Open loop, auto reversing liquid nitrogen circulation thermal system for thermo vacuum chamber

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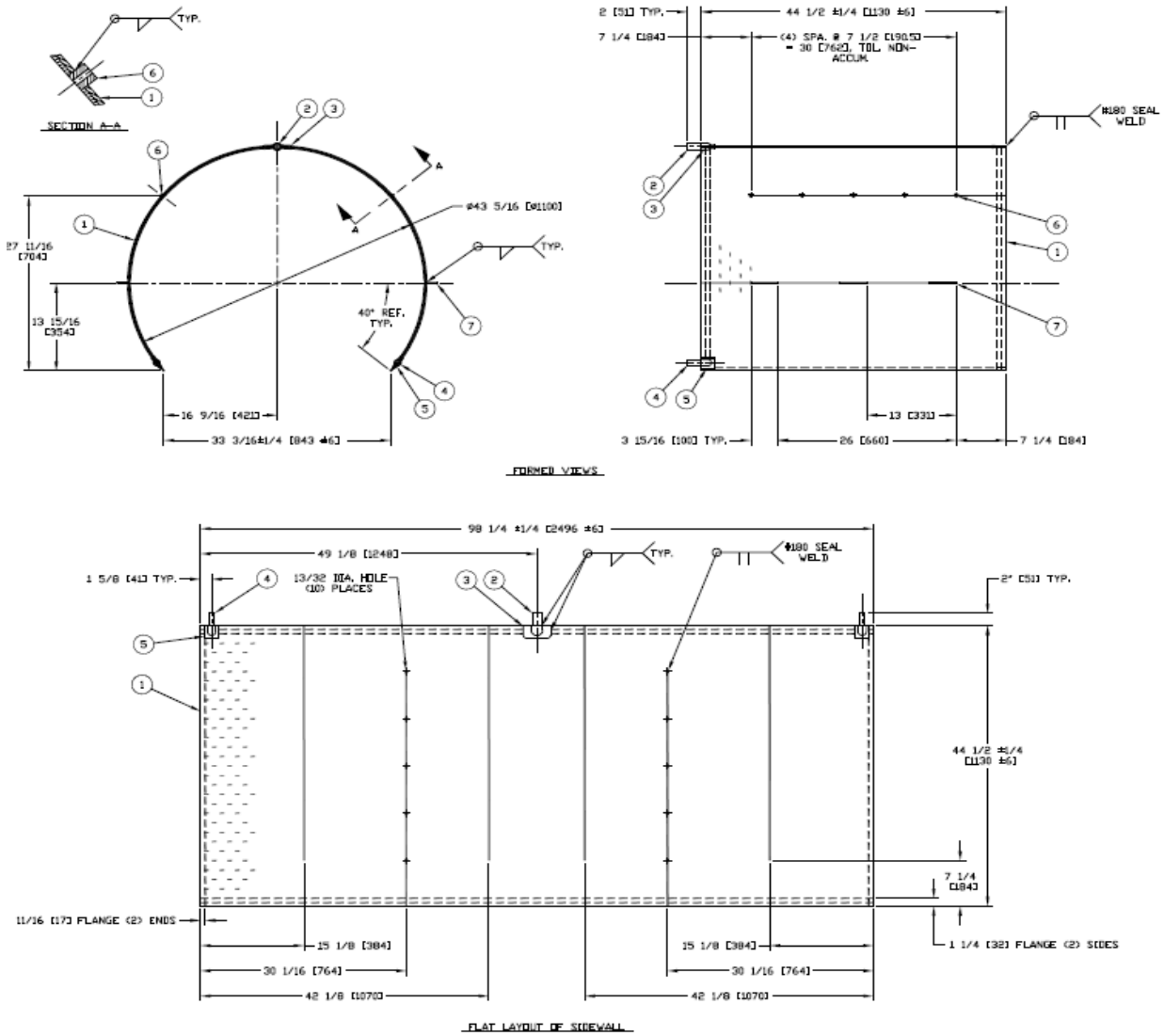
What for this thermal system?

This thermal system was developed as a part of augmentation of existing 1.2m dia thermo vacuum chamber, which is about 35 years old, to conduct extreme temperature cycling tests on passive antenna reflectors,

Thermal system consists of:

- **Shroud (double embossed panel)**
- **Solenoid operated cryogenic valves(4nos.) (ASCO make)**
- **IR lamps(9 nos.)(ACE make, 500 w each)**
- ***PT 100 sensors***
- ***PLC (Allen Bradley make)***


