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Two low temperature laboratories have been operating in the Division of Building Research, National Research Council of Canada, since July 1954. The initial design of these cold rooms was first described by Gold[1]. One cold room was used until 1970 by the Division's Building Services Section for experiments related to cold weather building research but is now being used by the Geotechnical Section for frozen ground studies (Permafrost cold room). The other cold room is used by the Geotechnical Section for ice research (Ice cold room). Construction and layout of the two rooms and a brief description of the associated refrigeration and control equipment are included in this paper.

In the 21 years since their construction these cold rooms have performed extremely well. Some modifications and changes have recently been made, however, and new control systems were installed following which a performance study was made of the air temperatures maintained during steady state and transient conditions. This study permitted fine adjustments to be made for optimum control of temperature stability and response. The results of this study are also included in this paper.

This information is necessary to evaluate experiments performed in the cold rooms. The temperature distribution and stability in the cold room affects the temperature history of samples of ice and frozen soil which are moved from zone to zone during storage, machining and testing, and also affect the time required for specimens to reach thermal equilibrium before testing.

PLANS AND CONSTRUCTION DETAILS

Details of the frame construction and wall section are presented in Figures 1 and 2. Both cold rooms are identical.

The only permanent service connections brought into the cold rooms were those required for lighting, refrigeration, and other permanent machinery. Three service panels each consisting of twelve 2-in. (50-cm) diameter capped ports arranged in three rows of four were installed in the walls of each cold room. Electrical connections were brought into the rooms through these ports. Recording equipment used in the experiments is located outside the cold rooms.

The layouts of the cold rooms, at the time of this study, are given in Figures 3 and 4. The equipment used for machining and testing can be moved to any location within the room thus providing maximum flexibility to accommodate a variety of testing procedures.

From Figures 3 and 4 it can be seen that there was a greater mass of equipment in the Ice cold room than in the Permafrost cold room at the time of this performance study.

DESCRIPTION OF REFRIGERATION PLANT

The cooling load of the two rooms is shared between three similar refrigeration circuits (Figure 5). The compressor and condenser are located in a separate machinery room, with only the evaporator unit and expansion valve in the cold room. Each room has two evaporator units (Figure 6). A main evaporator is connected to one compressor, the auxillary evaporator is connected to the third (auxillary) compressor which can be connected to the auxillary evaporator in either of the two rooms. This third (auxillary) refrigeration circuit serves several purposes, namely: back-up in the event of failure of one of the main circuits; extra cooling capacity for rapid "draw down" or high heat loads; and, as an alternate system during the defrosting of the heat exchanger coils in the main evaporator unit.

The system was designed to have a low inertia temperature control. This was accomplished through high volume air circulation and electrical reheating for fine temperature control. The compressors run continuously under a constant load, cooling the air to about -40°C. After being cooled, the air is warmed by electrical reheat coils to bring its temperature up to the set point temperature. A fan draws air from the room through the evaporator unit for conditioning and it is exhausted through a plenum above the false ceiling so as to provide relatively draft free air circulation. A schematic of the electrical side of the refrigeration circuit is shown in Figure 7.

Temperature control is achieved by varying the power supplied to the electrical reheat coils. Cold room temperature is measured by a 100-ohm resistance temperature sensor placed in the air intake at the bottom of the evaporator. This is the temperature control sensor that modifies an electrical signal fed into a solid-state current adjusting proportional controller. The electrical signals induced by the measured room temperature and the set point temperature are compared within the controller in order to produce a milliamp level control signal. This signal is sent to a silicon controlled rectifier package in the current valve which regulates the power supplied to the reheat coils. One half of the maximum power output is supplied to the reheat coils when the room temperature is equal to the set point temperature. If the measured room temperature is greater than the set temperature then the power output to the coils is less; if less than the set temperature then the power output is greater.

TEMPERATURE PERFORMANCE

It is necessary to "tune" the controller to the unique characteristics of the cold room in order to optimize temperature control. For this reason a temperature performance study was undertaken in both cold rooms. The control unit is shown in Figure 8. Thirty copper-constantan thermocouples were placed at various locations within the rooms and temperature measurements were made using a Kaye data logger having a resolution of approximately ±0.1°F (±0.06°C). Temperatures were converted to degrees Celsius and rounded off to the nearest tenth of a degree. One thermocouple was placed in an ice bath to check the performance of the data logger. Evaluation of the thermal behaviour of the cold rooms included measurements of the temperature profiles (both vertical and horizontal) at different room temperature settings, temperature fluctuations under steady state and transient conditions, and the change in room temperature during a defrost cycle.

(a) Temperature Profiles

Typical profiles for the Permafrost and Ice cold rooms are shown in Figures 9 and 10, respectively, for nominal control settings ranging from -5 to -40°C. Thermocouples were spaced every half metre. The horizontal temperature at midheight in each room fluctuated only ±0.2°C from one position in the room to another. The vertical distribution of temperatures in the centre of the Ice cold room showed little variation. In the Permafrost cold room a distinct vertical temperature gradient was found in the middle of the room with the difference in temperatures between the floor and just above the false ceiling being as much as 0.7°C.

(b) Constant Set Point

Temperature variations with time were recorded in both rooms for specific temperature settings. Figures 11 and 12 show the variations in temperature at the control sensor in the bottom of the evaporator and at the midpoint of the room when the Ice cold room was at a nominal temperature setting of -10°C. Figure 11 shows the short-term fluctuation over a period of 70 minutes. It was noted that opening the door for a few minutes raised the temperature at the midpoint of the room 0.5°C. Figure 12 shows the temperature fluctuation over a period of about 18 hours. Fluctuations of about ±0.1°C occur in both cold rooms at any one point. It should be noted that the temperature recorded at the control sensor was always a few tenths of a degree lower than that recorded at the midpoint of the room and that both were below the nominal set point. The temperature difference between the control sensor and the set point were still within the specified limits of the controller.

(c) Step Change in Set Point

Changing the temperatures of the cold rooms from one set point to another was investigated. Figures 13 and 14 show the temperature change with time recorded at the control sensors and midpoints of the two cold rooms when the setting was lowered from -10 to -30°C over a period of 5 to 6 hours. Figure 15 shows the temperature change in the Permafrost cold room when the nominal set temperature was raised from -30 to -10°C over a 4-hour period.

