ICANS IX

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Operational Experience with the ISIS Cryogenic Moderators

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1. Introduction

The basic design specifications have been reported at previous conferences together with initial operating experience. By way of a reminder, the fundamental parameters were as follows:-

H_2 System

Supercritical hydrogen at 15 bar pressure and 20 - 25 K with the following estimated heat inputs:-

1.	Nuclear heating in H_2	454 W
2.	Nuclear heating in aluminium vessel	30 W
3.	Heat inleakage	35 W
4.	Transfer losses	6 W
5.	Circulator heat input	60 W
	Total	585 W

Against this, the refrigerator provided by Sulzer Bros (UK) was specified at 600 W at 20 K.

CH_4 System

Liquid methane at 4 bar pressure and sub-cooled to 95 - 100 K with the following estimated heat inputs

1.	Nuclear heating in CH_4	625 W
2.	Nuclear heating in aluminium vessel	13 W
3.	Heat inleakage	26 W
4.	Transfer losses	60 W
5.	Circulator heat input	60 W
	Total	784 W

Against this, the single stage Stirling cycle cryogenerator manufactured by Philips and supplied in standard form, is rated at 1 kW at 100 K.

2. Circuit Description (H_2)

The basic circuit diagram is shown in Fig 1. The two circulators each with remotely operable isolation valves are located in the return leg of the circuit in order to minimise the temperature rise between the controlling sensor and the moderator. An ortho/para catalytic converter of iron oxide compacted into pellets and contained in a wire gauze basket is also located in the flow line of the circuit.

Either circulator can be isolated from the main circuit, pumped out and filled with helium to allow replacement without affecting the main circuit.

3. Circuit Description (CH_4)

The circuit diagram is shown in Fig 2. The circulators were located in the moderator feed line on account of the high density difference between gas and liquid. The cryogenerator is positioned at the highest level, in an attempt to prime the circulator during initial liquifaction.

A pair of remotely valved filters is located in the remote leg.

Both circulators and filters are described in greater detail later.

4. Cooldown Performance

Typical cooldown curves are shown in Figs 3 and 4. The liquifaction phase of the methane system proved the most difficult and tedious part of the operation. This was because of difficulty in keeping the circulators primed with liquid, resulting in vapour locks bringing fluid flow to a standstill. To overcome this, a short circuit bypass valve was added. When the loop had filled with liquid, which was relatively easy on account of the much reduced circuit pressure drop, the bypass valve could be shut and the remainder of the circuit filled and sub-cooled without difficulty.

5. Methane Polymerisation

In the absence of general data on the chemistry of methane in radiation, a relatively large cylindrical filter element with an outside surface area of 385 cm^2 was designed. Flow direction was outside to inside and remotely operated isolation valves afforded replacement without shutting down the system.

The initial filter bore size was 10μ, but because of rapid blocking this was increased to 45μ. It was subsequently noted that periods of rapid blocking coincided with a vertically mis-steered beam when it is possible that the moderators were receiving high energy protons with a correspondingly high level of methane degradation.

6. Recent Modifications

i. CH_4 Filters

It was observed that filters became initially blocked, with with soluble materials which could be readily removed by warming and evacuating the isolated filter unit.

It is unknown at this stage how many times this can be repeated before blockage of a more permanent nature occurs, but it was obviously desireable to enable the regeneration cycle to be carried out remotely. To this end, a pneumatically operated valve panel was installed to enable either filter to be vented, evacuated and purged with inert gas. Heaters and temperature sensors were also fitted to the body of each filter containment. It is intended to regenerate a filter during normal operation of the system.

ii. Methane and Hydrogen Circulators

The basic circulator units were supplied by Philips as modified standard units. In order to meet the RAL safety requirements for flammable gases, the unit was enclosed enclosed in a low pressure inert gas containment.