SECTION A-A
TYP.
ø43 5/16 [ø1100]
27 11/16 [704]
13 15/16 [354]
40° REF. TYP.
16 9/16 [421]
33 3/16±1/4 [843 ±6]
FORMED VIEWS
44 1/2 ±1/4 [1130 ±6]
7 1/4 [184]
ø180 SEAL WELD
13 [331]
3 15/16 [100] TYP.
26 [660]
7 1/4 [184]
98 1/4 ±1/4 [2496 ±6]
49 1/8 [1248]
1 5/8 [41] TYP.
13/32 DIA. HOLE (10) PLACES
2" [51] TYP.
11/16 [17] FLANGE (2) ENDS
15 1/8 [384]
30 1/16 [764]
42 1/8 [1070]
1 1/4 [32] FLANGE (2) SIDES
FLAT LAYOUT OF SIDEWALL

Shroud

This idea of auto reversing was evolved while doing experiments on thermal system

Entire operation and logic is fully

auto mode with

PID loops and

PLC based

With an

Option to switch on to manual mode

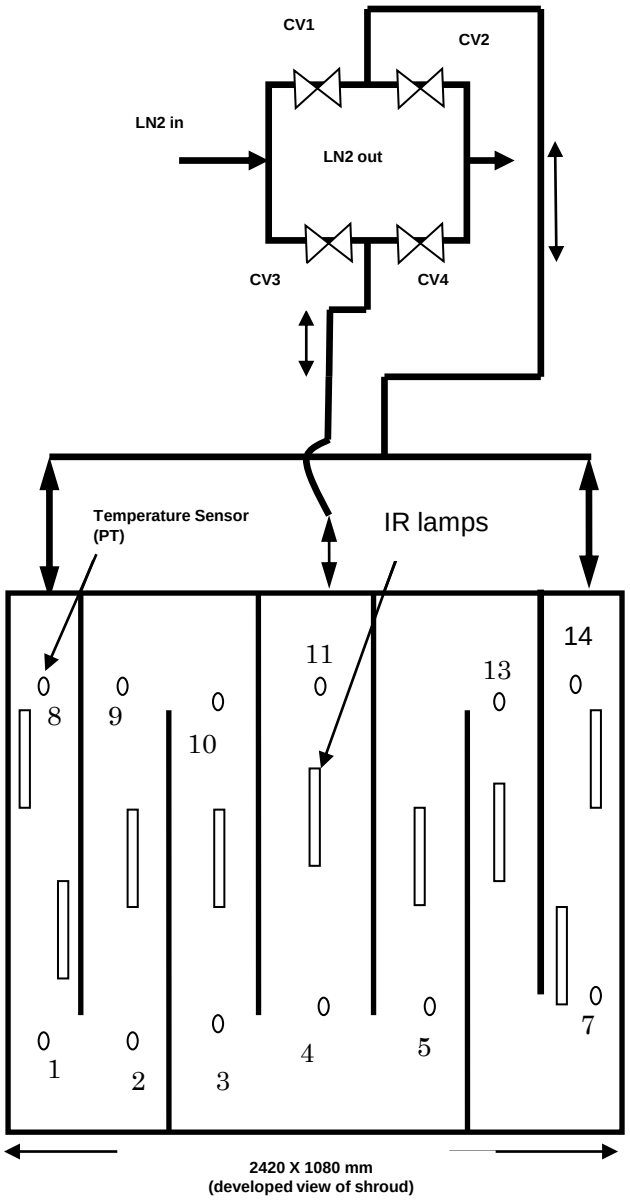
Shroud has

two inlets and one outlet.

Inlets are at the bottom.

outlet at the top.

The sequence of operation :



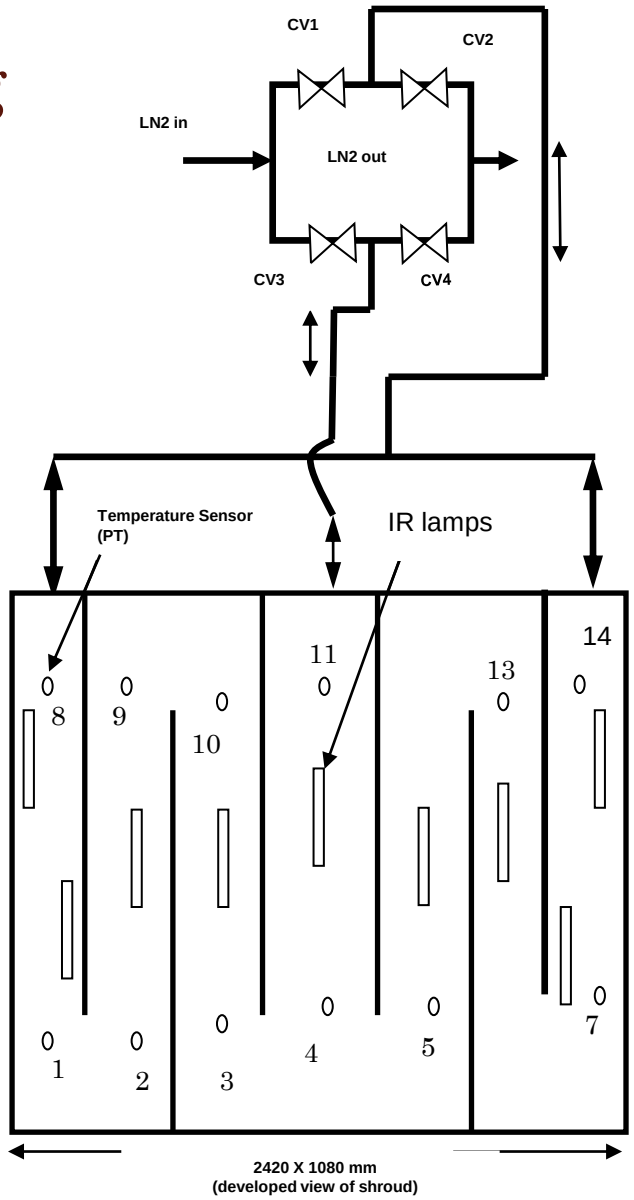
The sequence of operation contd. :

