N89-12604

THE INSTRUMENT TEST DEWAR: TESTING SATELLITE INSTRUMENTS AT 1.5 K

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ABSTRACT

The Instrument Test Dewar (ITD) is a cryogenic facility designed and built to test Cosmic Background Explorer (COBE) Satellite instruments at 1.5 K. The facility provides a high vacuum and thermal environment with payload thermal, electrical and optical interfaces. There are two concentric vacuum spaces which are not hermetically sealed. The instrument vacuum space is 81.28 cm x 243.84 cm and is cooled by an LHe shroud. The guard vacuum space surrounds an LN2 shroud. There are two separate cryosorption pumping systems and a mechanical LHe pumping system. Two data acquisition systems provide payload and housekeeping data. There have been various problems with the facility, and changes and improvements have been made to assure optimum test conditions. COBE instrument testing has been completed on structural, thermal model hardware and the protoflight units.

INTRODUCTION

The Cosmic Background Explorer (COBE) is an in-house project at the Goddard Space Flight Center. The purpose of the satellite is to study the Big Bang Theory of how the universe was formed. Two of the three COBE instruments are cryogenically cooled. The Far Infrared Absolute Spectrophotometer (FIRAS) is a liquid helium cooled interferometer and the Diffuse Infrared Background Experiment (DIRBE) is a liquid helium cooled filter photometer. Both instruments are housed together in the Cryogenic Optical Assembly (COA) which is cryogenically cooled in the inside of a flight liquid helium dewar. COBE project requirements for development of instruments dictated the need for a test facility capable of testing at 1.5 K, but there was no test facility with this capability.

The Instrument Test Dewar was built specifically to simulate the COBE flight dewar and to provide a 1.5 K vacuum environment for the COBE instruments (see figure 1). The facility was developed by the Goddard Cryogenics Technology Section and was built by Janis of Massachusetts. The facility was turned over to the Simulation Test Section to complete COBE instrument testing. The facility is housed in a Class 10,000 clean room where strict contamination conditioning and monitoring is maintained. The COBE instruments can be tested together as the Cryogenic Optical Assembly (COA) or can be tested individually. Six tests were completed at various stages of hardware development including a thermal structural unit, thermal unit and a protoflight unit.

SYSTEMS DESCRIPTION

GENERAL

An external shell surrounds two concentric vacuum spaces inside of which is a liquid nitrogen (LN2) reservoir and a liquid helium (LHe) reservoir. The ITD is 3.35 m (11 feet) high by 1.52 m (5 feet) diameter. The instrument test space is 81.28 cm (32 inches) by 243.84 cm (96 inches) high (see figure 2). The dewar weighs 4,500 pounds without cryogens and approximately 5,270 pounds with cryogens.

VACUUM

High Vacuum System

The Instrument Vacuum Space (IVS) and the Guard Vacuum Space (GVS) are two concentric vacuum spaces but are not hermetically sealed. Each space has its own roughing pump and cryosorption pump. The cryosorption pumps are good to a static pressure of less than 1 x 10E-4 torr. When the cryogens are added and the dewar is cold, a pressure of less than 1 x 10E-7 torr is achieved.

LHe Pumping System

A mechanical pumping system is used to lower the pressure above the 4.2 K LHe to lower the temperature to approximately 1.5 K. The mechanical pumping system consists of a Roots blower in tandem with a rotary vane pump. The LHe bath temperature can be adjusted slightly by throttling valves.

CRYOGENIC

Liquid Nitrogen

The liquid nitrogen reservoir (surrounded by the guard vacuum space) holds 277 liters of liquid nitrogen. The reservoir is initially filled with LN2 from the house supply and thereafter can be topped off either manually or automatically from 160 liter LN2 dewars.

Liquid Helium

The LHe reservoir surrounds the instrument vacuum space. The reservoir is filled to its 475 liter capacity from 500 liter LHe dewars. The reservoir is always backfilled with GHe to atmospheric pressure before LHe is transferred. The LHe is transferred through a flexible vacuum jacketed (V-J) line which connects the 500 liter supply dewar dip tube to the ITD internal fill line.

