Cryogenics for VTS and HTS facilities

VTS: Vertical Test Stand
HTS: Horizontal Test Stand

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Choice of Operating Temperature

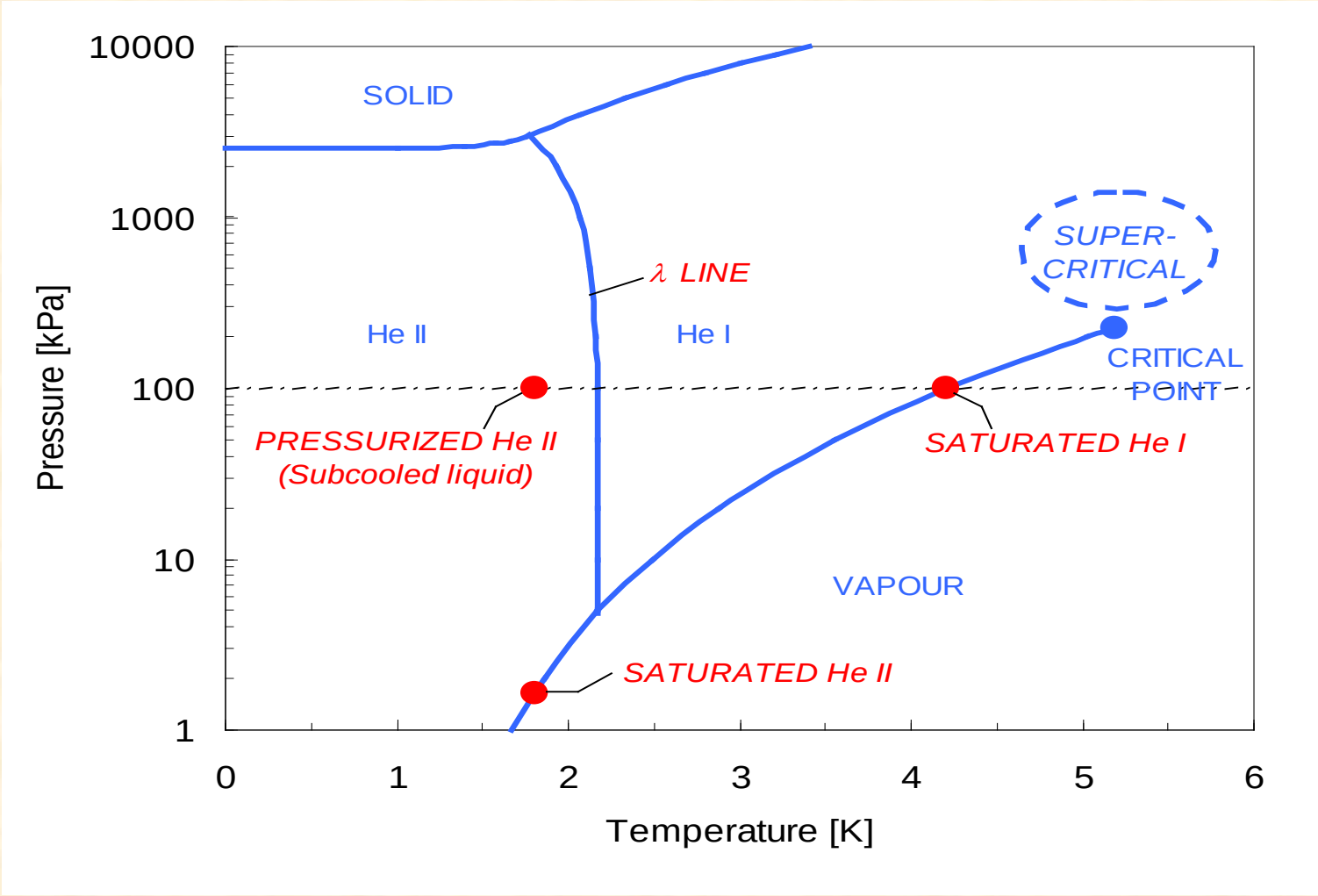
4.5 K or 2K ?

- Superconducting cavities needs cryogenic temperatures for their operation
- Such low temperatures have to be maintained even during operations when cavity is dissipating large amount of heat as much as 30 W at 2K, per cavity in case of CW operation.

Choice of temperature:

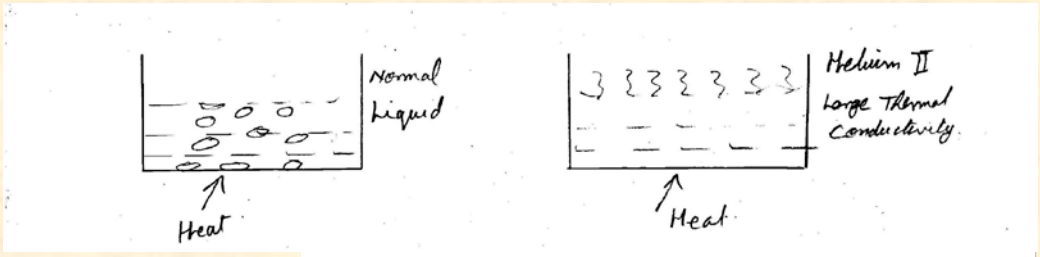
- Cavities can be operated at 4.5K or below 2.17K (lambda point)
- Decrease BCS resistance & increase unloaded quality factor Q_o.
- For Example for CERN's super conducting proton LINAC they have estimated that for 704MHz and 25MV/m, $Q_{2K} = 45 \times Q_{4.5K}$

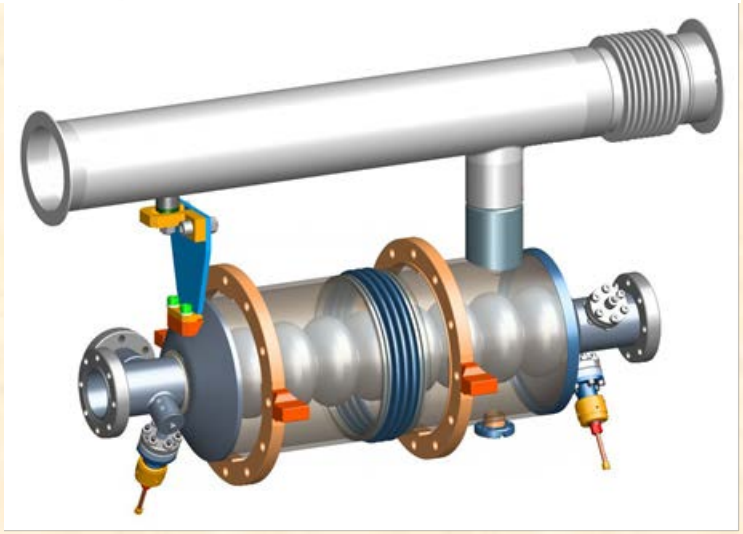
Phase diagram of helium



Helium-4 Properties below the lambda point

- Thermal conductivity increases many times –
  much higher than that of pure copper at room temperature.
  [Thermal conductivity of He I is approximately 0.024 W/(m K)
  whereas He II has 86,500 W/(m K)]