In auto reversing mode

inlets become outlets

and

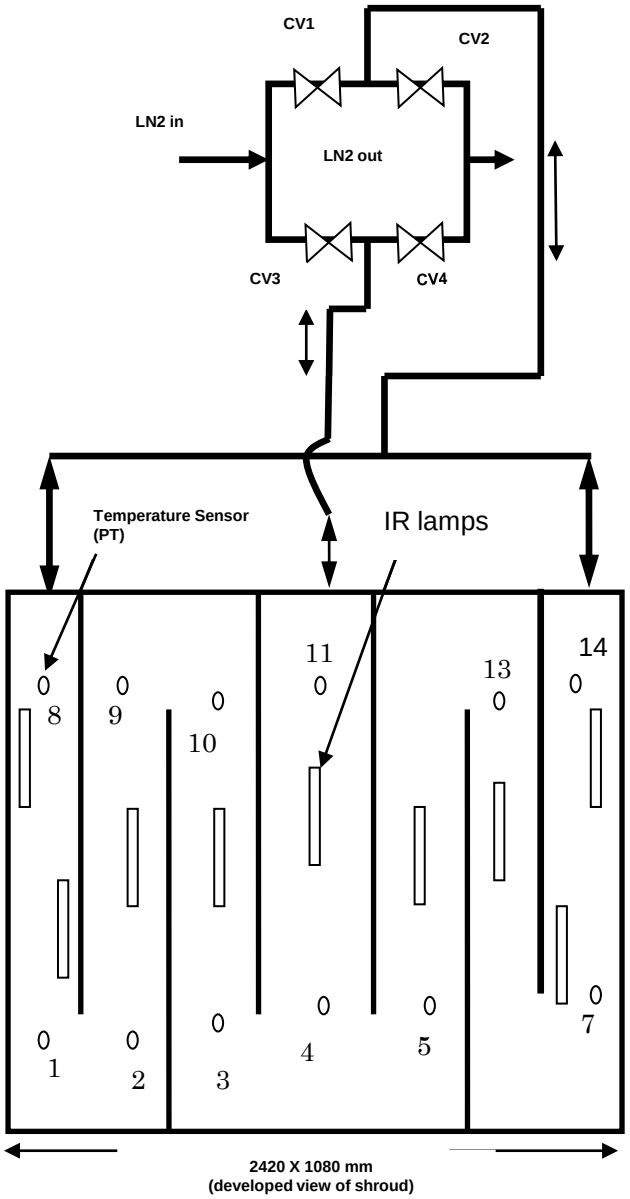
outlet become inlet



The sequence of operation contd. :