THERMAL INTERFACE

The mechanical interface which also serves as the main thermal interface in the ITD is the Instrument Interface Flange (IIF). The IIF is bolted onto the bottom flange of the LHe reservoir, and the COA is bolted to the IIF during testing. There are also several attachment points at the top of the LHe reservoir for copper thermal straps which are connected to the payload.

ELECTRICAL INTERFACE

The electrical interface at the IIF consists of five 196-pin blindmate connectors wired to nineteen 61-pin external connectors. At the top of the instrument vacuum space there are six 196-pin blindmate connectors wired to twelve 61-pin external connectors, which provide for additional instrumentation and housekeeping instrumentation.

OPTICAL INTERFACE

On the IIF there is a blindmate assembly wired to a 12-pin external optical fiber connector. The ITD has ports which were originally aligned with the COBE instrument axes at the top of the dewar. These ports can be blanked off or special optical quartz windows (for laser alignment) may be installed.

DATA ACQUISITION AND CONTROL

The facility is operated from a central control console which houses the controls and gauges for the high vacuum system, LHe pumping systems and the cryogen level monitors.

There are two separate identical data acquisition systems for test monitoring. The systems work independently; one system is dedicated to the payload and one to internal ITD housekeeping. Each system can read up to 140 channels of 4-lead resistance measurements, 2-lead voltage measurements or a combination of both. The systems are configured to read 4-lead Germanium Resistance Thermometers (GRT) or Platinum Resistance Thermometers (PRT) and either 4 or 2 lead strain gauges. Ten channels of data may be plotted on the CRT screen. The test data is stored on hard disk, floppy disk and magnetic tape. During testing hard copies of data can be obtained in real time. The wait period between scans can be pre-set and varied during the test. Plots of data can be obtained after the end of the test. The ITD has 18 GRTs and 4 PRTs for housekeeping purposes. The PRTs are accurate from 300 K to 60 K and the GRTs are accurate from 80 K to 1.2 K. There are four cryogenic accelerometers installed on the IIF which can be monitored if requested. The dewar internal cabling consists of Teflon coated manganin wire and stainless steel coax cable.

TEST DESCRIPTION

The ITD GVS and IVS are roughed down to 100 micron before opening the main valves to the cryosorption pumps which pump the system down to a static pressure of 1 x 10E-4 torr (figure 3). At this time the LN2 shroud can be filled. It typically takes 2 hours to fill the LN2 shroud to 100 percent. The LN2 shroud is allowed to cool the ITD before starting the flow of LHe. After LHe flow has begun, it takes approximately 72 hours to fill the LHe reservoir to 100 percent. A typical cooldown curve from 300 K - 4.2 K is shown in figure 4. It takes six to eight 500 liter LHe dewars to initially fill the reservoir. The helium is pumped on by the mechanical pumping system to obtain the superfluid helium. Superfluid temperatures can be obtained in 24 hours and can be maintained at an average of 72-90 hours depending on power being dissipated from the payload. A typical cooldown from 4.2 K - 1.5 K is shown in figure 5. The LHe reservoir can be backfilled with GHe to atmosphere, refilled and pumped back down to superfluid conditions as many times as required for the test. The warm-up of the facility is highly dependent on the payload. It is desirable to begin warm-up when the LHe is pumped out for the last time, however, it is possible to force any remaining LHe out of the reservoir. The LN2 is drained out of the LN2 shroud. After all internal temperatures are above 45 K the facility can be backfilled with GN2 to 1 torr. The only internal heat source is the payload itself. If the payload can be turned on it helps to expedite the warm-up. The facility has been warmed to ambient temperature in 4 days.

DISCUSSION

The facility has been used for instrument testing for the past 4 years. After each test, improvements and changes for project needs were made to the systems. There was one continuing problem with the facility which was solved this year and that was with iceplugs forming in the ITDs internal LHe fill line. The ice plugs would form during the changing of the 500 liter dewars and always just after some liquid had started to accumulate inside the reservoir. It was suspected that when the V-J line was disconnected from the supply dewar, some air was cryopumped into the line and would cause a plug inside the internal fill tube. The plugs were not dangerous but caused delays in the test and were tedious to break. The problem was solved by having a valve added to the flexible V-J fill line which connects the 500 liter supply dewar to the internal fill preventing any air leakage and since the line was modified no ice plugs have formed. The internal ITD cabling consisting of #28 and #36 teflon coated manganin wire and Type S1 stainless steel coax cable was replaced in the facility. This was necessary because during two different tests the project had poor resistance readings, shorts and open circuits which was determined to be attributed to the dewar cabling. All of the testing in this state-of-the-art facility was completed successfully. Approximately 6000 test hours were logged over a 4.5 year period.