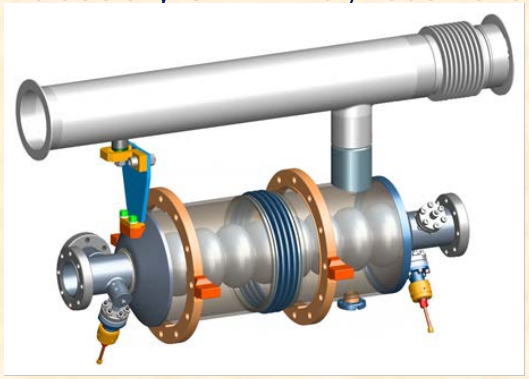


Choice of Operating Temperature

4.5 K or 2K ?

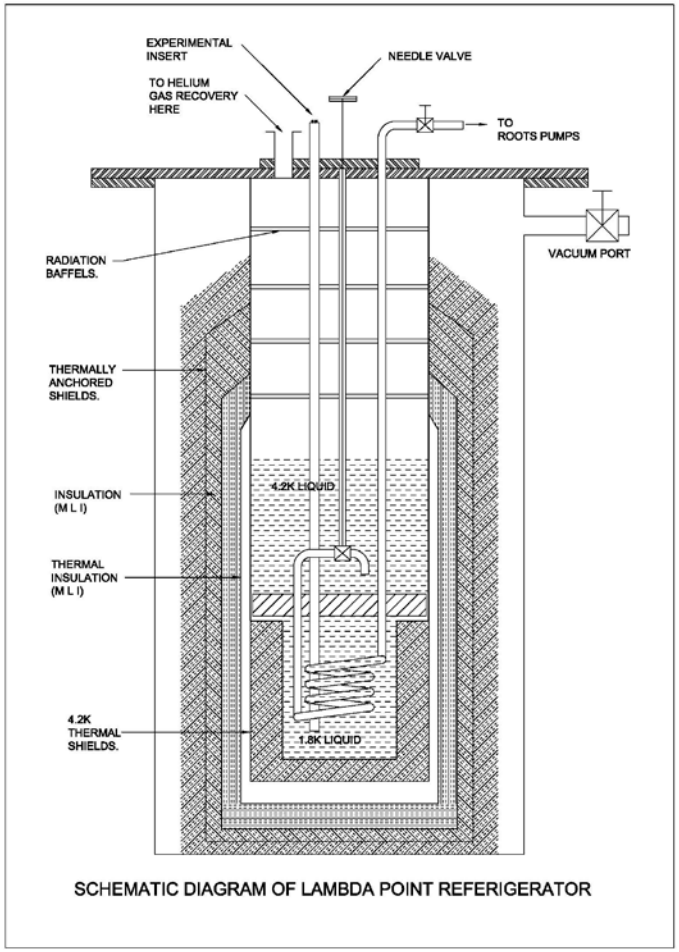
Benefit of Helium II properties, also brings in complications:

- Limit to heat transfer comes from Helium II heat conductivity properties, bath temperature, dimensions of helium vessel and attached tubing. Hence proper sizing of pipes, helium vessel, chimney etc is essential.



- Whole circuit at below atmospheric pressure, a small leak 1mb. l/s will block operation of heat exchangers in few days of operation. Leak tightness crucial.
- Thermodynamic efficiency is low at 4.5K.
- Cost of cryogenic installation is roughly 2 times more for 2K

Methods of achieving 2K or below



SCHEMATIC DIAGRAM OF LAMBDA POINT REFERIGERATOR

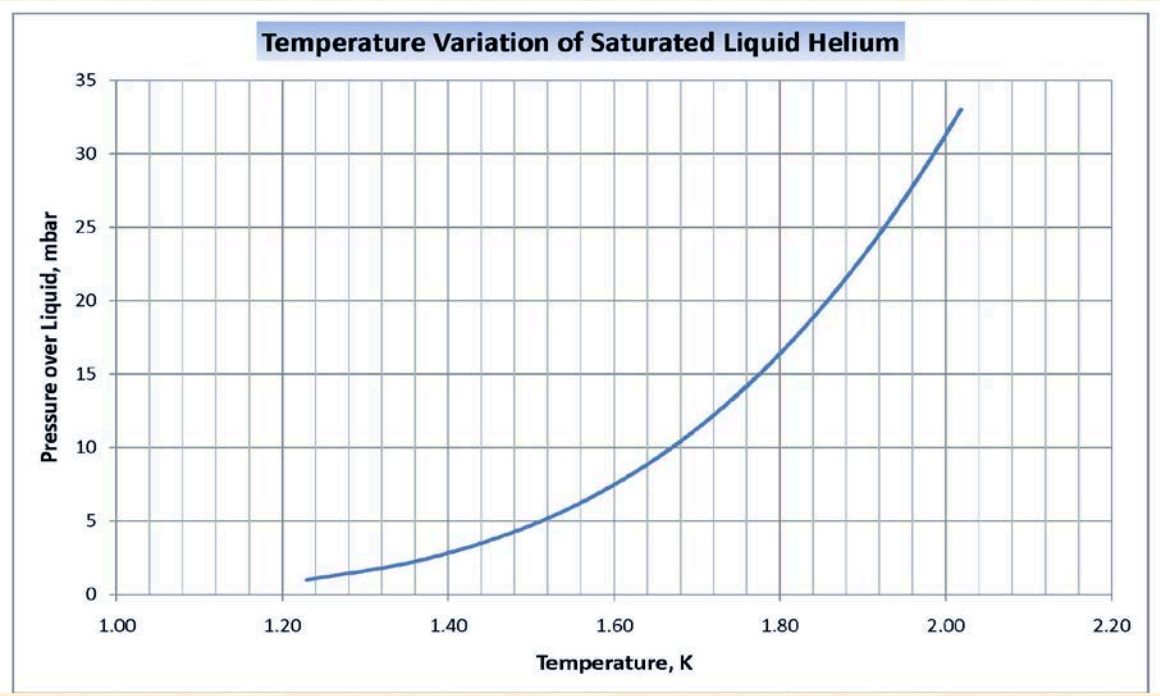
Advantage:

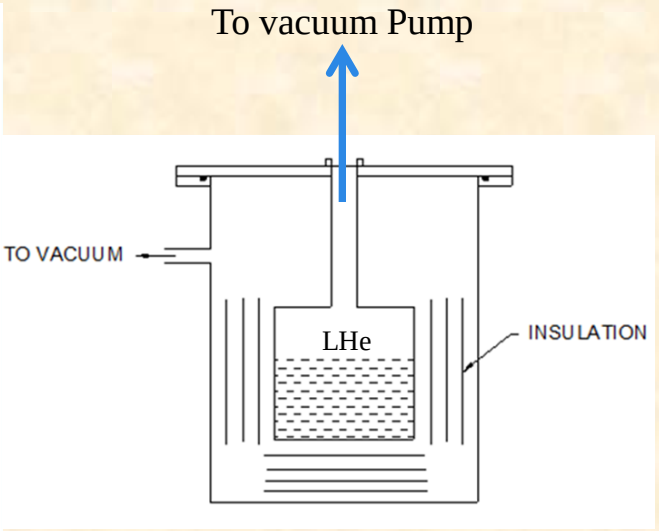
Bulk of liquid helium becomes sub-cooled liquid – remains at higher pressure: Impurities do not enter due to leaks to atmosphere.

Disadvantage:

Poor long term temperature stability.