Figures 13 and 14 show that the temperatures at the control sensor and midpoint come to equilibrium in the Permafrost cold room after approximately 3 hours and in the Ice cold room after about 5 hours. This difference was probably due to the differences in size and configuration of the two cold rooms and the bulk mass of equipment in each of them. As shown in Figure 15, when raising the temperature in the Permafrost cold room, the temperature at the control sensor smoothly approached the set temperature after 3 hours. The midpoint of the room experienced an "overshooting" of the set temperature by two degrees. Fine tuning of the control system can eliminate "overshoot" at any point in the room where the control sensor is placed.

(d) Defrost Cycle

Moisture in the air precipitates out, forming frost on the cooling coils of the evaporator unit. For this reason, the relative humidity in the cold rooms ranges from 35 to 40 per cent. The evaporator unit must be shut down about once a month for defrosting during which time the temperature is controlled by the auxillary cooling system. Heating elements are used to remove the frost build-up on the cooling coils. The effect of defrosting the main unit in the Ice cold room on the measured temperature at the control sensor of the auxillary unit and midpoint of the room is shown in Figure 16.

As the defrost heaters melt the frost the room temperature rises gradually but when all the frost has melted a sharp increase in air temperature occurs. At this point the heaters are turned off and within an hour the temperatures stabilize. When the main unit and fan are turned on a blast of hot air enters the room which raises the temperature considerably for a short time.

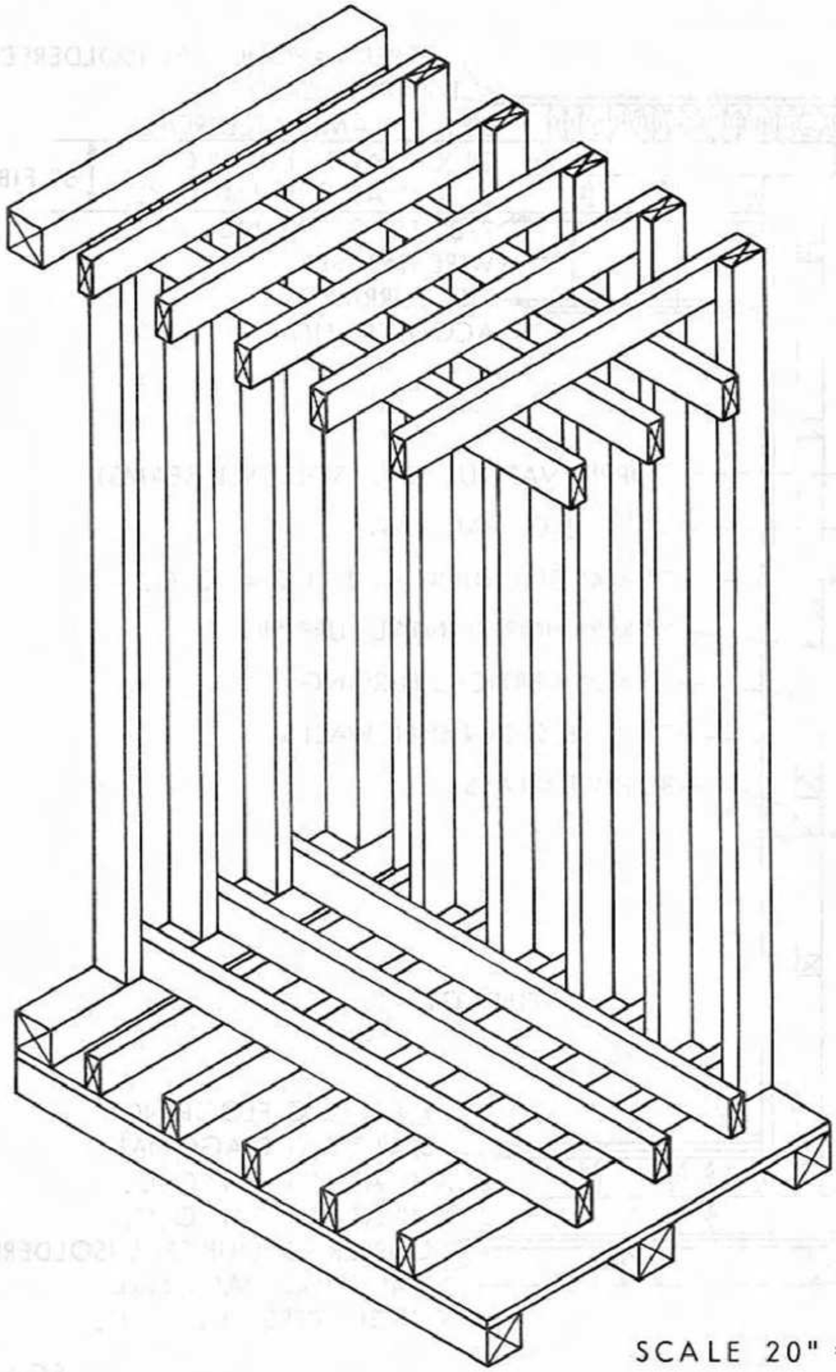
SUMMARY

The DBR Geotechnical cold rooms have the following characteristics:

1. Temperature can be controlled from 0 to -40°C.
2. Air temperature fluctuates, at any one point, ±0.1°C.
3. Temperature variation between different locations in the rooms is 1°C.
4. Relative humidity is between 35 and 40 per cent.
5. Three to 5 hours are necessary for the rooms to reach equilibrium when the set room temperature is changed 20 Celsius degrees.
6. Erratic temperatures occur during the monthly defrost cycle.

