|---|
| G101 | J3 | RACK 1 (& PUMP UNIT) |
| G102 | J5 | " " (" " " ) |
| G103 | C5 | " " (& PUMPING TEE) |
| G104 | C5 | " " (" " " ) |
| G105 | C5 | " " (" " " ) |
| G106 | C6 | " " (" " " ) |
| G107 | C6 | " " (" " " ) |
| G108 | D5 | " " (& DIFF PUMP ) |
| G109 | D5 | " " (" " " ) |
| G110 | G4 | PUMP UNIT |
| G111 | G5 | " " |
| G112 | D9 | CONTROL PANEL |
| G113 | B6 | " " |
| G114 | G8 | PNEUMATIC PANEL |
| G115 | H8 | " " |
| G116 | H9 | " " |
| G117 | H10 | PURGE PANEL |
| G118 | G10 | " " |
| G119 | G11 | " " |
| G120 | D10 | CONTROL PANEL |
| G121 | C4 | " " |
| G122 | B5 | RACK 2 |
| BD1 | C4 | PRESSURE VESSEL TOP PLATE |
| BD2 | C8 | CONTROL PANEL |
| FM1 | B1 | CONTROL PANEL |
| FM2 | B1 | " " |
| FM3 | B2 | " " |
| FM4 | F6 | PURGE PANEL |
| FM5 | A7 | CONTROL PANEL |
| FM6 | G10 | PURGE PANEL |
| R1 | G10 | PURGE PANEL |
| R2 | G10 | " " |
| R3 | H9 | PNEUMATIC PANEL |
| R4 | G9 | " " |
| R5 | D10 | CONTROL PANEL |
| PS1 | H8 | PNEUMATIC PANEL |
| PS2 | G8 | " " |
| PS3 | H9 | " " |
| PS4 | H11 | PURGE PANEL |
| SCV1 | G7 | RACK 3 |
| SCV2 | G7 | " " |
| SCV3 | H7 | " " |
| SCV4 | H7 | " " |
| SCV5 | J7 | " " |
| SCV6 | J7 | " " |
| SCV7 | J7 | " " |
| DP1 | E6 | H² TARGET AREA |
| RP1 | J4 | BRIDGE |
| RP2 | J5 | " |

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MATERIAL & SPEC

REMOVE ALL BURRS

TOLERANCES UNLESS STATED

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FINISH | SURFACE TEXTURE µm ▽ UNLESS STATED

ORIGINAL SCALE | mm. INCHES

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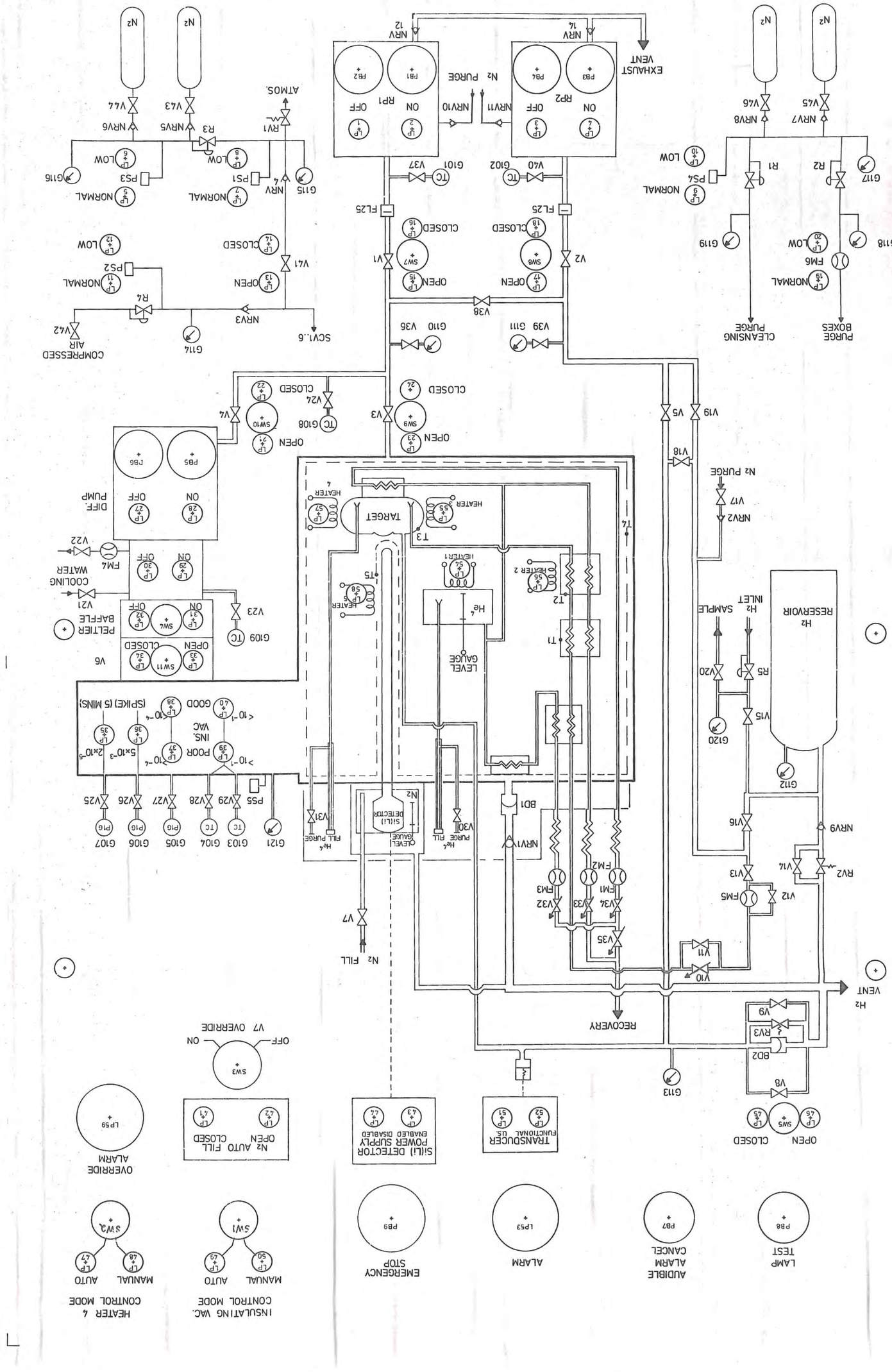
TITLE: SPECIAL HYDROGEN TARGET FLOW DIAGRAM

CONTR'S REF

1R156151

1R 156152

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| DRN. C.E.HALLIDAY | CHD. G.E.H. | APPD | | | |
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