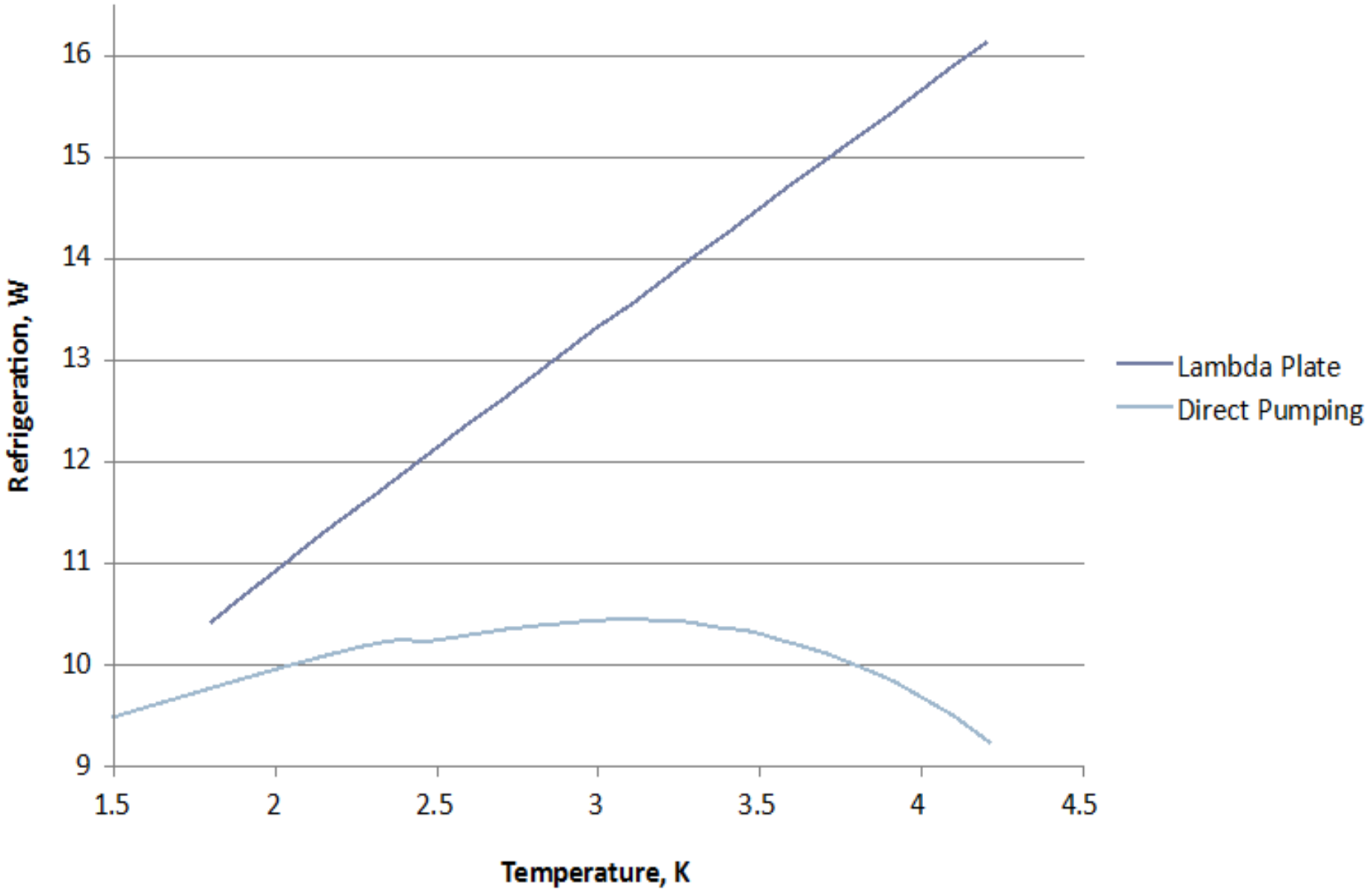
Saturated Vapour Method



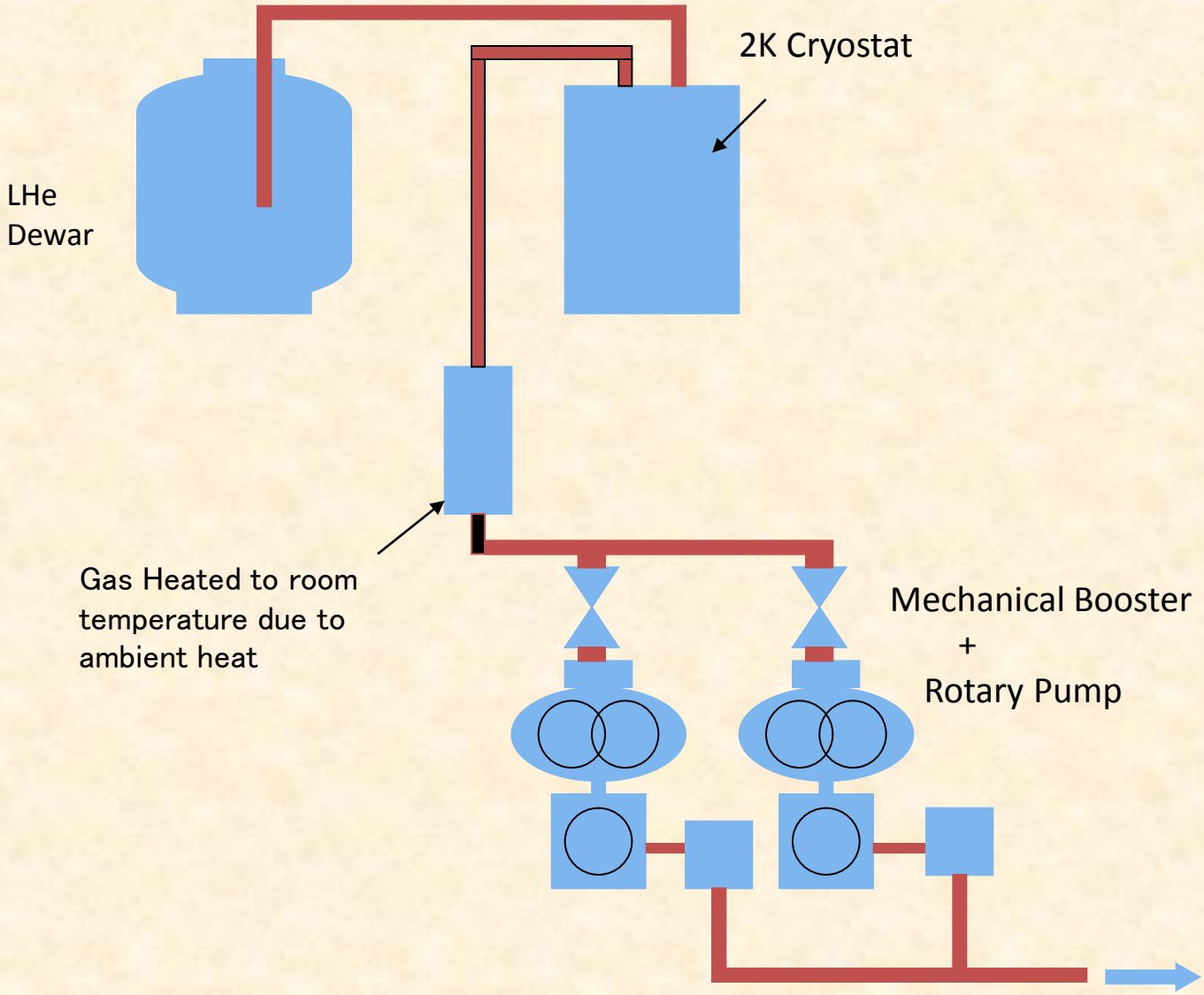


- Advantage: Good temperature stability due to involvement of latent heat. Change in Temperature is linked with change in pressure.
- Disadvantage: System operates at sub atmospheric pressure. Needs Leak tight system.