In order to ease circulator replacement, the main vessel was re-designed as shown in Fig 5. This obviates the need for a separate secondary containment by separating the gas from electrical connections which are in an integral inert gas chamber at the top. The inert gas surrounds the cables and feeds the chamber. Two of the original three rubber 'O' rings which occasionally became chilled and subsequently leaked were eliminated in the new design. The circulator vessels were designed to ASME VIII pressure vessel code, and are regarded as the first step in a circulator development programme.

The thermal break between cryogenic fluid and the nominally room temperature circulator vessel, is effected by an overhung shaft. This suffered problems of instability particularly during its run up to the operating speed of 18,000 RPM, which was overcome by an increase in the shaft diameter at the cost of an increased heat input to the cryogenic fluid. It was also found necessary to provide a step in the shaft with a matching step in the bore of the resin block through which the shaft passes. This acts as an effective block to convective currents greatly reducing transfer into the fluid.

To enable circulators to be warmed up for removal, heaters and temperature sensors were added to the diffusers together with remotely operated pumping and purging facilities.

iii. Circuit Modification

In addition to the above modifications three additional remotely operated cryogenic valves were recently added in order to afford the system improved flexibility.

The problem of liquid filling of the methane system is not fully solved, but plans are in hand to automate the complete cooldown operations using a programmable controller.

Conclusions

The two systems are operating with a fairly high degree of reliability. Circulators continue to be the greatest single cause of breakdowns, although the average life of a unit is probably longer than was at first expected. There is however room for considerable improvement, and at least three full cycles of four weeks running without servicing is considered a reasonable goal for a single unit with the second unit being regarded only as a spare. Whilst existing units have survived such periods and longer, others have suffered premature bearing and other mechanical breakdowns.

One of the problems of the Stirling cycle cryogenerator is that of the control of its output. Unless checked, methane can easily be frozen in the heat exchanger when a vapour block occurs. At the present time, this is avoided by switching off the drive motor, but an electrical heater on the main heat exchanger is to be commissioned in the near future which it is hoped will give much improved control of refrigerative output. Once filled with liquid, a remotely positioned heater now controls the temperature of the system, but this cannot be used during the gas and liquifaction stages on account of the low heat transfer properties of the fluid.

The levels of heat applied by the heater in the two systems, are 450 watts for the methane, and 800 watts for the hydrogen. Because of some heat cycling it is impossible at this stage to ascertain with any degree of accuracy, the heat contribution of the neutrons at running levels so far encountered.

Although designed for pressures of 15 bar at which hydrogen at 20 K is supercritical, the present level of beam current precludes the possibility of boiling if the hydrogen is in a liquid state which was the original purpose of using supercritical hydrogen. The system is therefore run at about 10 bar to give a greater safety margin. This corresponds to a liquid sub-cooled by about 16 K.