REFERENCE

1. Gold, L.W., New Snow and Ice Research Laboratory in Canada, Journal of Glaciology, Vol. 2, No. 19, March 1956, 4 p.

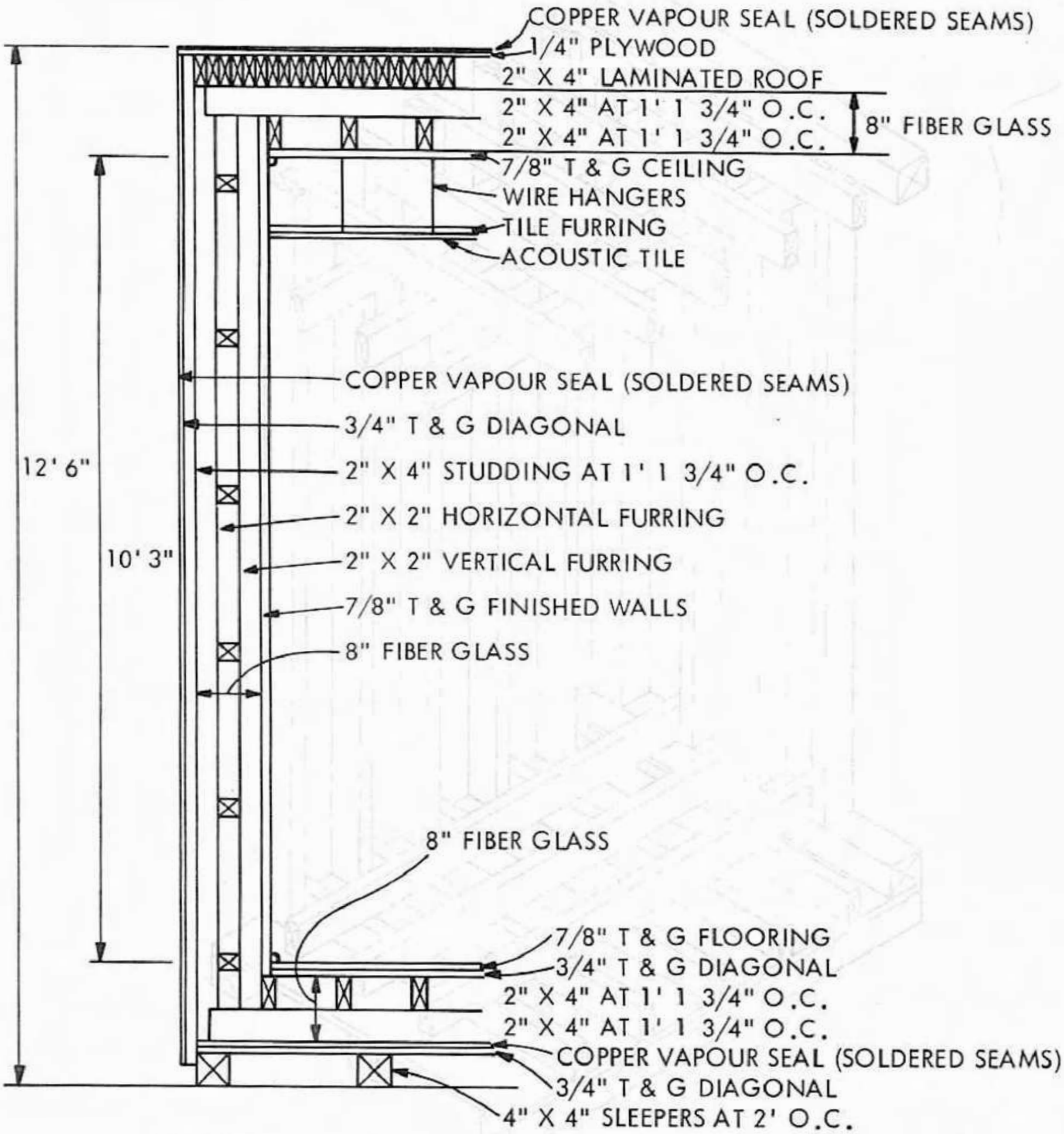


SCALE 20" = 1"

FIGURE 1

FRAME CONSTRUCTION OF COLD ROOM

BR5455-1



SCALE 20" = 1"