Refrigeration by Pumping Down

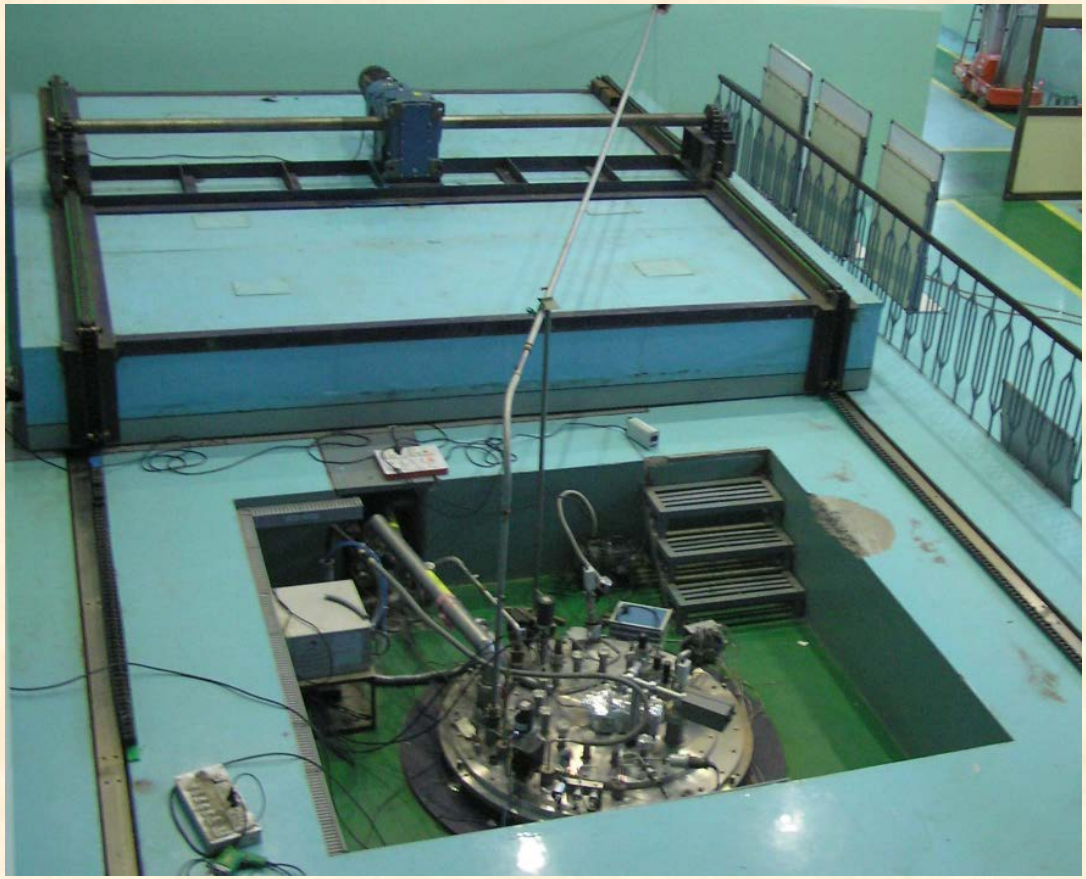


Scheme of VTS 2K Cooling System

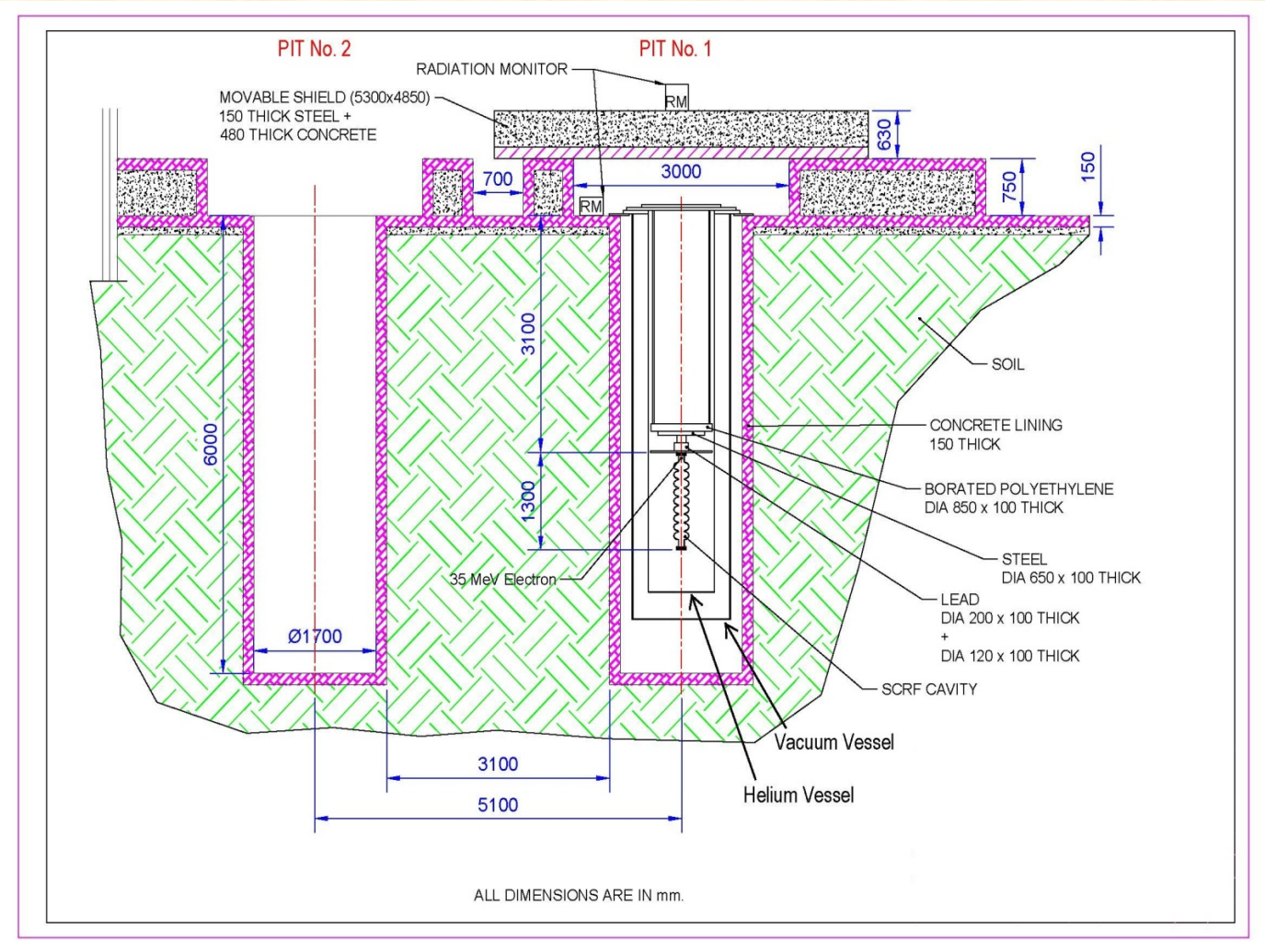


Cryogenic infrastructure for testing SCRF cavities

VTS Cryostat Pit



Cut away section of cryostat pits



145 lit/ hr Liquid helium plant with 10,000 lit main Dewar

2K pumping station

Mechanical booster pumps

Vacuum pumps

Vacuum pumps	
CP120	112 m^3/hr.
SP250	330 m^3/hr.
Booster pumps	
EH1200	1435 m^3/hr.
EH2600	3110 m^3/hr.

Helium Gas Recovery Compressor

Recovery Compressor
Capacity: 210 Nm^3/hr
Motor Power 100 kW

For comparison it takes only 1 ½ minutes to fill a regular cylinder up to 140 bar with this compressor .

This compressor is capable of recovering helium gas when a cooling power of 250 W at 2K is being produced by pumping over liquid helium.
Made and supplied by INDIAN Company.

Large Helium Gas Cylinder Banks

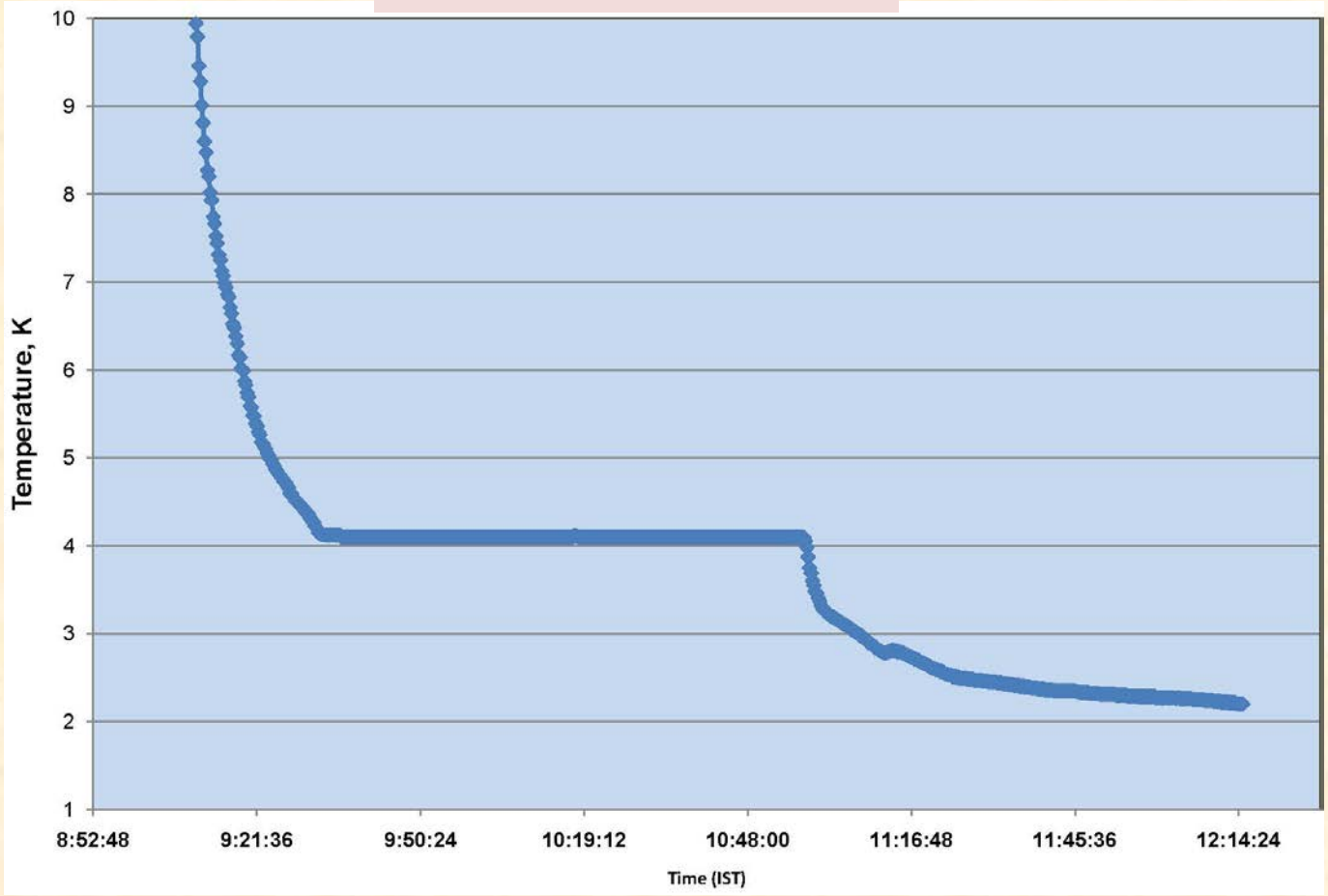
Water capacity of each Cylinder: 2,250 liters (= 50 conventional Cylinders)
No. of cylinders in each bank: 08
Total Banks: 03 nos (= 1200 conventional cylinders)