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RAL

FIG 1

SCHEMATIC DIAGRAM OF HYDROGEN MODERATOR CIRCUIT

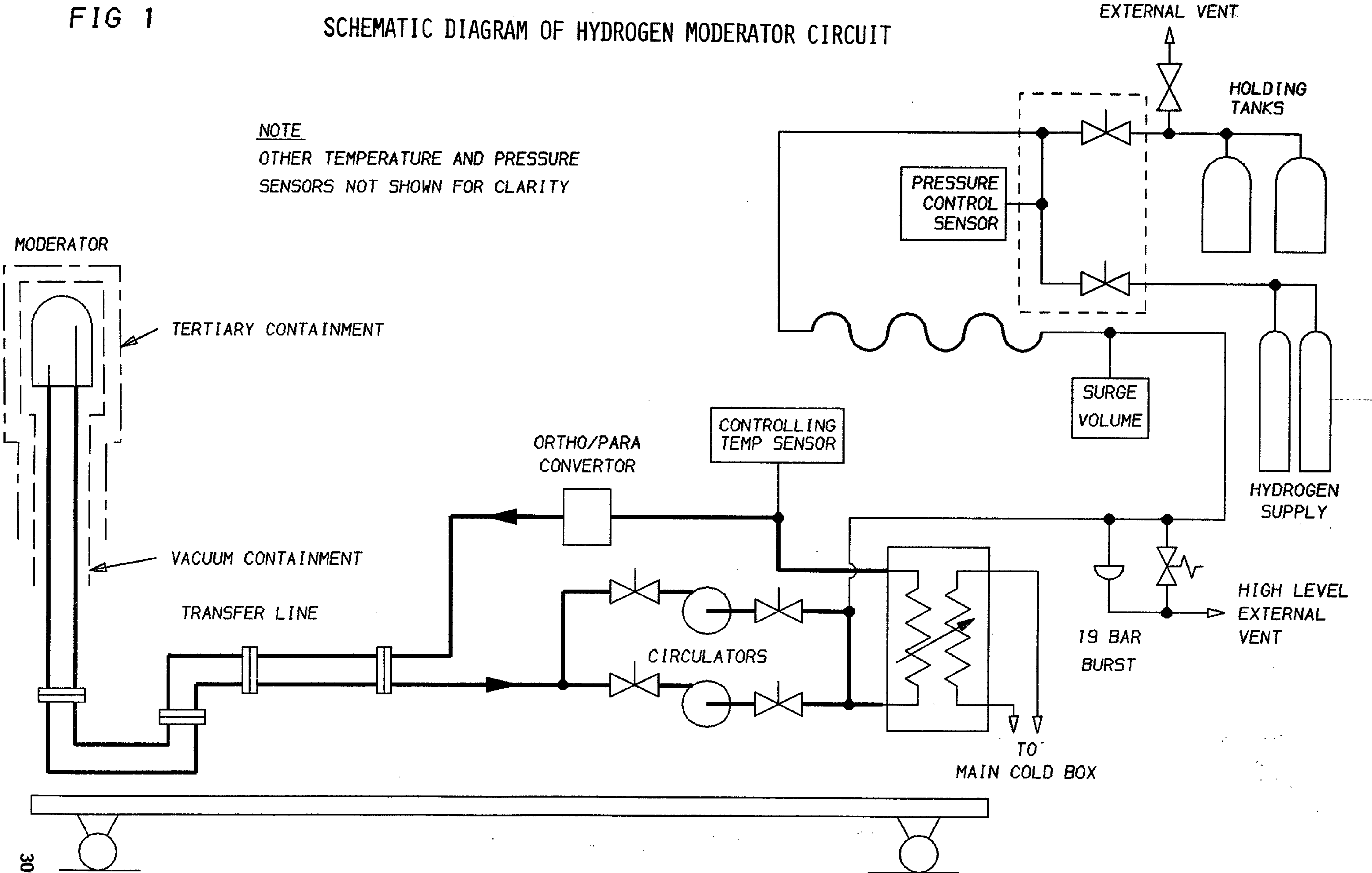
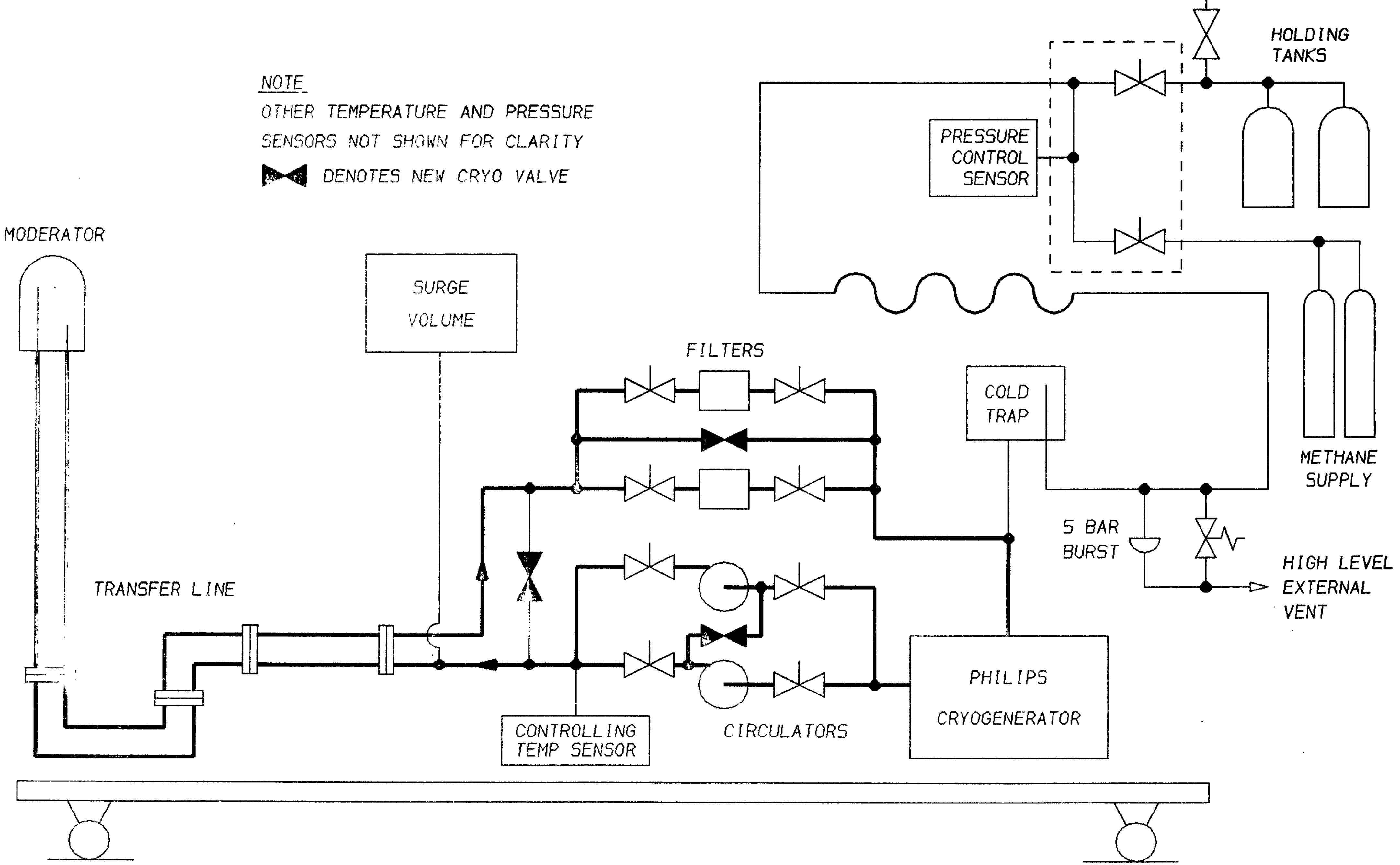