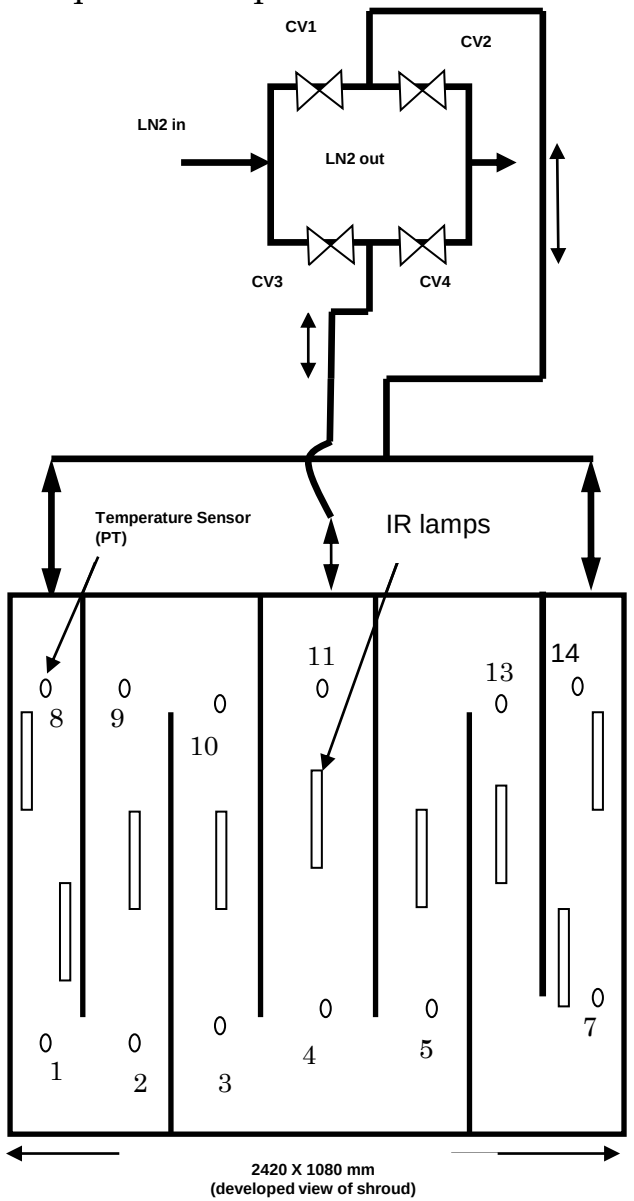
When CV1, CV4 are open, CV2, CV3 are closed.

In reverse flow, when CV2, CV3 are open, CV1, CV2 are closed.



The sequence of operation contd. :

- During the initial cooling cycle, liquid nitrogen will flow from bottom inlets (near PT8,14)
- The temperature difference between inlet and outlet is set as a differential set point
- Liquid nitrogen will flow from the bottom inlets, till a differential set point is reached
- Then the liquid nitrogen will flow from top, as a reverse flow(near PT11)

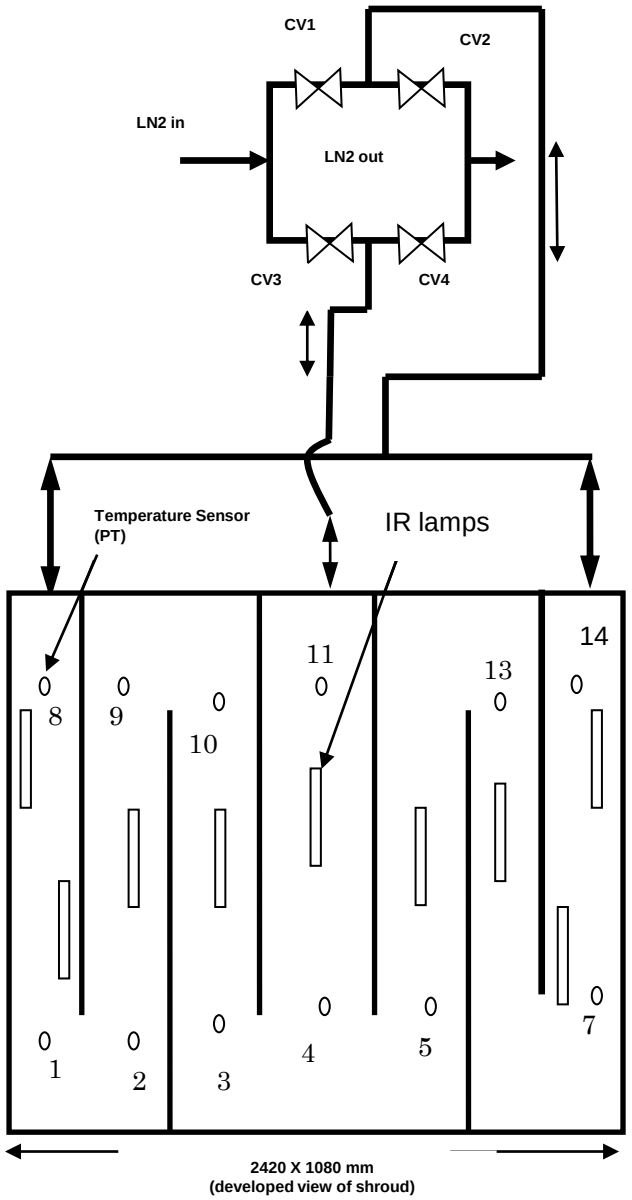


The sequence of operation contd. :

- This way the operation of valves takes place till the set temperature is reached

- Once the set point temperature is reached, the valves remain closed for few minutes