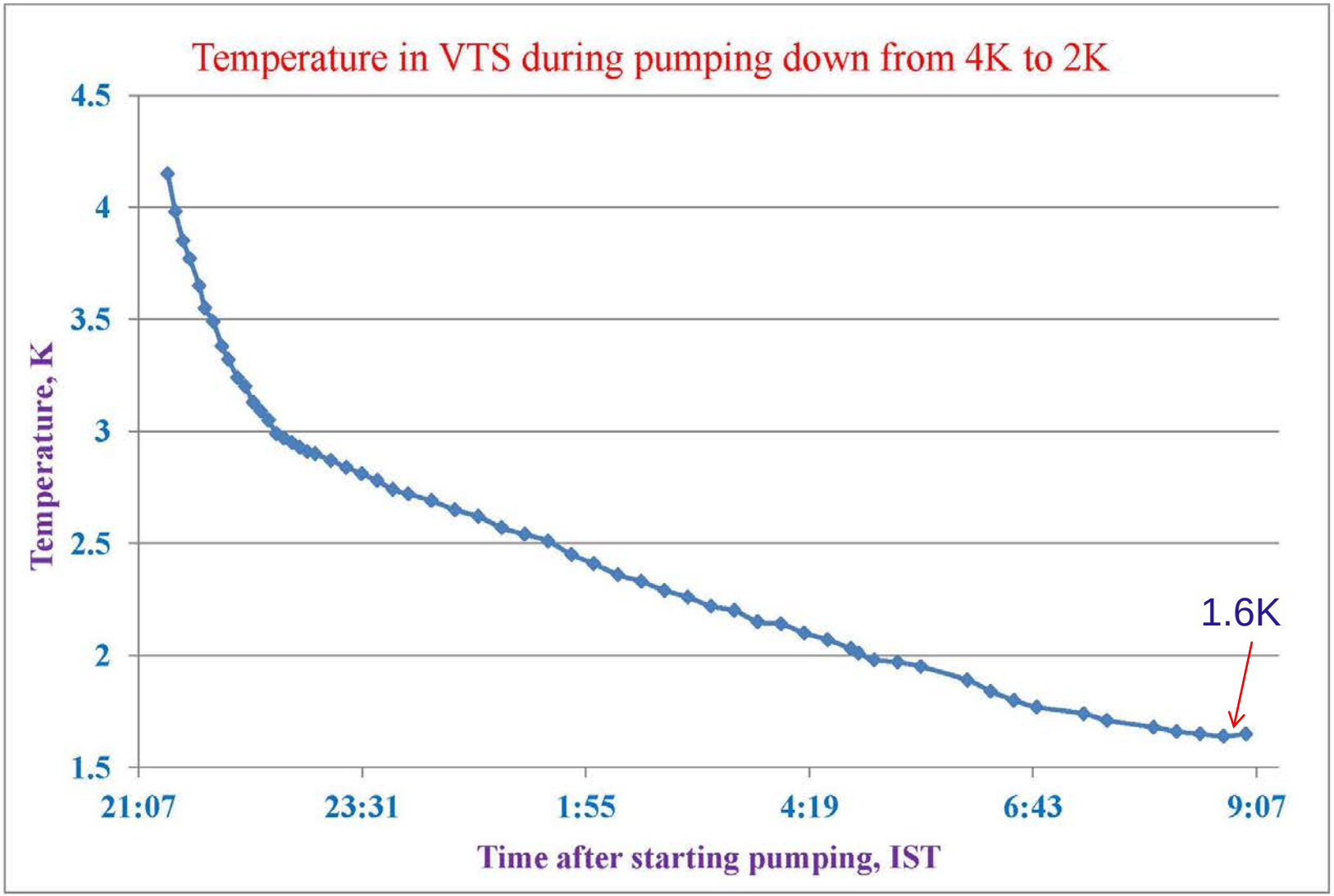
Helium gas evaporated from 10,000 liters of liquid helium can be stored in these cylinder banks at 140 bar
Cylinder banks made by M/s Everest Kanto Cylinders Ltd. , INDIA)

Cryogenic Operation of Vertical Test Cryostat

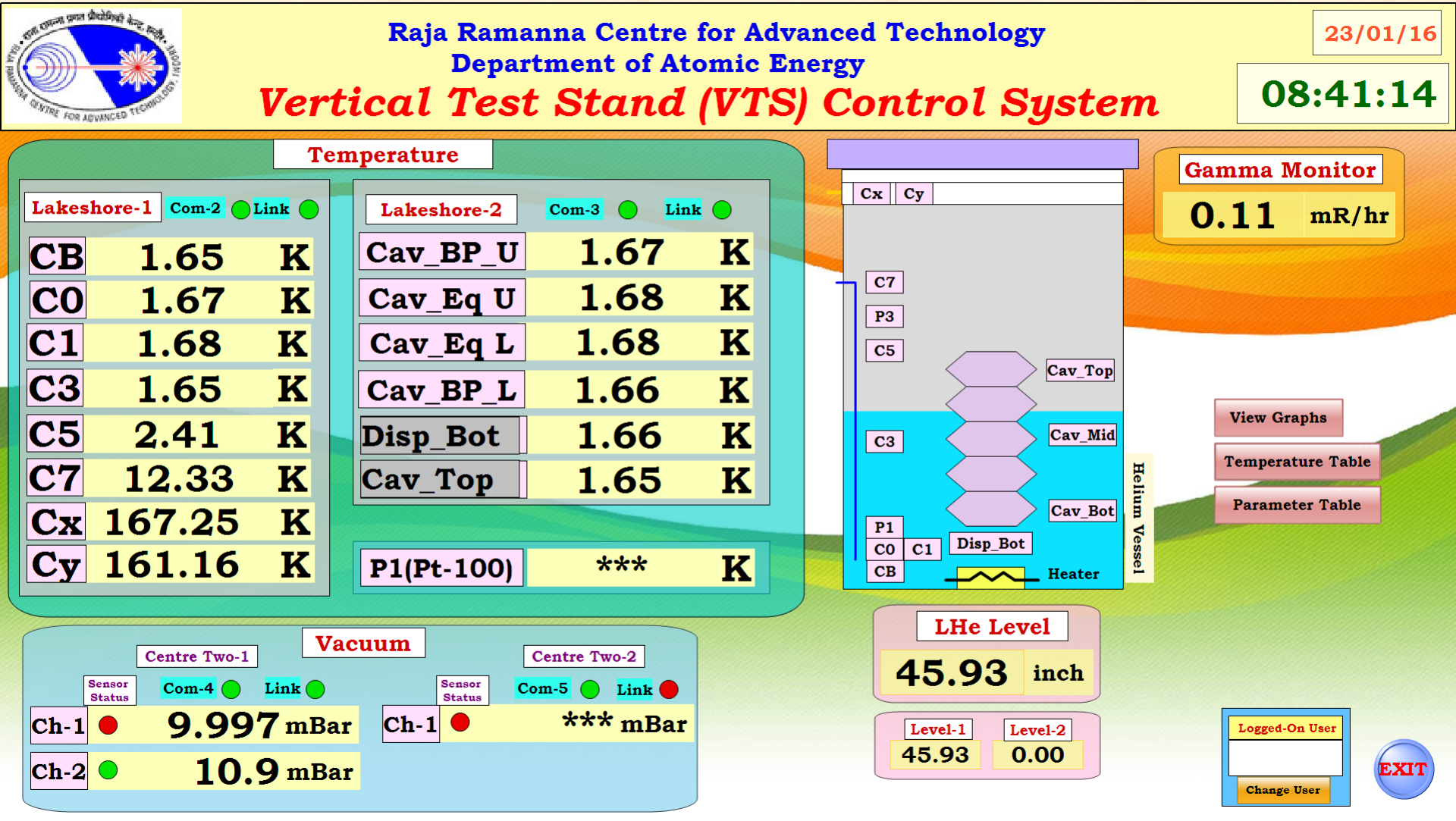
This facility is operational since November 15, 2013.