FIGURE 2

WALL SECTION OF COLD ROOM

BR 5455-2

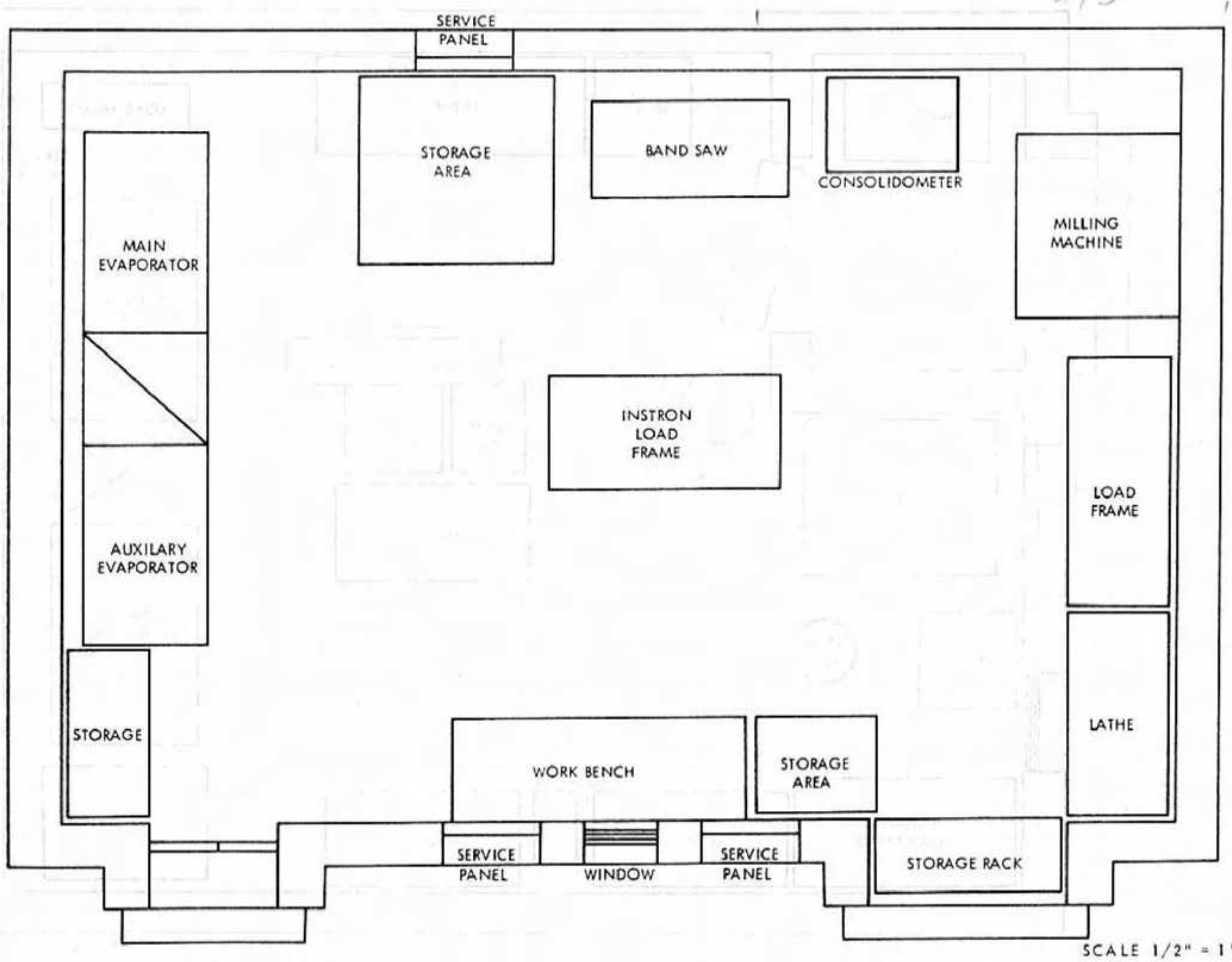


FIGURE 3

LAYOUT OF PERMAFROST COLD ROOM

BR 5455-3

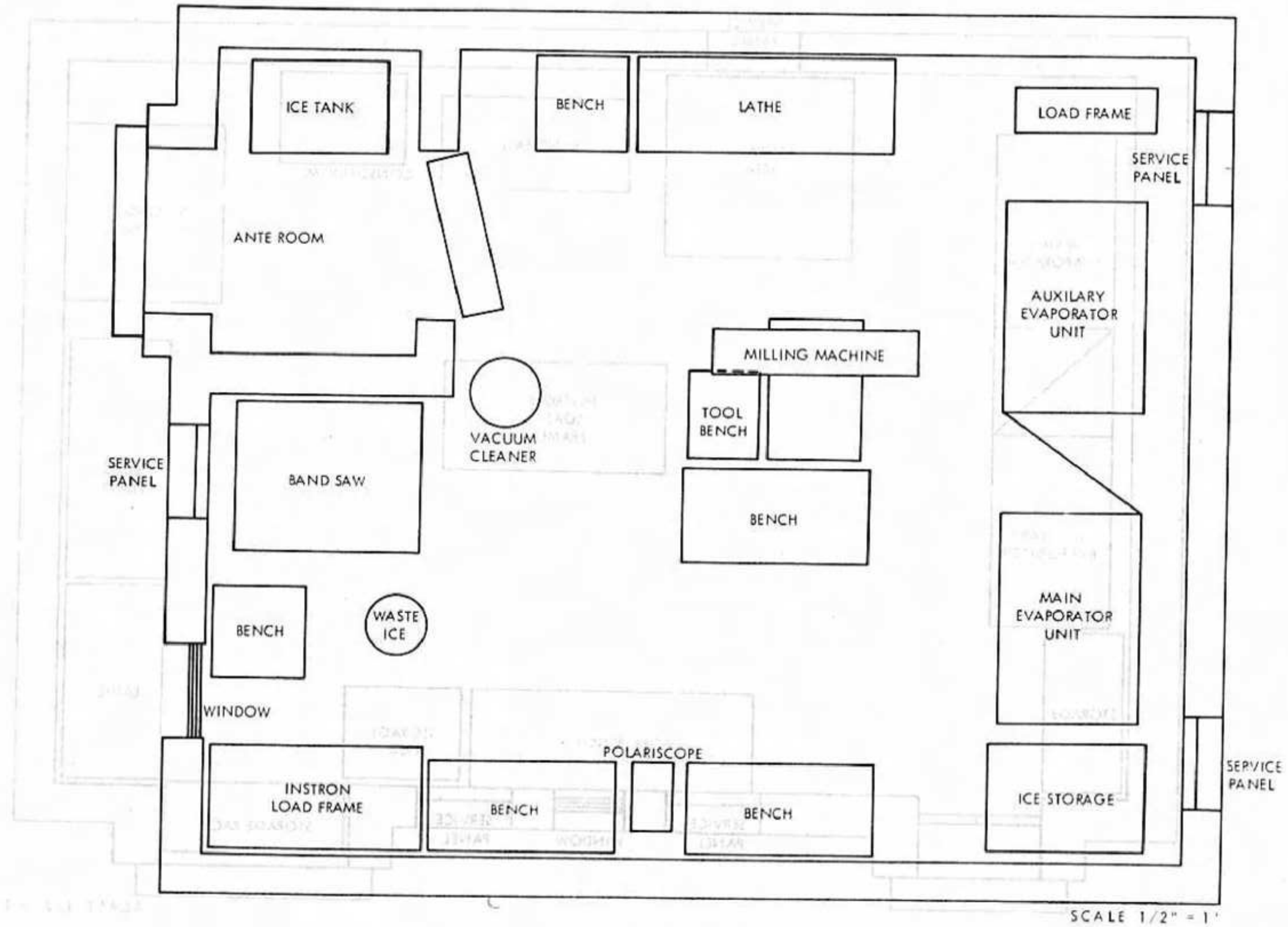


FIGURE 4