- To maintain the set temperature, frequent on / off of valves will take place

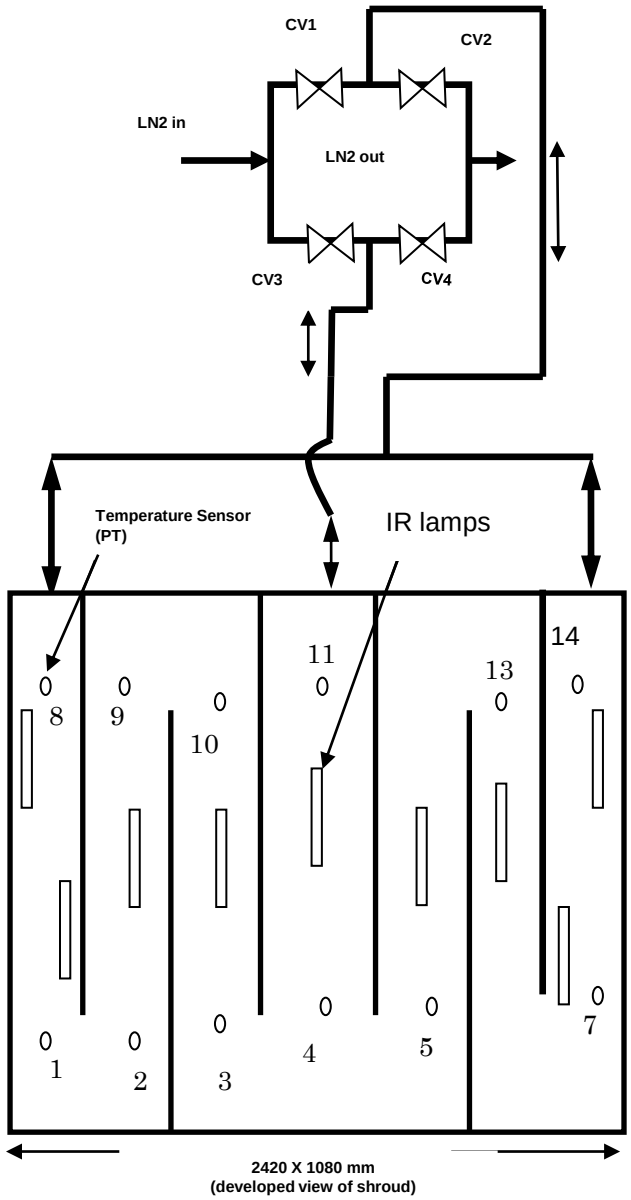


The sequence of operation contd. :

- During off condition of valves, the liquid nitrogen in the pipe lines gets warmed up and become gas

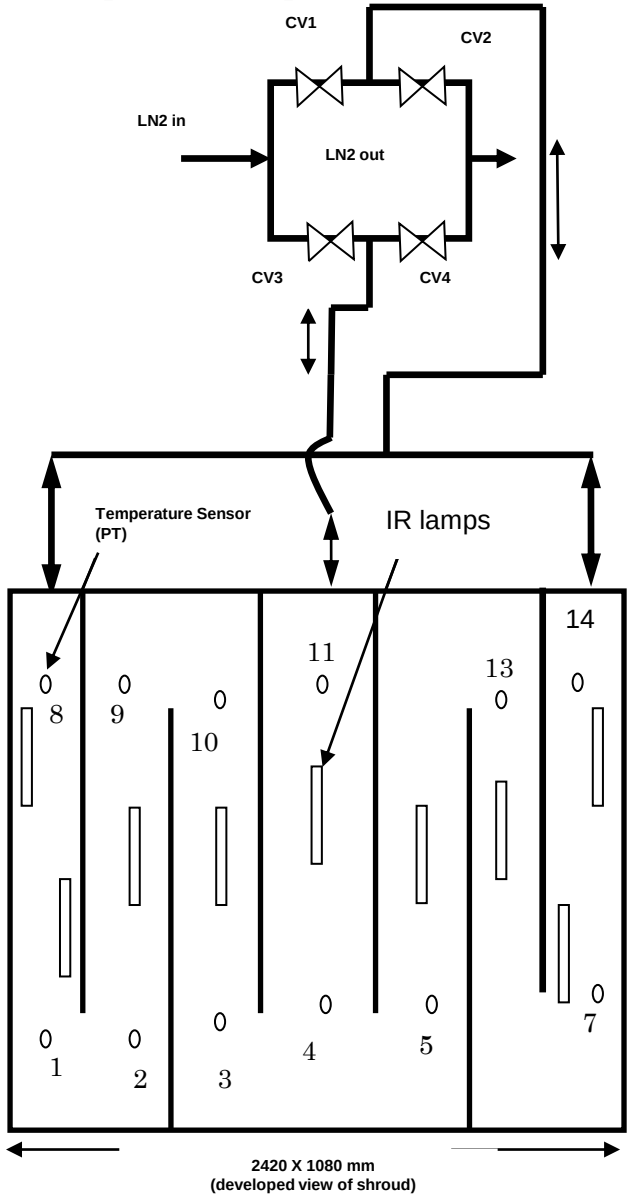
- At this time, if any valve opens, gaseous nitrogen will flow inside the shroud and disturb the temperature

- To avoid this, auto flushing system was incorporated. The gas will be flushed out automatically for 10 seconds and then start the operation of inlet valve. This was electronically incorporated. Auto flush valve was incorporated before LN2-in valve, not shown in the fig.)