Result of first test

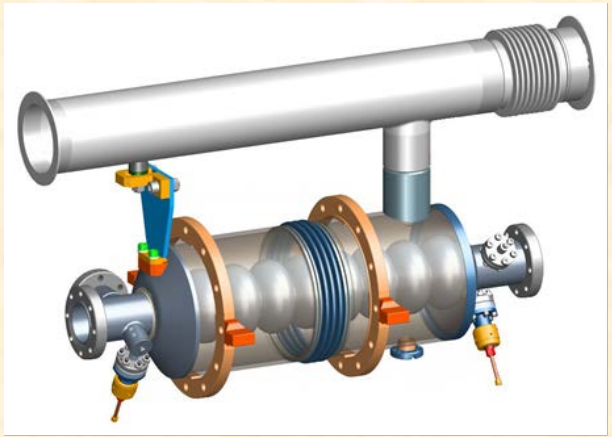



Temperature in VTS during pumping down from 4K to 2K
4.5
4
3.5
3
2.5
2
1.5
Temperature, K
1.6K
21:07
23:31
1:55
4:19
6:43
9:07
Time after starting pumping, IST

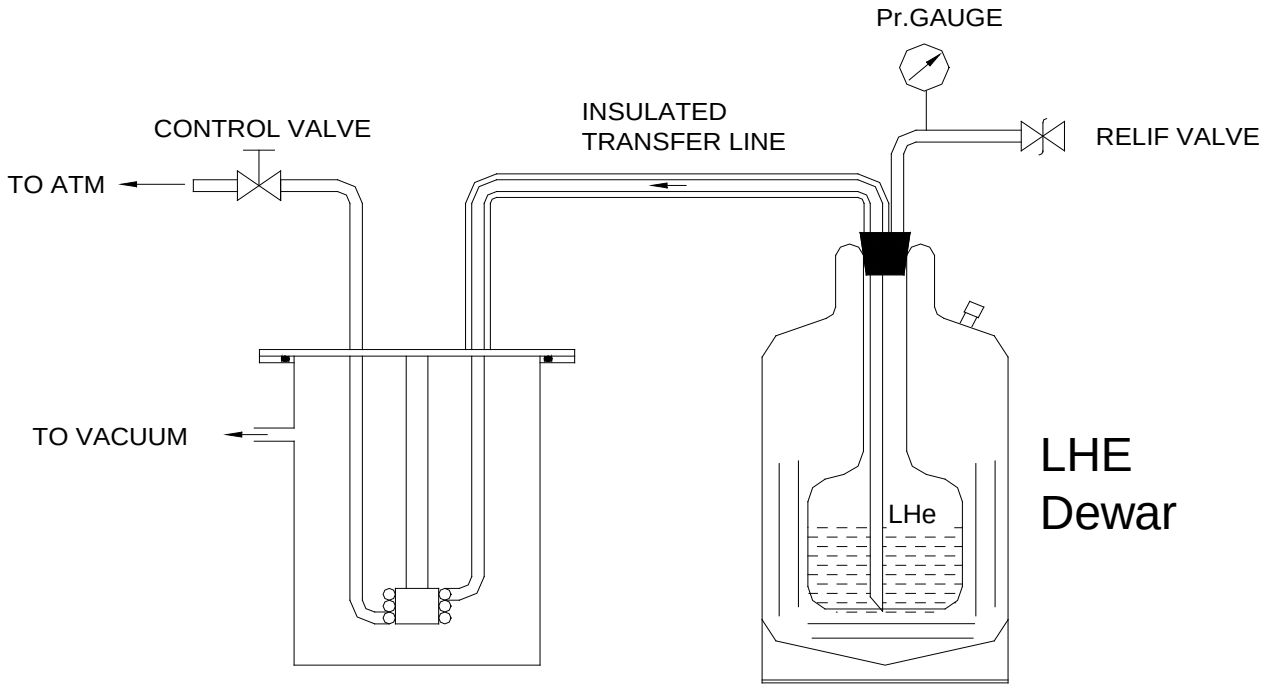
Minimum temperature in VTS during testing



Bare SRF after qualifying in the VTS test is dressed with helium vessel, mechanical tuner, RF power coupler etc.