LAYOUT OF ICE COLD ROOM

BR5455-4

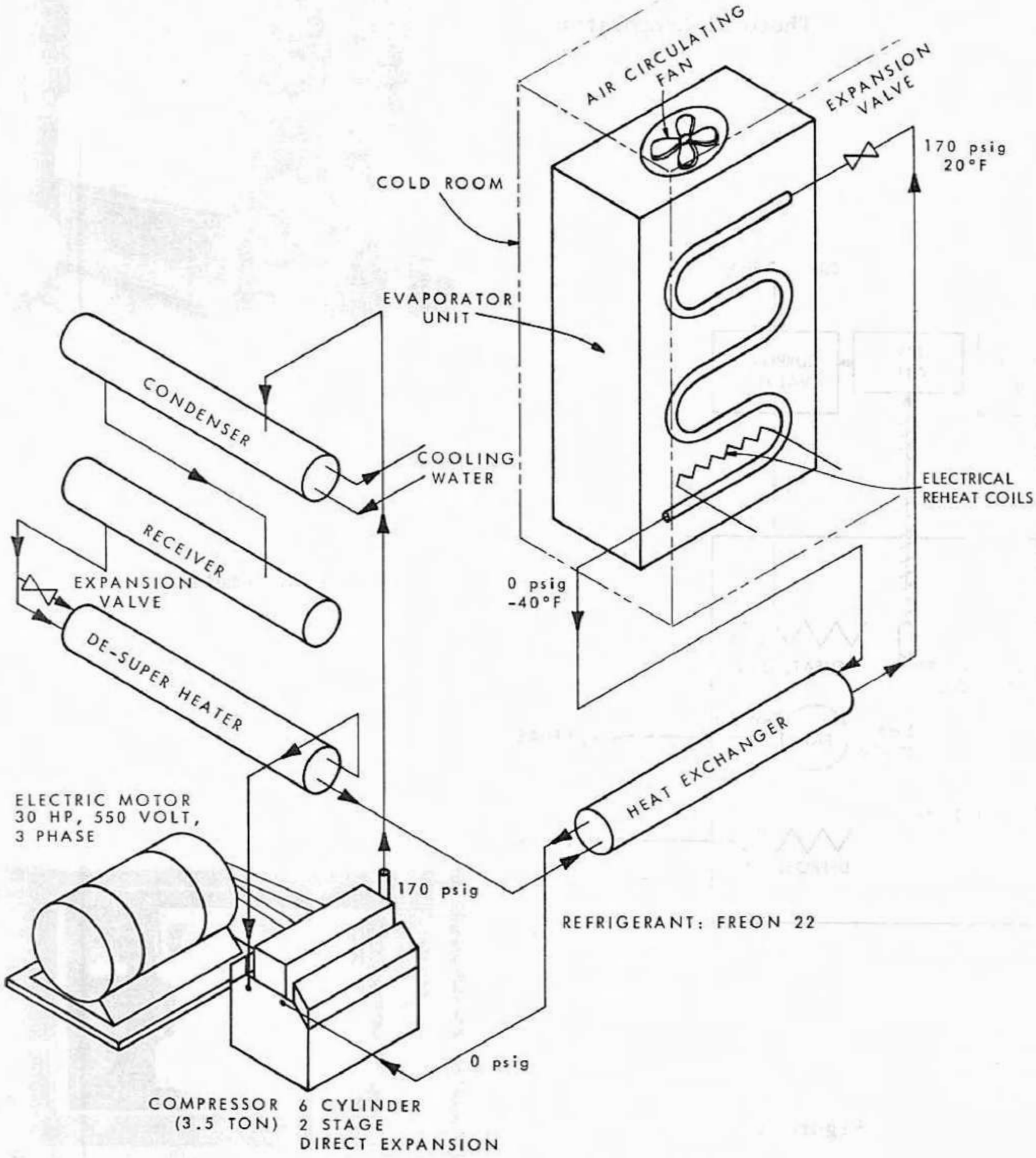


FIGURE 5

TYPICAL REFRIGERATION CIRCUIT

BR 5455-5

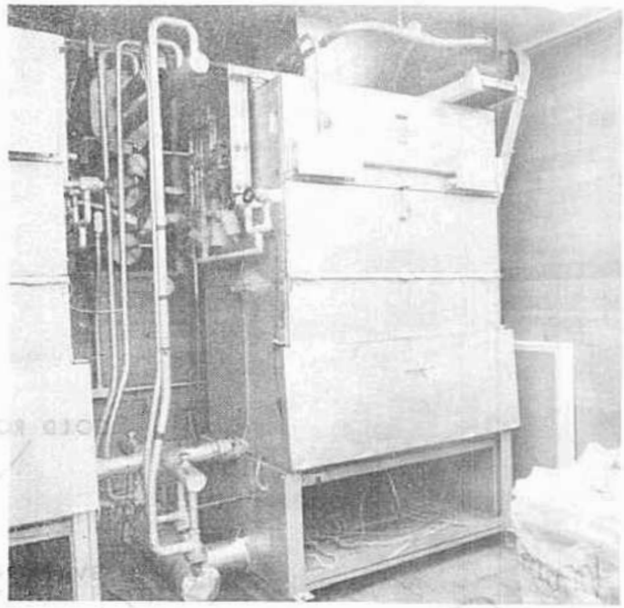


Figure 6

Photo of Evaporator