The sequence of operation contd. :

- To maintain the temperature gradient (+/-7.5 Deg. C as specification) on shroud, IR lamps will be occasionally "ON" with variable power input



- Instrumentation and control system consists of a dedicated PLC, PID controller, Temperature sensors, solenoid operated liquid nitrogen valves and IR lamps

- In PLC program, proportional derivative integral control logic is developed

- Temperature sensors reading is fed as input to PID, PID output is sent to solenoid operated liquid nitrogen valves through contactors

INSTRUMENTATION AND CONTROL contd.

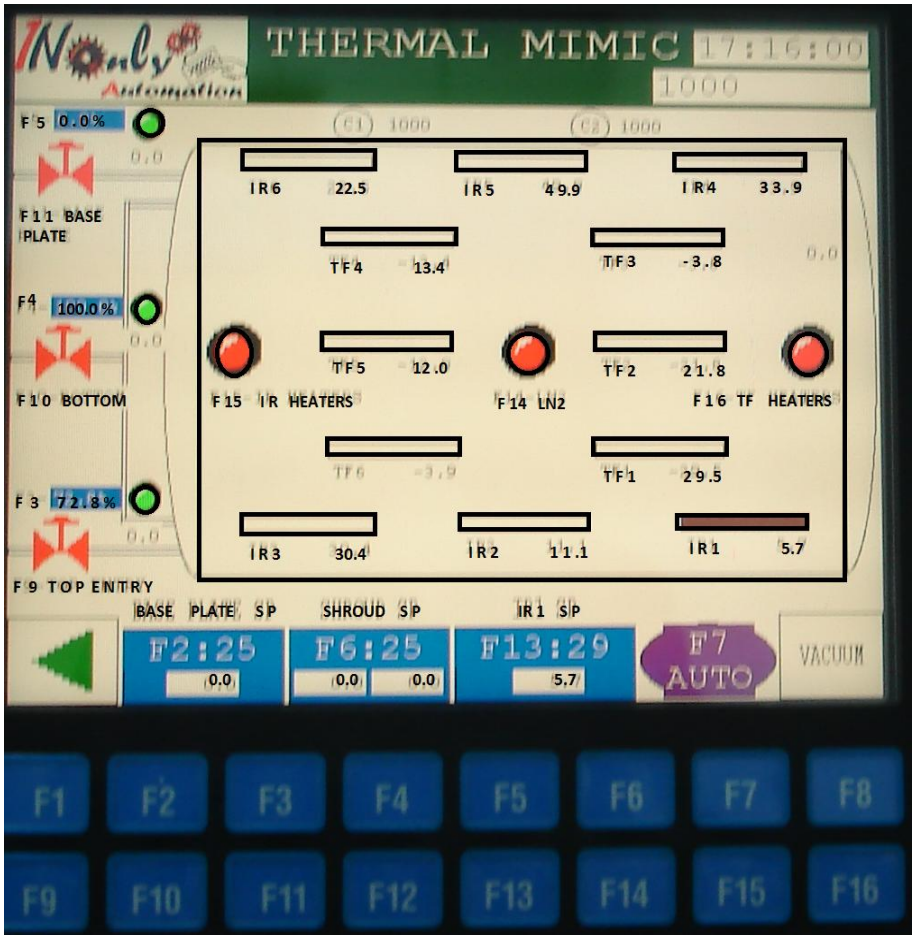
- IR lamps are controlled with individual temperature sensors through thyristers

- First, to go to auto mode, auto mode to be activated by pressing a dedicated switch

- In auto mode operation, PID loops will take care of opening and closing liquid nitrogen valves and IR lamps according to their given set points