FIG 2

SCHEMATIC DIAGRAM OF METHANE MODERATOR CIRCUIT



NOTE

OTHER TEMPERATURE AND PRESSURE SENSORS NOT SHOWN FOR CLARITY

(filled valve symbol) DENOTES NEW CRYO VALVE

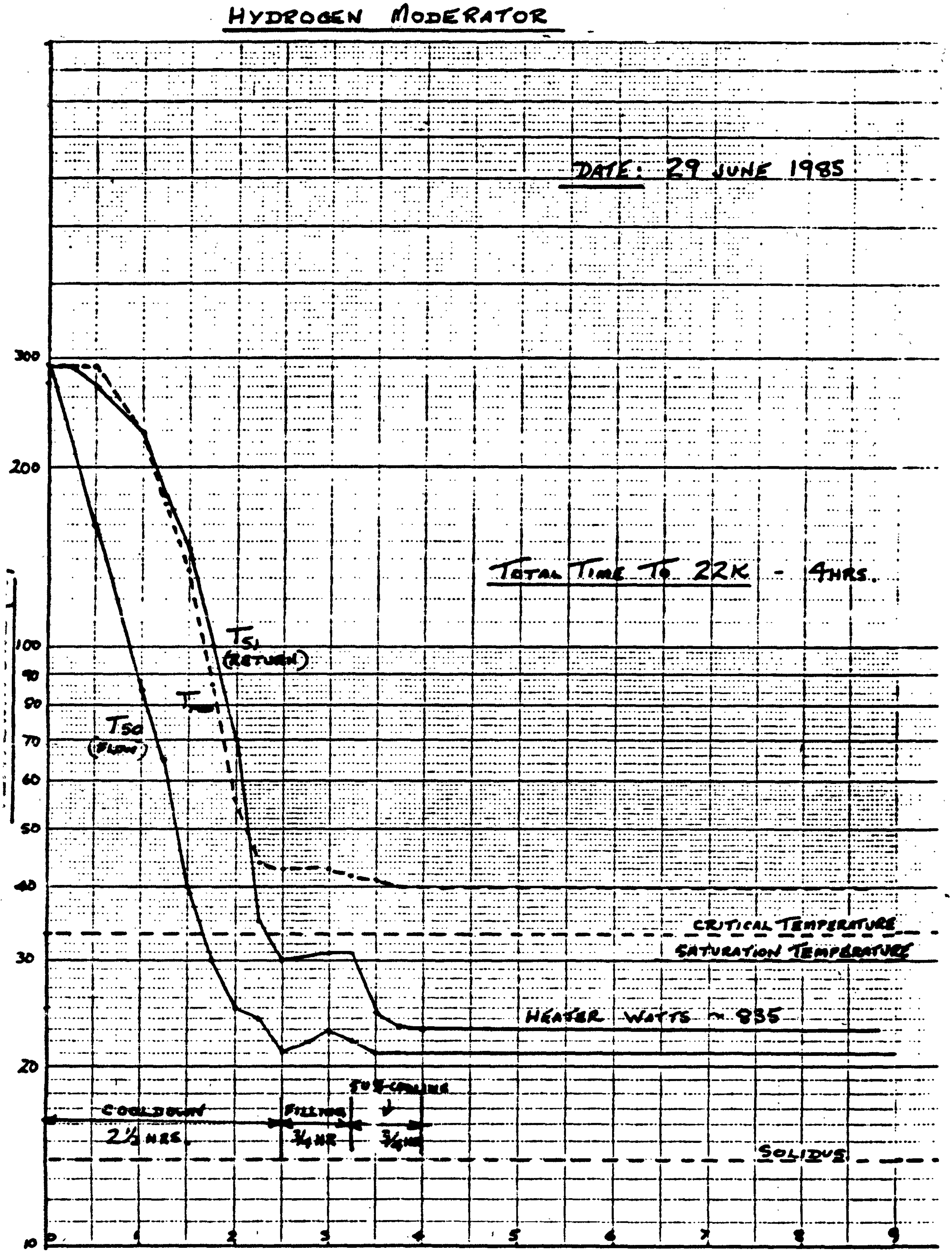

HYDROGEN MODERATOR
DATE: 29 JUNE 1985
TOTAL TIME TO 22K - 4HRS.
TS1
(RETURN)
TSO
(FLOW)
CRITICAL TEMPERATURE
SATURATION TEMPERATURE
HEATER WATTS ~ 835
COOLDOWN
2½ HRS.
FILLING
¾ HR
SOLIDUS
300
200
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9