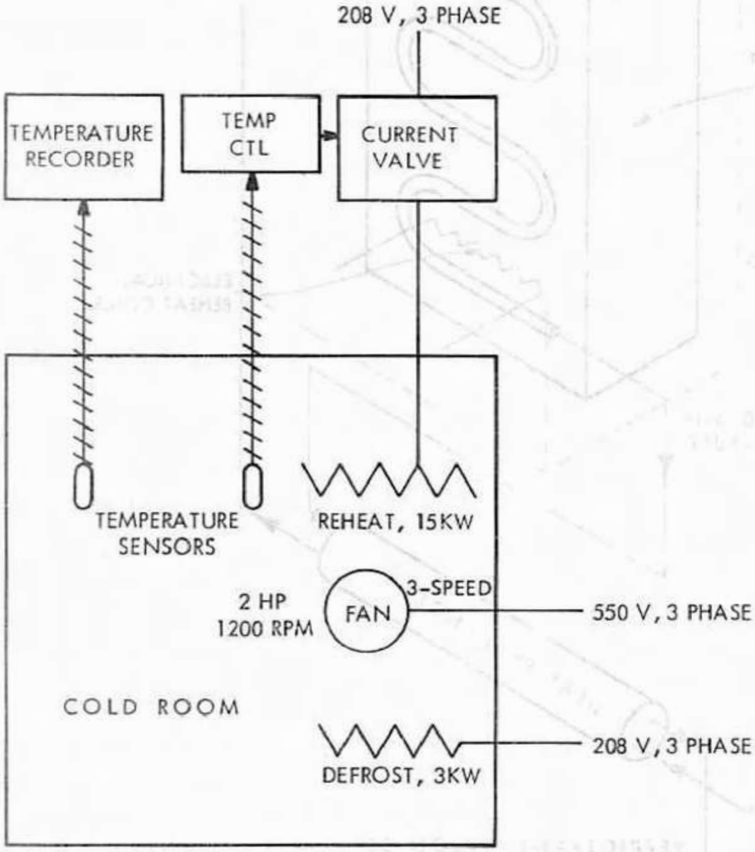


Figure 7

Electrical Schematic

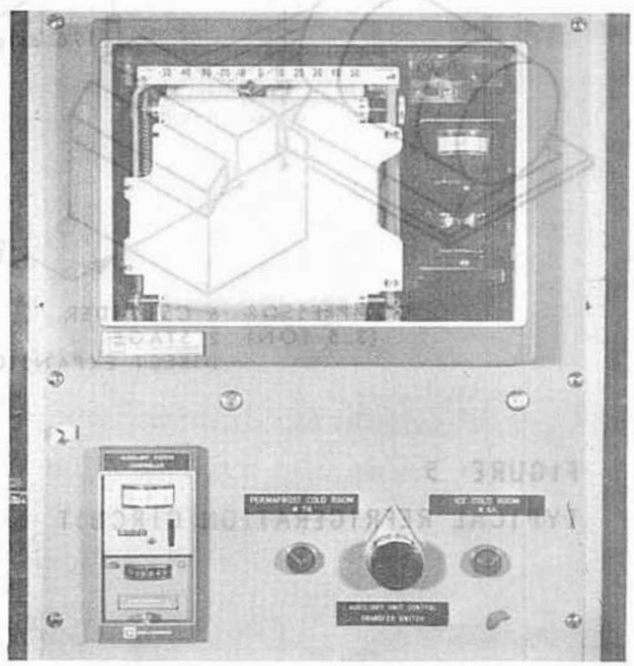


Figure 8

Photo of Control Panel

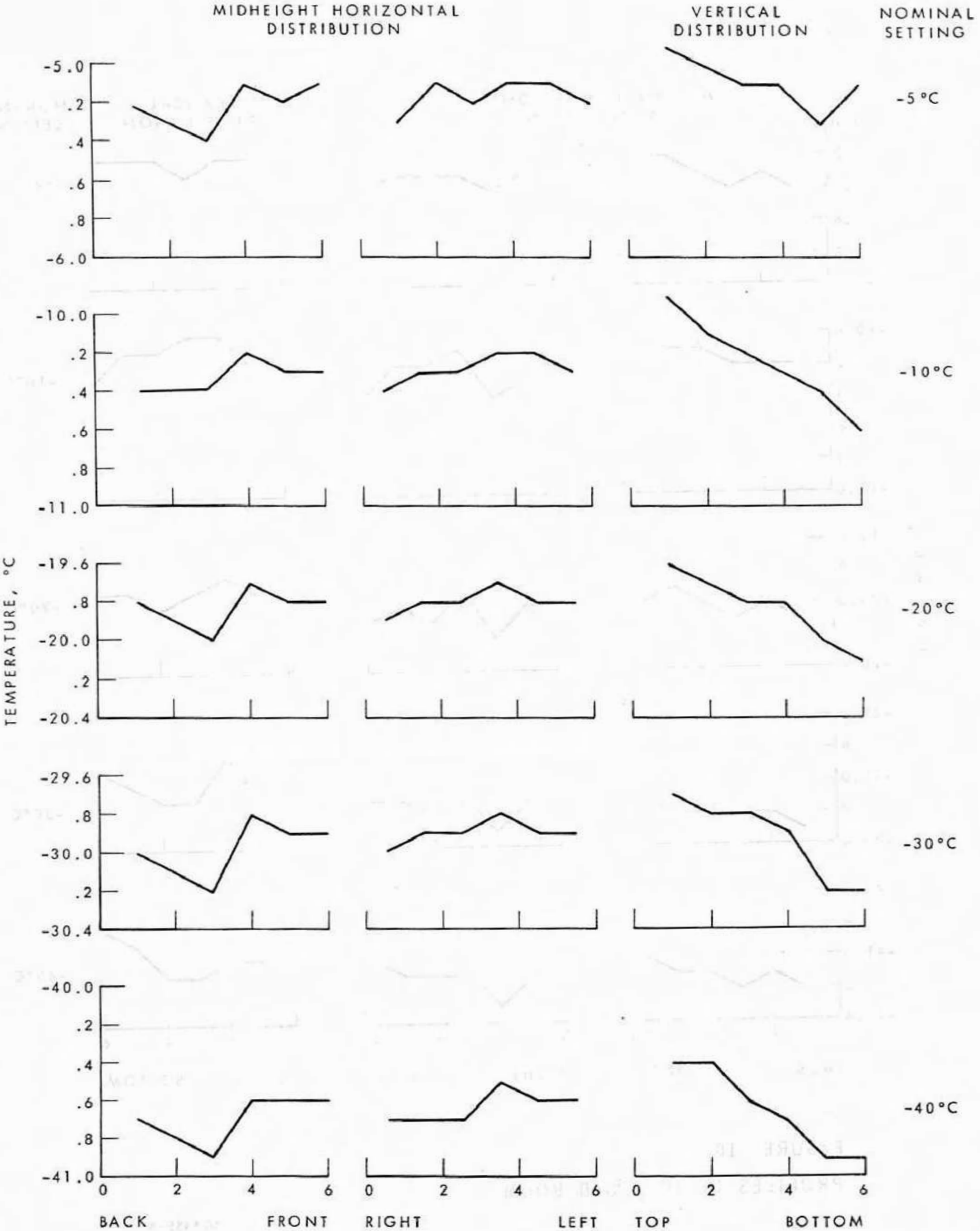


FIGURE 9