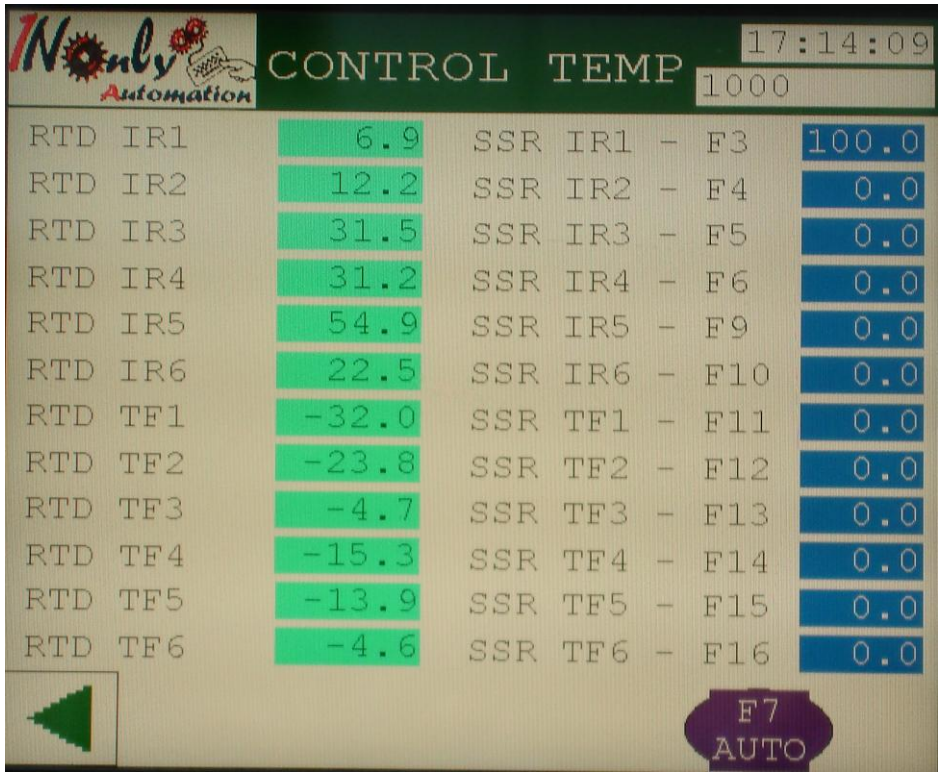
INSTRUMENTATION AND CONTROL contd.

- In case, manual mode to be activated the dedicated switches for liquid nitrogen valves for top entry, bottom entry and IR lamps, to be pressed.



"ON /OFF" status of liquid nitrogen valves and IR lamps along with % power of IR lamps

- In manual mode, all IR lamps can be controlled by manually entering the percentage value



PLC (Micrologix 1200 base module with 14 DI / 10 DO) have the following cards:

a) 12 channel RTD input module,

b) 12 channel analogue output module,

c) 6 channel digital output modules

Experiments were carried out to know:

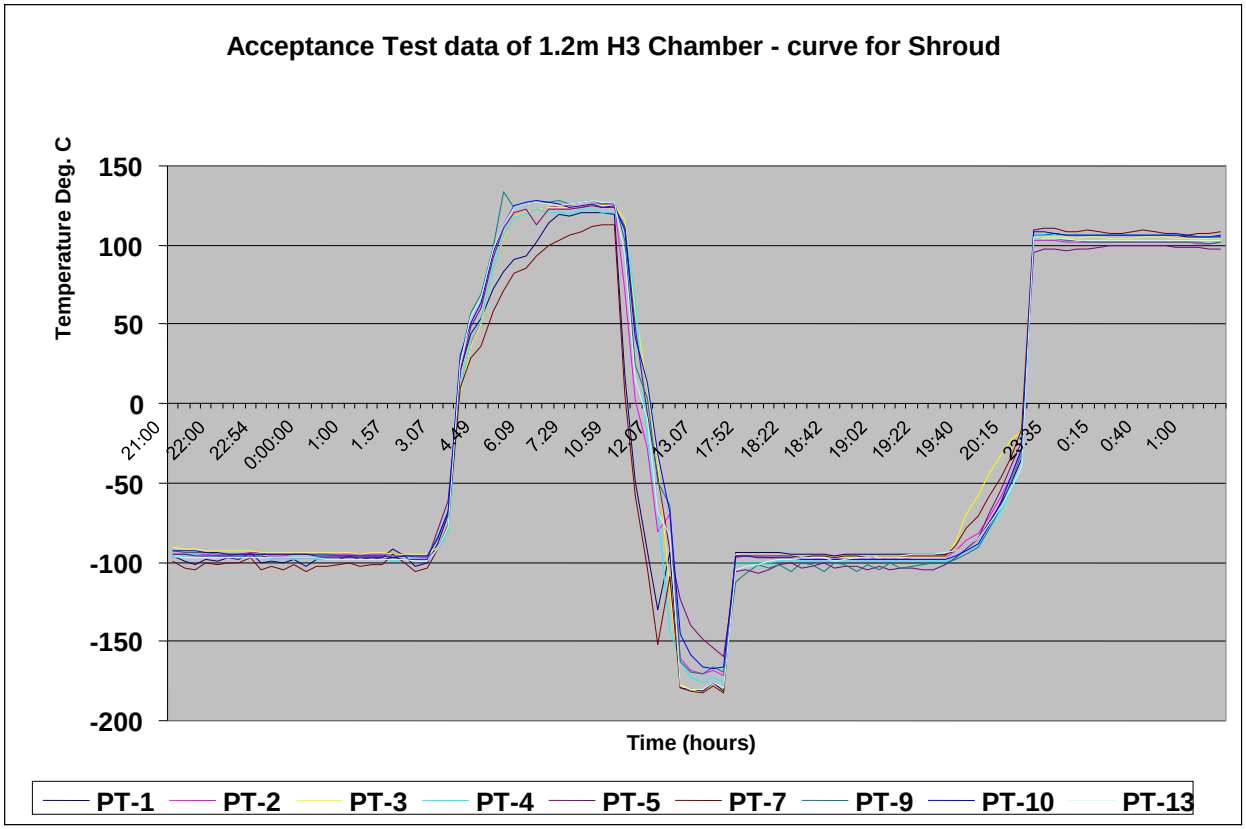
- The variation of temperature along the length of bottom inlets by placing 5 temperature sensors in the same line