SUMMARY

The Instrument Test Dewar is highly unique facility. It is the only known facility of its kind which can test a full size spacecraft instruments at superfluid liquid helium conditions. The facility was built to simulate the COBE spacecraft flight dewar, but now that the facility is no longer needed for testing COBE instruments it will be maintained and modified as necessary for future cryogenic satellite instrument testing.

REFERENCES

1. "Engineering Services Division Facilities and Capabilities Handbook", Engineering Services Division, NASA-Goddard Space Flight Center, January 1987.

2. "Facility 223 Operating Procedure", NSi Procedure Number 21-01-102-4, Revised February 1988, SSOS Mission, Northrop Services, Inc., NASA/Goddard Space Flight Center.

3. "Plan/Procedure for the Cryogenic Thermal Testing of the DIRBE and FIRAS PFU's in the ITD Facility", COBE-PP-750-1200-01, October 1987.

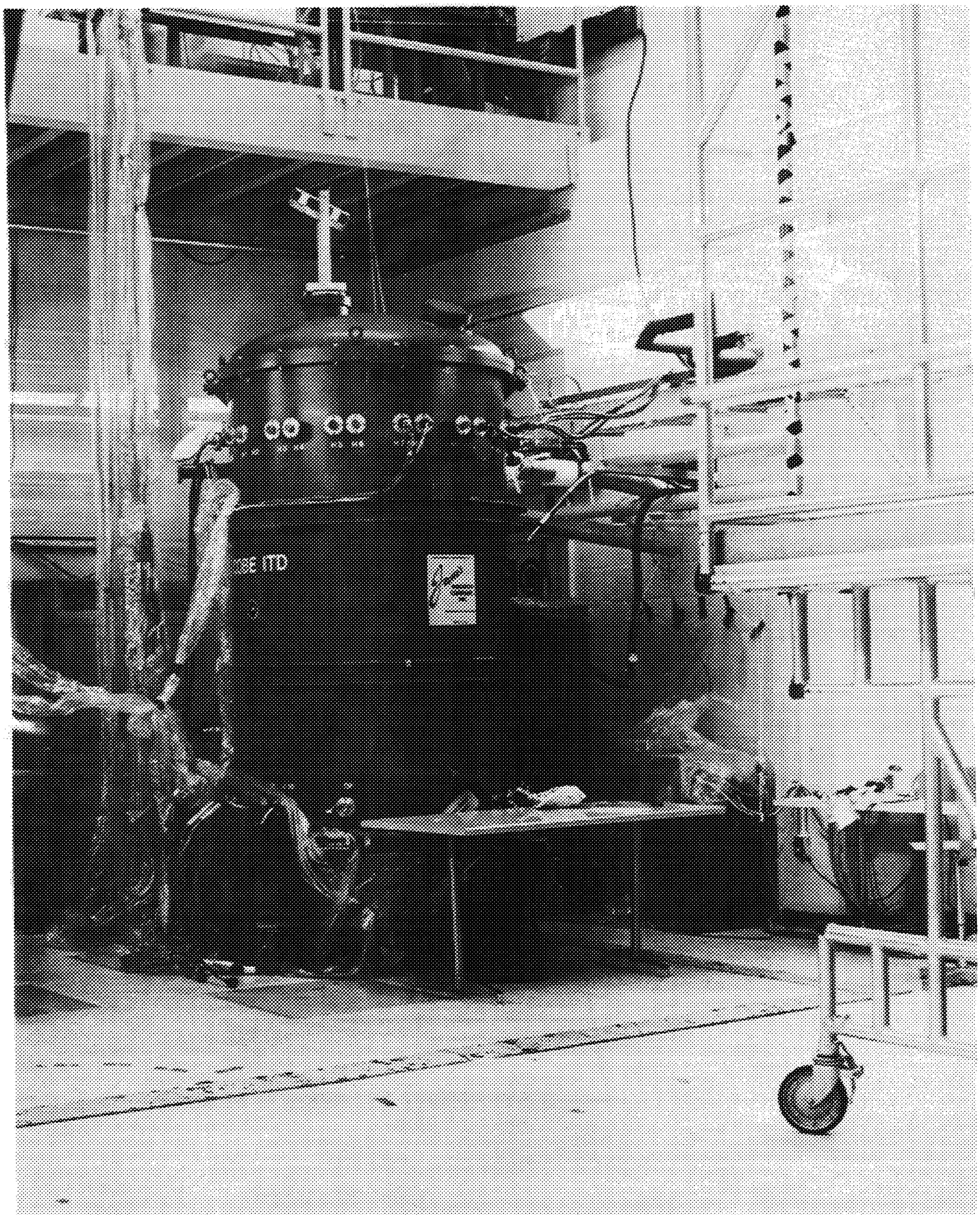

Figure 1. Instrument Test Dewar

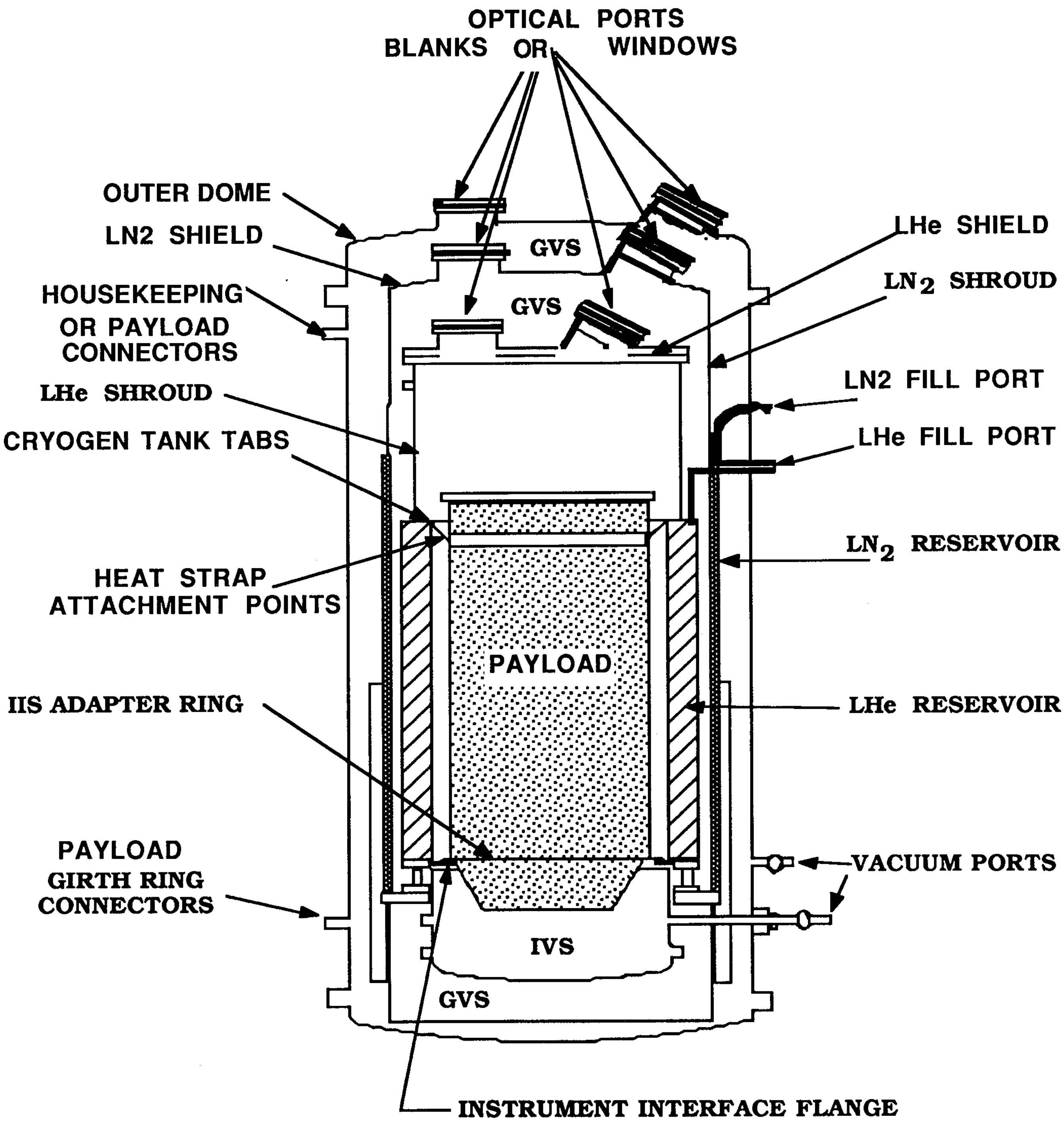