PROFILES OF PERMAFROST COLD ROOM

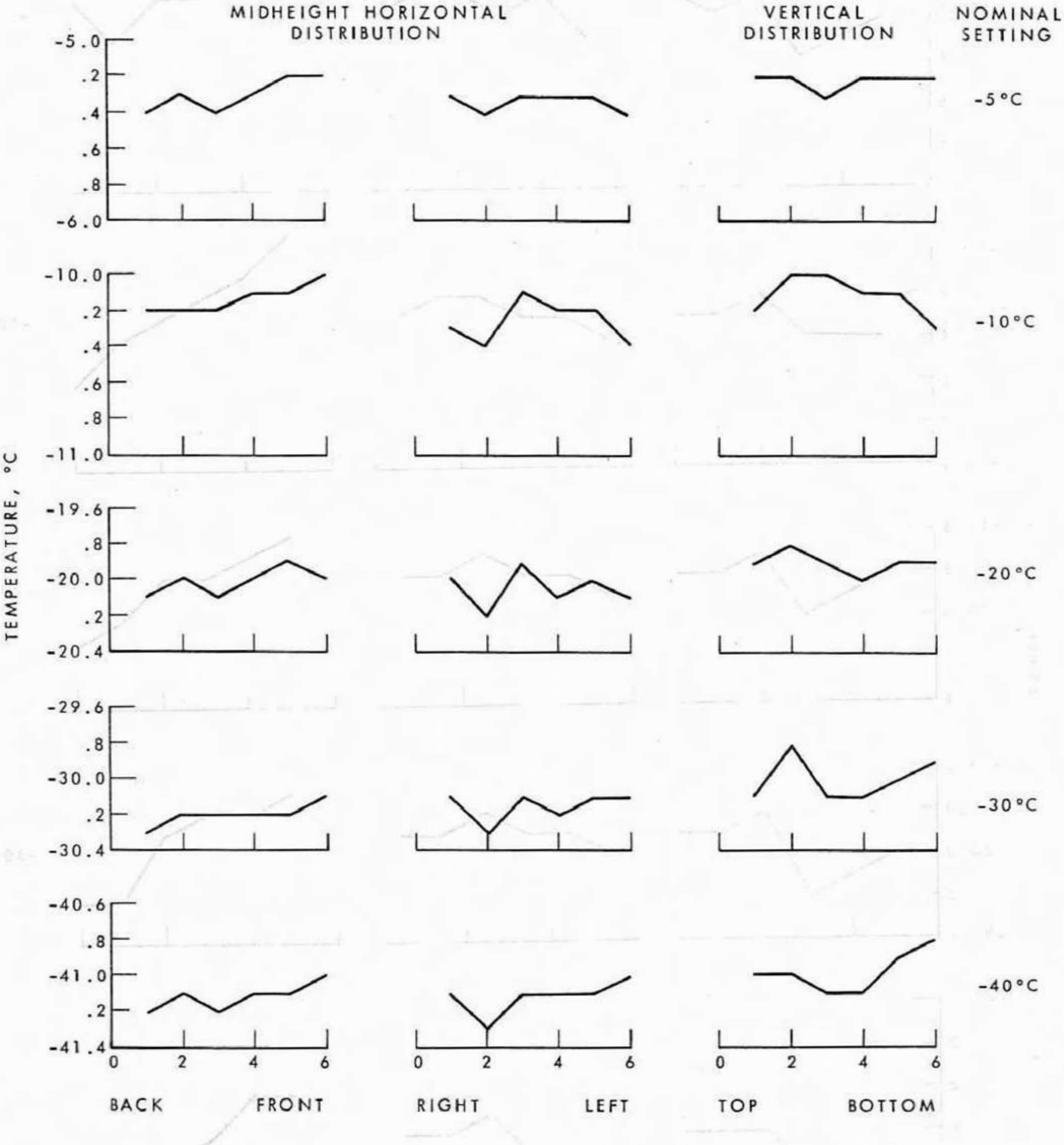


FIGURE 10

PROFILES OF ICE COLD ROOM

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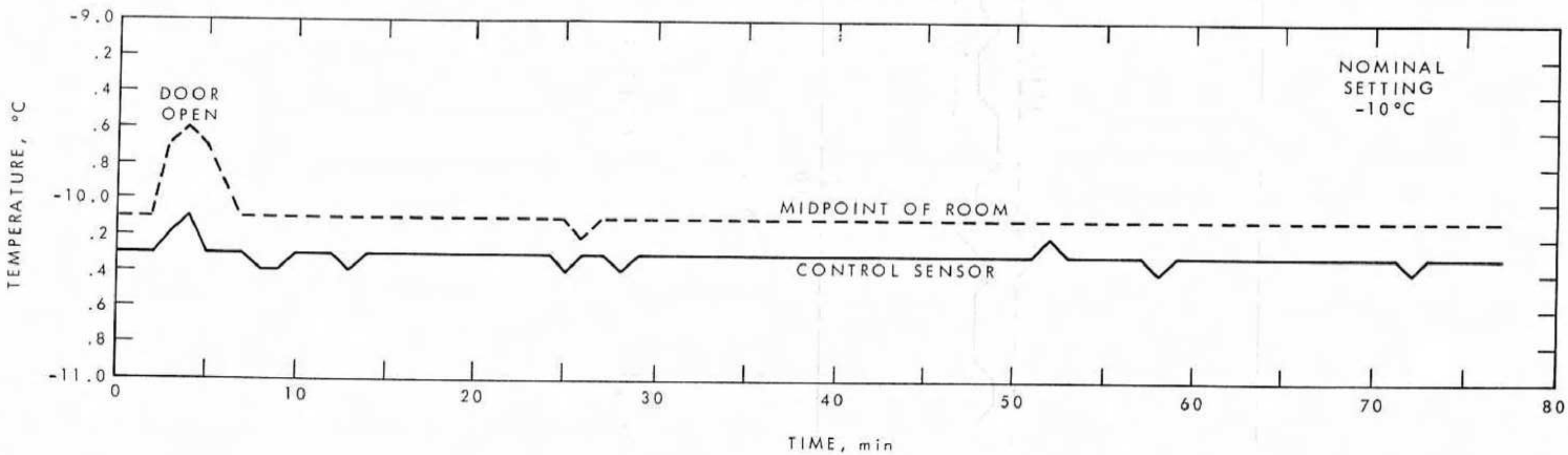