- Identified the conductive sensitive locations on the shroud and got information on the fluid flow pattern

- Mapping of temperature profile of bottom inlet and top inlet was done and fixed the locations of sensors

Advantages of this system

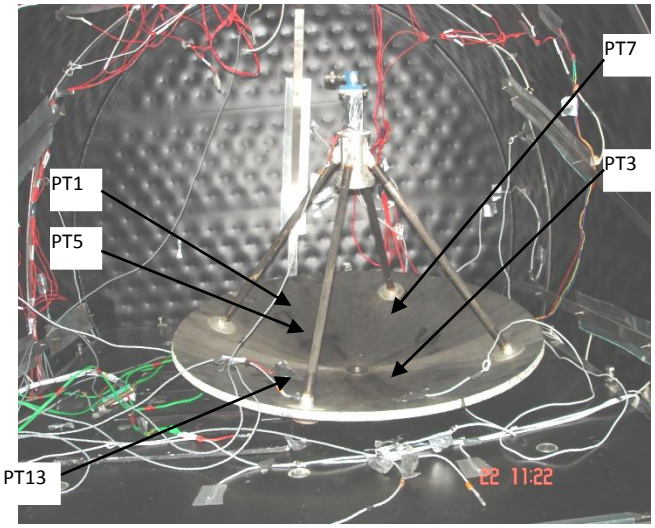
- It occupies less space, as there are only two pipe lines one, vacuum jacketed (25NB inner pipe) line as inlet line and another one, armaflex insulated (25 NB pipe) line as outlet, on the ground
- Operation of the system is silent, as there are no noise making blowers
- Low power consumption (4.5 KW) (IR Lamps)
- Nominal liquid nitrogen consumption (approx. 80 liters/hour)



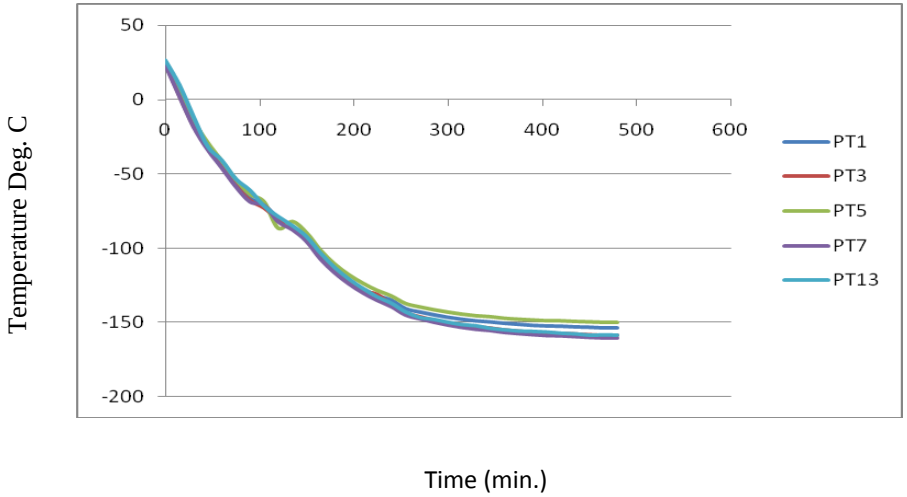
Maximum gradient of +/-6.5 deg.C was achieved @ -100 Deg.C, with a control accuracy of +/- 1.5 deg. C.

Maximum gradient of +/- 7.5 deg.C was achieved @ +120 Deg.C, with a control accuracy of +/- 1 deg. C.

The test was extended to see the lowest attained temperature on shroud which was seen as -186 deg.C



0.8m antenna reflector was tested in the same chamber



Thank You