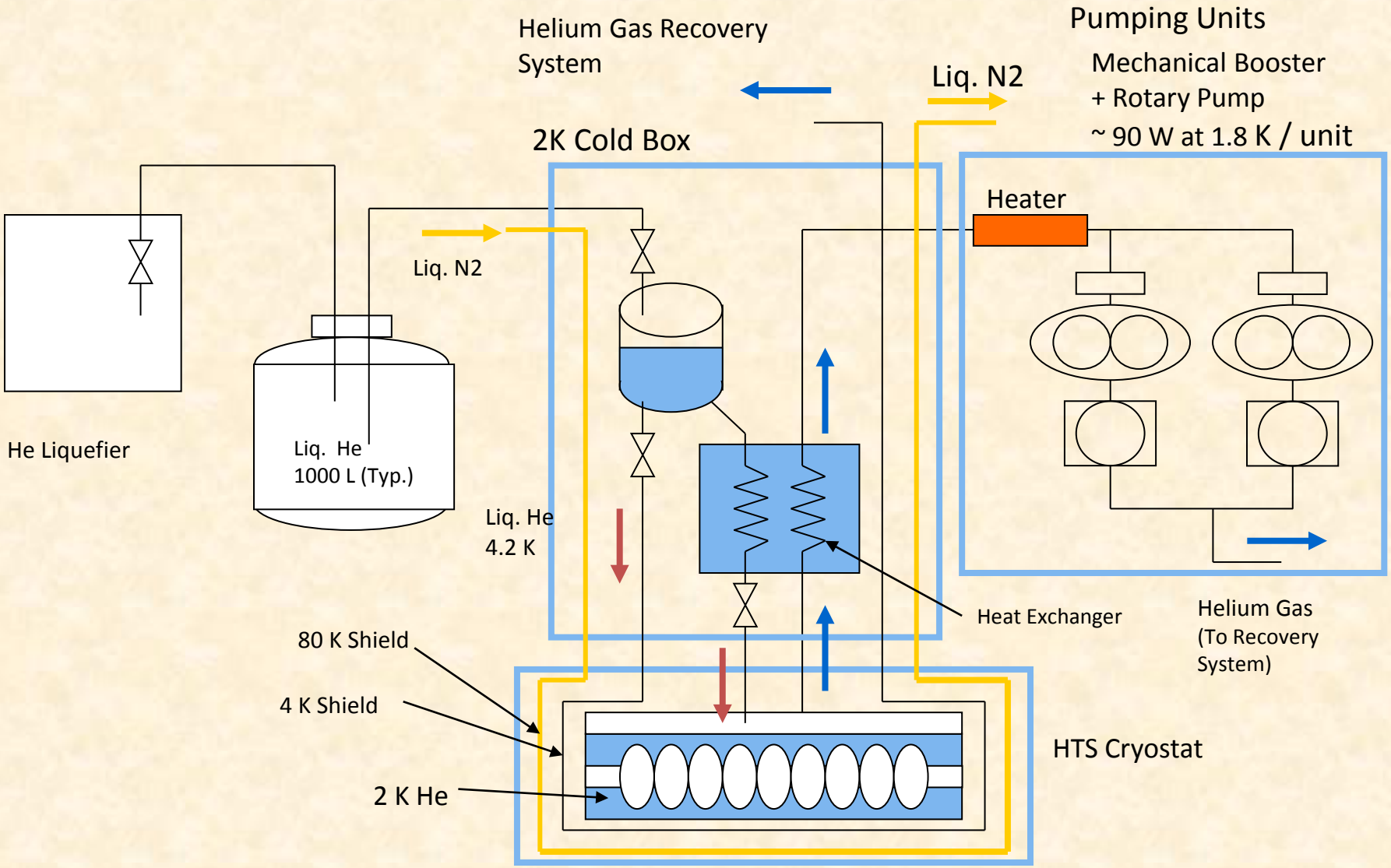


Simplified scheme for a continuous cryostat

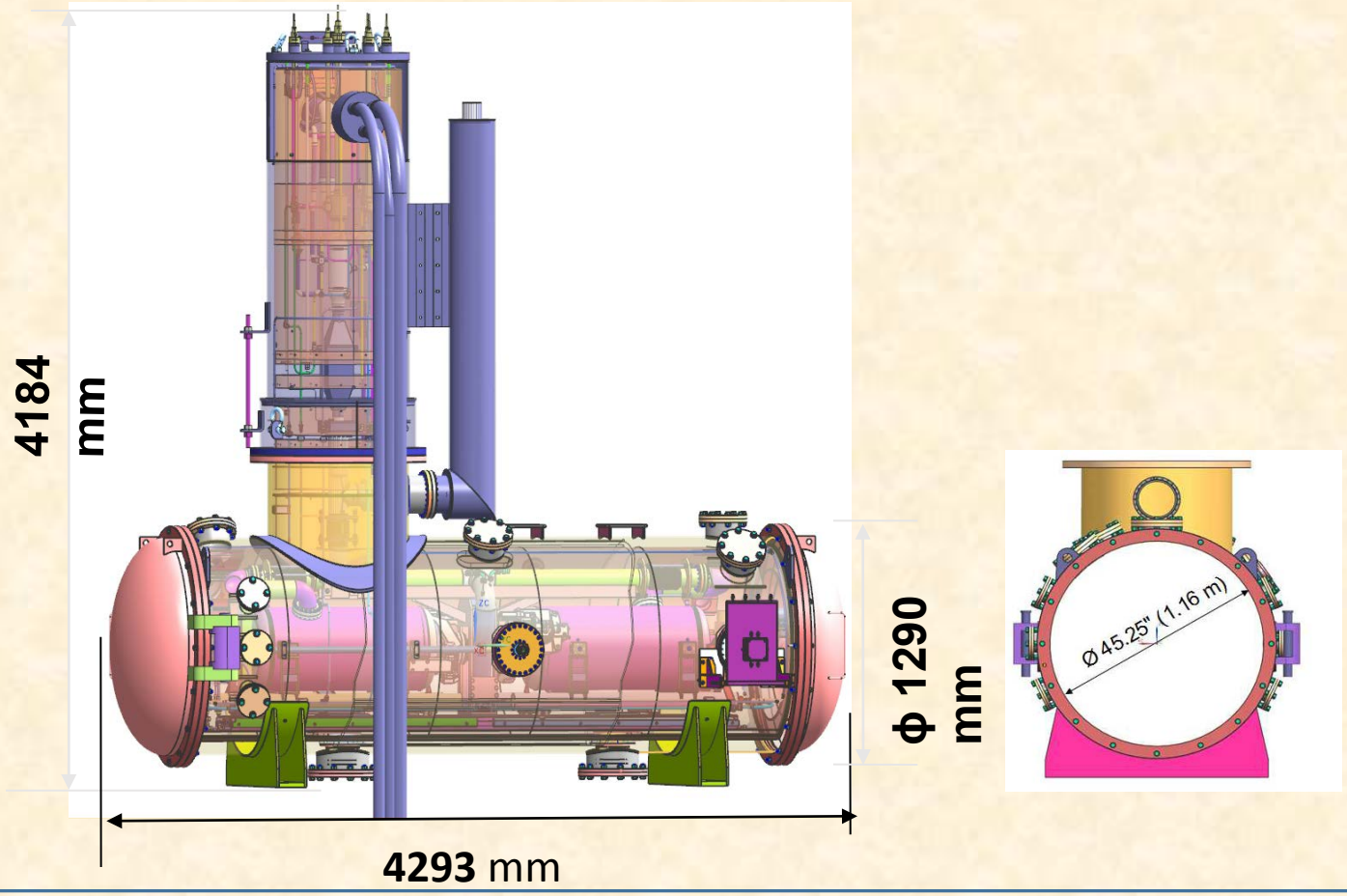


CONTINUOUS FLOW CRYOSTAT.