Figure 3

Figure 4

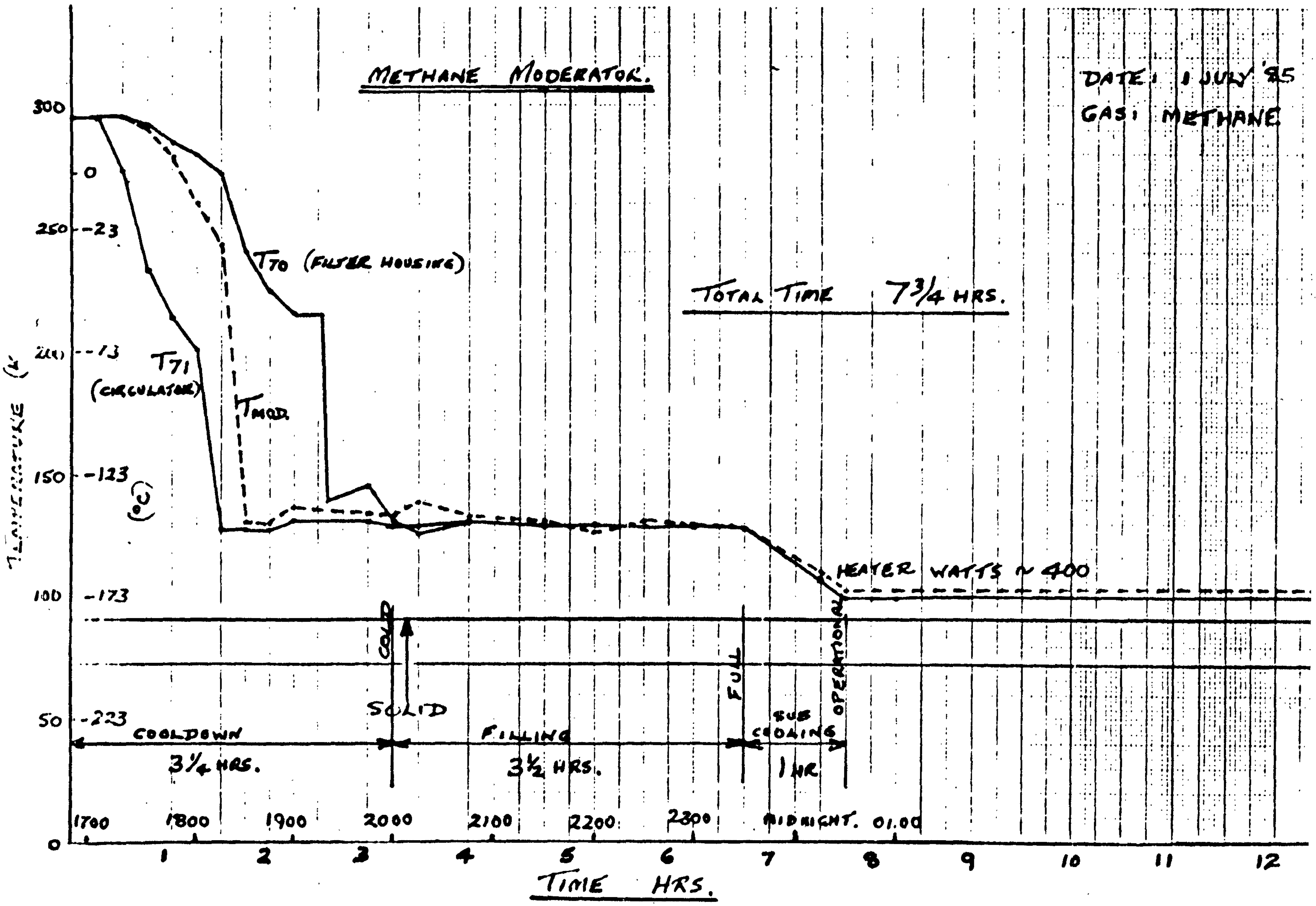

METHANE MODERATOR.
DATE: 1 JULY '85
GAS: METHANE
T70 (FILTER HOUSING)
TOTAL TIME 7¾ HRS.
T71 (CIRCULATOR)
TMOD
HEATER WATTS ~ 400
COLD
SOLID
FULL
OPERATIONAL
SUB COOLING
COOLDOWN
3¼ HRS.
FILLING
3½ HRS.
1 HR
(°C)
300
0
250 -23
200 -73
150 -123
100 -173
50 -223
0
1700
1800
1900
2000
2100
2200
2300
MIDNIGHT.
01.00
1 2 3 4 5 6 7 8 9 10 11 12
TIME HRS.

FIG 5 MAIN CIRCULATOR VESSEL