Figure 2. Cutaway View of the ITD

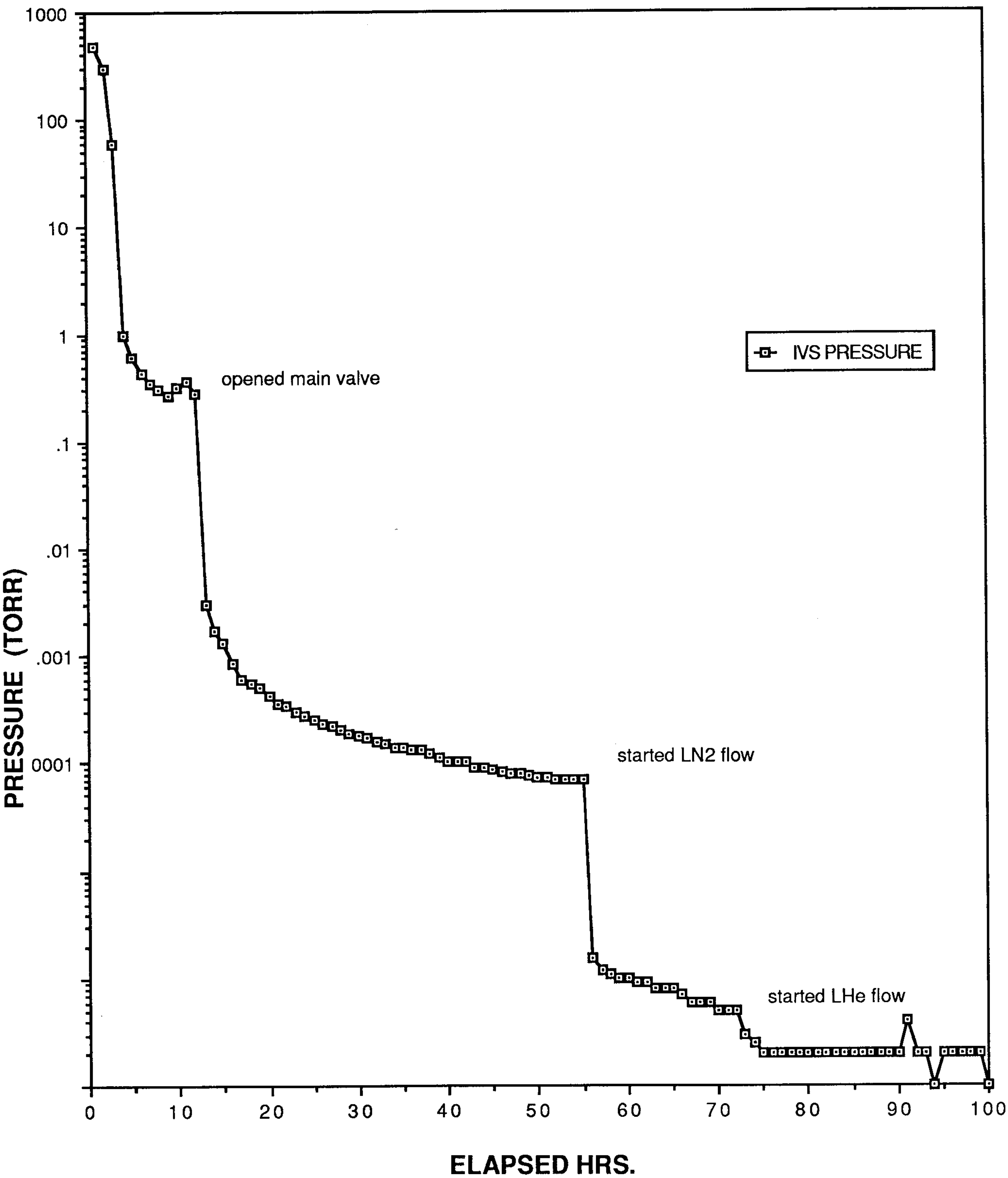

Figure 3. Typical ITD Pumpdown

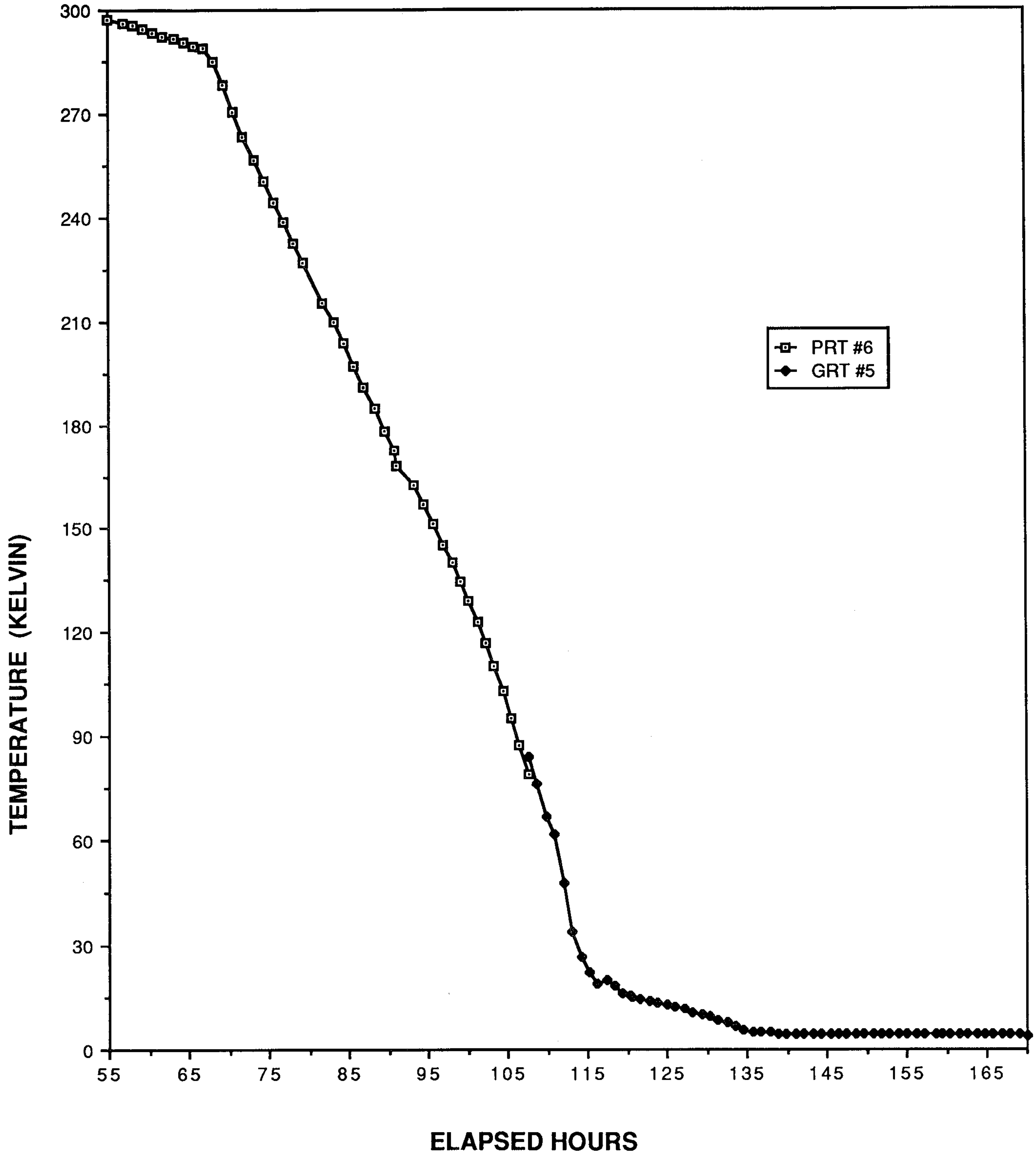

Figure 4. Typical Cooldown Curve 300K-4.2K

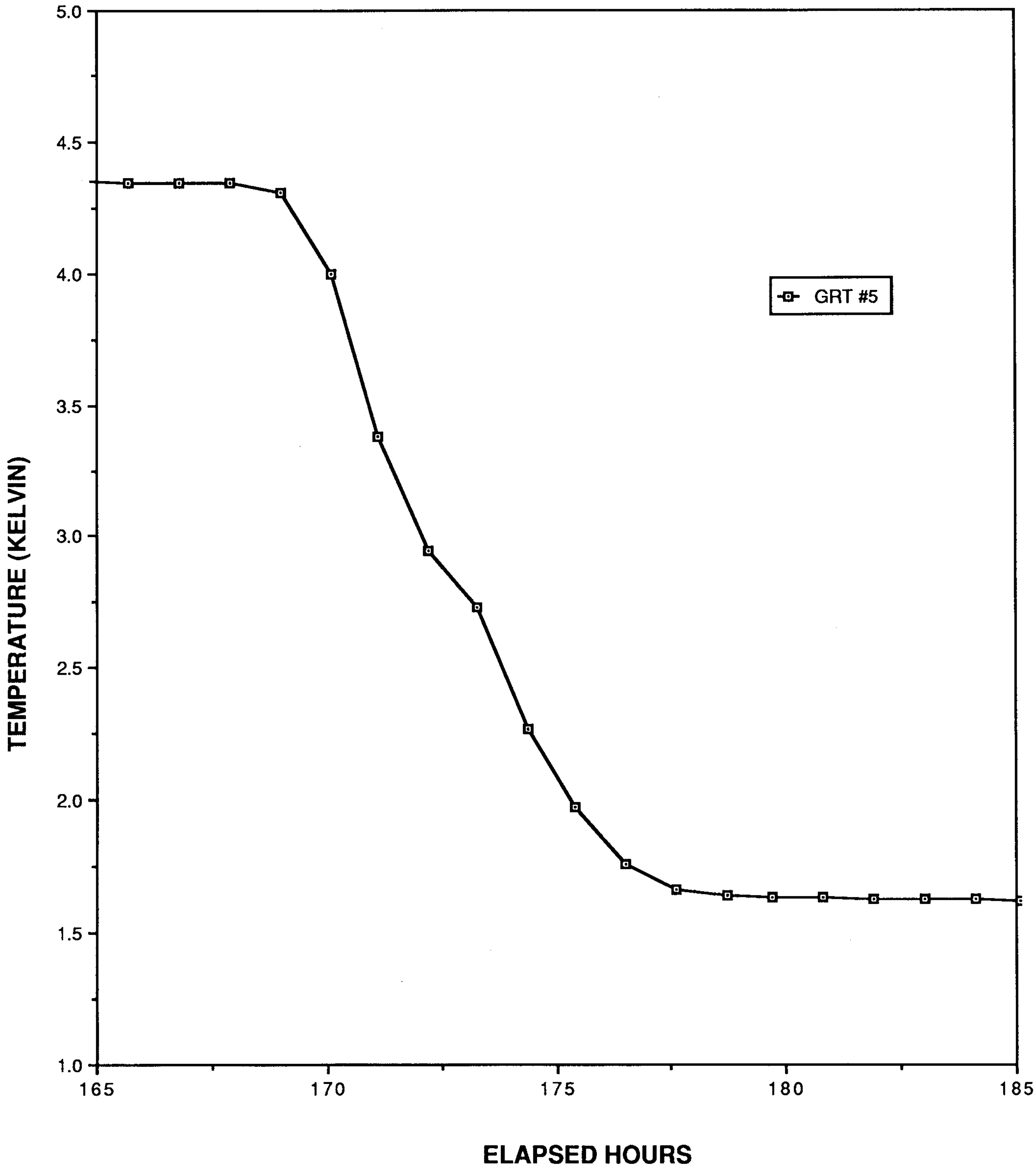

Figure 5. Typical Cooldown 4.2K-1.5K