Scheme for 2K Cooling System for HTS Cryostat



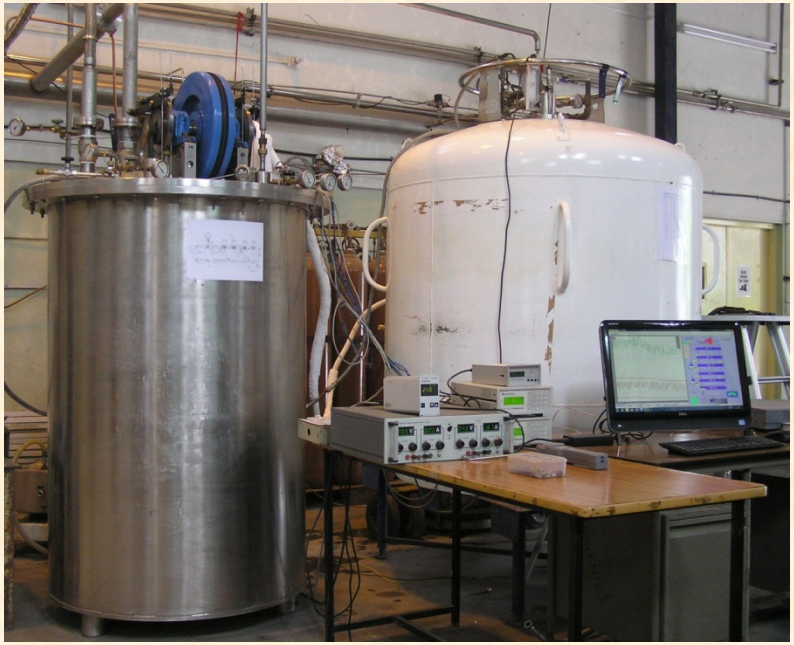
3-D Model of HTS Cryostat

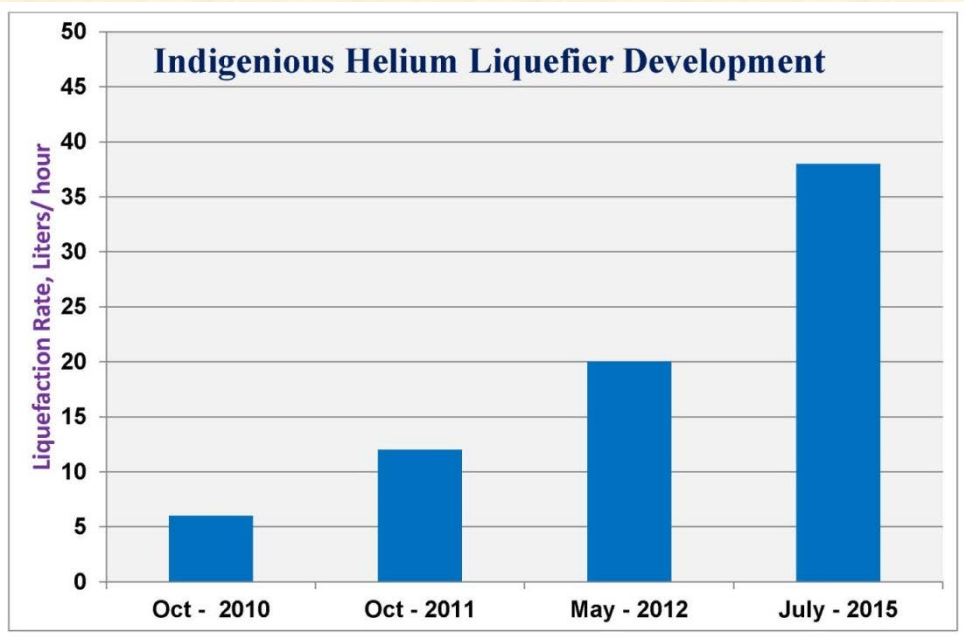


3-D MODEL OF HORIZONTAL TEST CRYOSTAT -2 WITH FEEDCAN

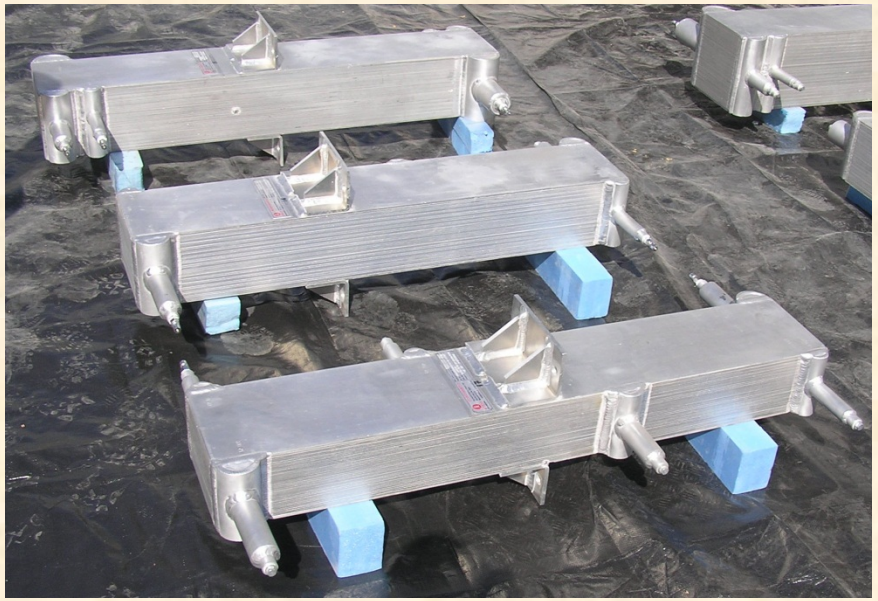
Indigenous Helium Liquefier Development

Helium was liquefied in indigenous system on October 2010. This was for the first time in the country. Gradually its capacity was increased to 35 lit/ hr. Now trails are in progress for 50 lit/ hr liquefier



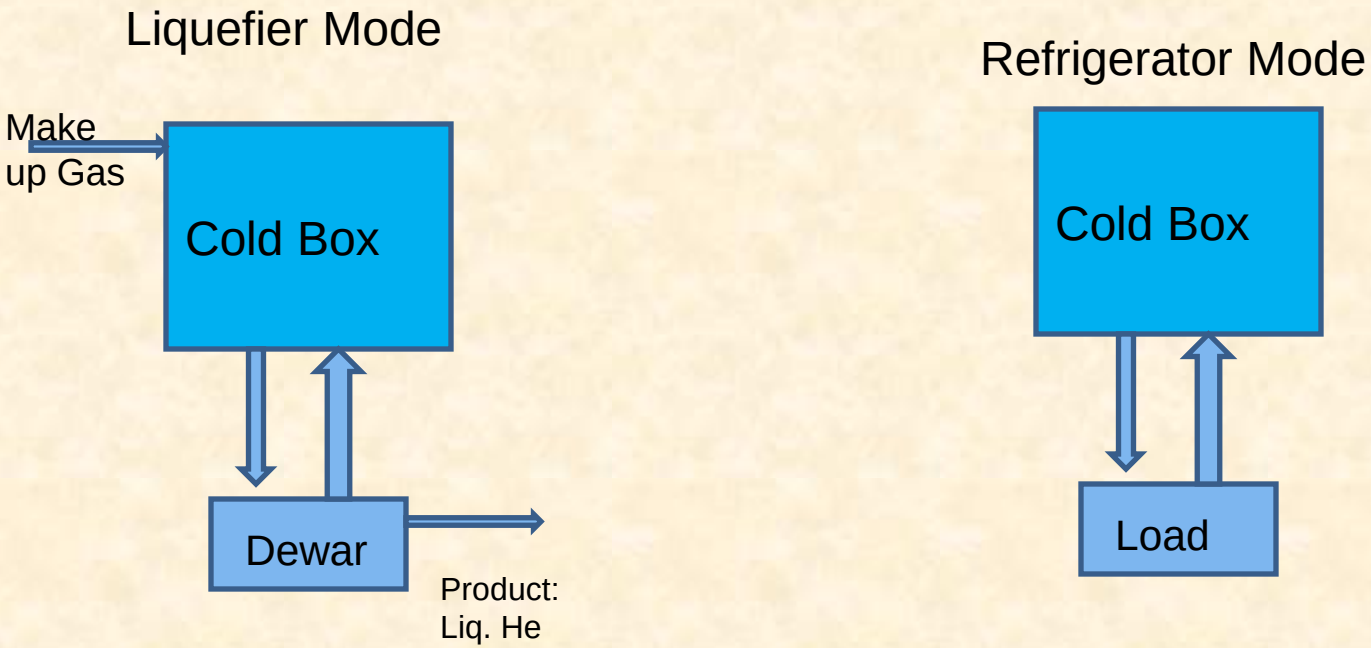


Development of Heat exchangers for helium liquefier

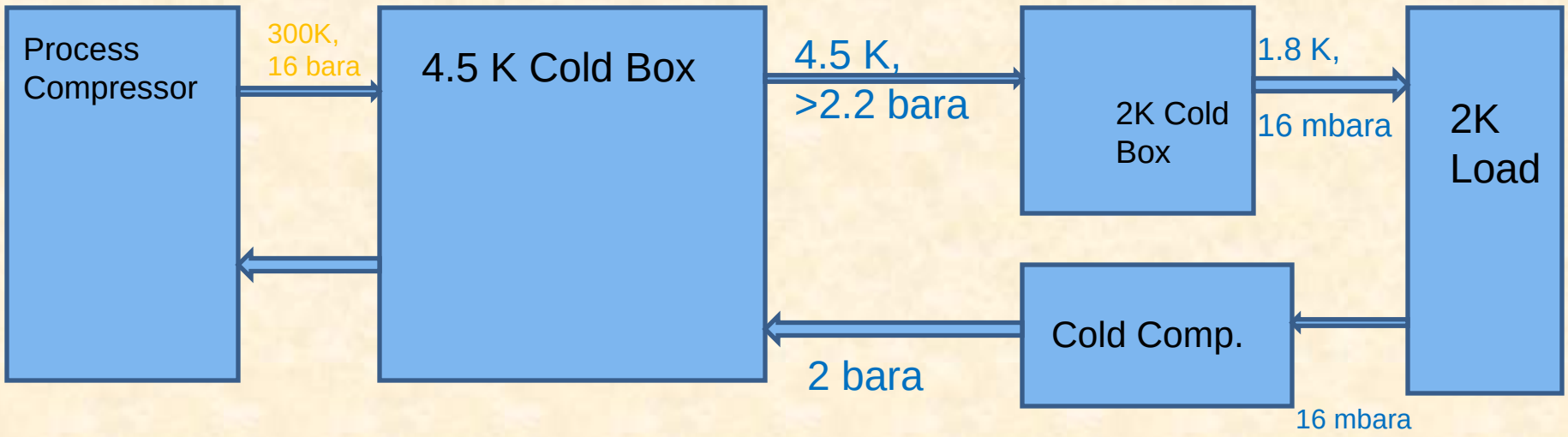


State of the art Brazed Aluminium Plate fin Heat Exchangers

Large size 2 K Refrigerators



Schematic of a 2K Refrigerator



Thank you