detection methods at room temperature. However, as soon as the temperatures go below say 20 K, the insulating vacuum starts degrading. Due to this reason, the fabrication procedure with intermediate inspection/ testing steps needs to be worked out carefully.

Basically, there are two methods by which one can reach at 2 K or low using Liquid Helium. The first one is by pumping over the liquid bath. This method is also called "saturated temperature" type. In this method, temperature of the liquid remains constant due to the latent heat of evaporation. Heat loads only results in higher boil-off. In this method, the stability of temperature is directly linked with the stability in pressure over the bath. This method is normally used to meet the temperature requirements in case of Superconducting RF Cavities.

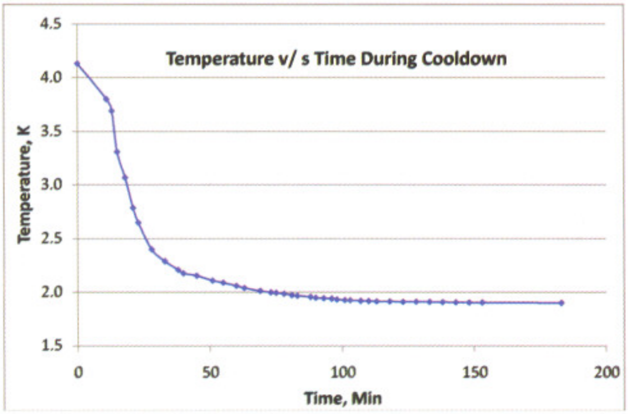

Fig. A.11.1: Cooling down from 4.2 K to 1.9K

In the second method, a portion of liquid helium at 4.2 K is separately expanded through a J-T valve, and using heat exchangers, the remaining liquid is cooled. In this method the liquid helium is in "Super Cooled state". Special cooling properties of Liquid helium at 2 K viz. Super Fluid properties - property to flow through fine capillaries and large thermal conductivity are utilised, at the same time the bulk of the liquid in the cryostat remains at pressure above atmospheric pressure. Normally, this method is used to cool Superconducting magnets operating in 2 K region. This method relaxes conditions for system integrity of the peripheral systems, i.e., in case of very small leaks, helium gas can leak to atmosphere. Limitations of this method are: in case of excessive heat load, the temperature of the liquid will start rising that gives poor temperature stability. The first case has very good temperature stability due to involvement of latent heat, but small leaks in the system will result in air and moisture entering the system, thereby limiting the reliability or operation time of the system.

Cryostat designed by us is based on the first method viz. saturated liquid type. It was fabricated by a local fabricator. It was first tested at normal liquid helium temperature (4.2 K). Heat in-leak calculated from the boil-off was less than 70 mW. These values of heat in-leak match closely with the designed values.

The 2 K Temperature was reached in about 73 min after starting the evacuation pump at 4.2 K. We started with about 08 liters of liquid in the cryostat, and when we reached 2 K it was still left with about 4.5 liters. After reaching 2 K the helium boil-off was quite low for maintaining 2 K to 1.9 K, as the self heat load of the cryostat to the 2 K liquid chamber is about 70 mW. In next two hours, less than 0.5 litres got boiled. This cryostat will be used among others, to calibrate cryogenics temperature sensors in 4.2 to 1.8 K range.

Fig. A.11.2: Experimental setup with 2 K cryostat

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A.12: Prototype solid state bouncer modulator designed and developed by RRCAT has been commissioned at CERN

A prototype solid state bouncer long pulse modulator for LEP 1MW klystrons was successfully designed, developed, tested and shipped to CERN by RRCAT under the DAE CERN Novel Accelerator Technology Project. The First acceptance tests were done at RRCAT by CERN engineers. Additional features and modifications requested by CERN team were then incorporated and tested. The modulator was then dismantled and shipped by RRCAT. RRCAT engineers completed the integration and commissioning of the modulator at CERN's test stand. After reintegration, the modulator passed the electrical safety inspections of CERN. All the tests for the rated operation were performed with 5 kΩ, 110 kV load. Tests of slow and fast interlocks and controls were also done. Finally, the solid state bouncer modulator was accepted by CERN engineers. Table A12.1 presents the main results of the bouncer modulator during these tests.

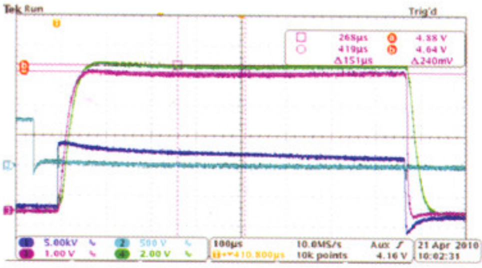
Table A.12.1: List of major acceptance test parameters of the modulator

Parameter	Design Targets	Achieved results
Klystron modulator type	Solid state Bouncer	Solid state Bouncer
High Voltage pulse amplitude	-10 kV to -110kV	-10 kV to -110kV
High Voltage pulse width at 70% to 70 % of peak.	800 µsec	800 µsec
Minimum Flat top available	600 µsec	600 µsec
Maximum current during pulse	24A	24A
Pulse repetition rate	2Hz	2Hz
Acceptable voltage droop at flat top	≤1.0%	≤1.0%
Allowed ripple on flat top (≥ 10 kHz)	≤0.1%	≤0.1%
Rise time/fall time	< 100 µs	< 80 µs
Limiting energy dissipated in klystron during its arc	< 10 J	< 10 J

Fig. A.12.1: Inspection and evaluation testing of the modulator on a 110 kV load at CERN Test Stand

Fig. A.12.2: Scenes during acceptance of modulator at CERN

Figure A.12.1 shows the bouncer modulator during inspection and acceptance tests. Fig. A.12.2 shows CERN senior scientists and group leaders with RRCAT engineers during acceptance of modulator. Figs. A.12.3 and A.12.4 show some of the test results of bouncer modulator on high voltage load during acceptance tests.



1: Primary high voltage terminal signal w.r.t. ground on normal scale (5kV/div.)
2: Bouncer switch voltage signal on normal scale (500V/div.)
3: Primary current signal (0.05V / 2A) on normal scale (1V/div.)
4: Secondary output voltage signal (10000 : 1) on normal scale (2V/div.)

Fig. A.12.3: Results of acceptance tests at CERN. Waveforms from top indicate output voltage 104kV@20kV/div, output current@5A/div, primary voltage referred to ground and bouncer switch voltage respectively

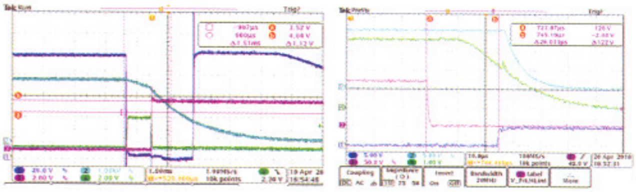


Fig A.12.4: Trace on left shows crowbar action on pulse width overrun fault @ 1ms. See from top, Bouncer switch voltage signal, Main Capacitor voltage, Crowbar trigger signal, Modulator output voltage. Trace on right shows crowbar action on under voltage due to arc fault @ 750us pulse width. See from top: Reference Pulse for UV detection, Secondary voltage signal. Main switch input Pulse, Crowbar trigger signal

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