FIGURE 11

SHORT TERM FLUCTUATION IN ICE COLD ROOM

BR 5455-9

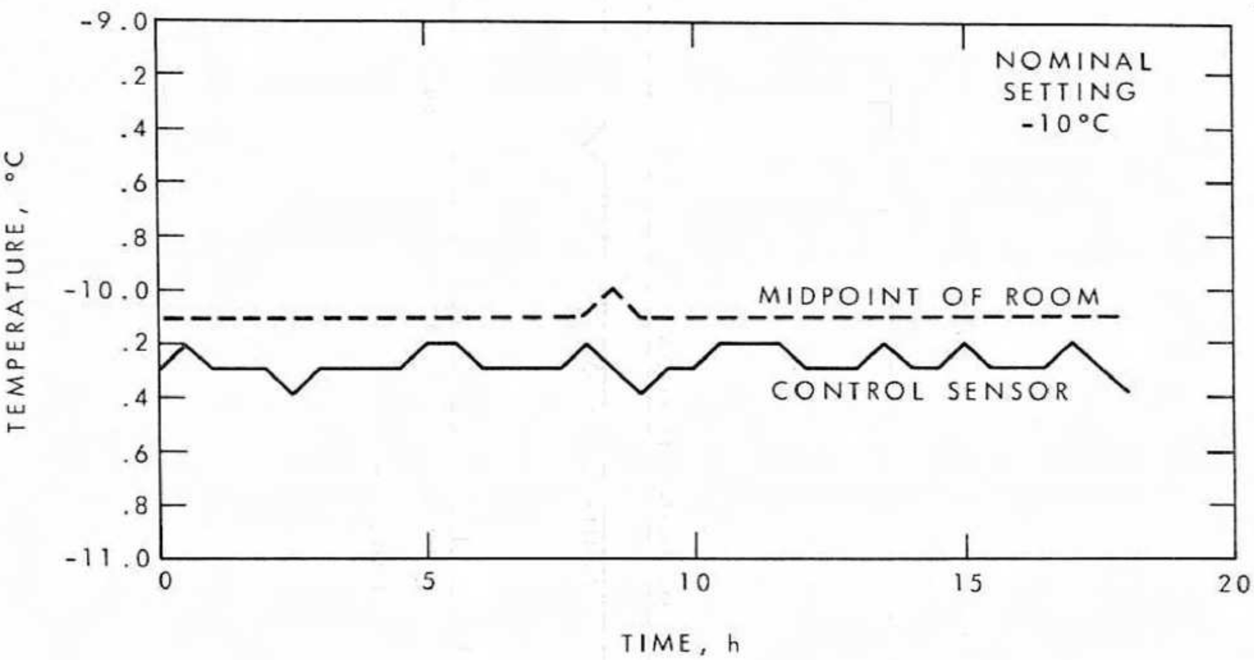

FIGURE 12
LONG TERM FLUCTUATION IN ICE COLD ROOM

BR 5455-10

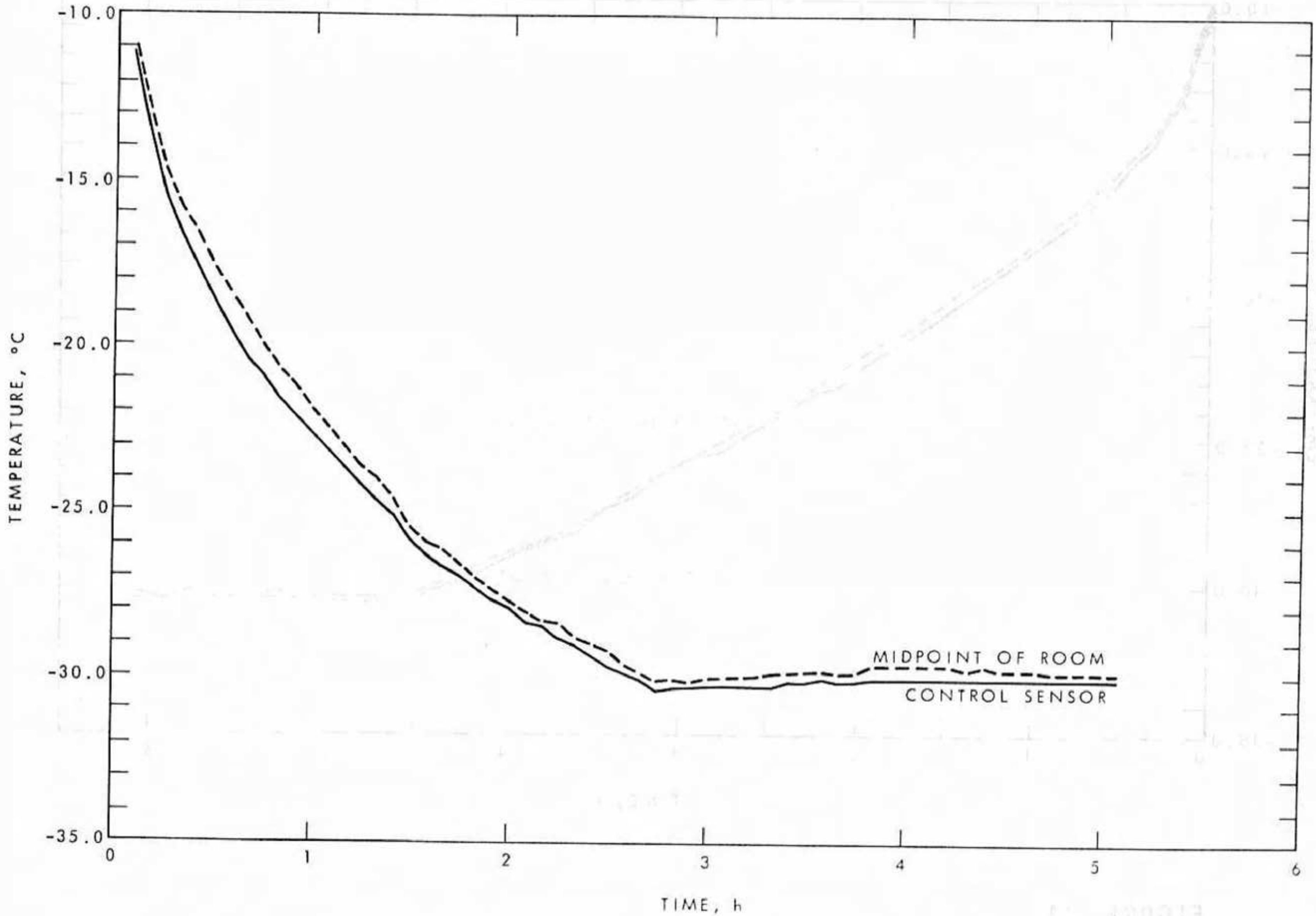

FIGURE 13

TRANSIENT EVENT, -10°C TO -30°C IN PERMAFROST COLD ROOM

BR 5455-11

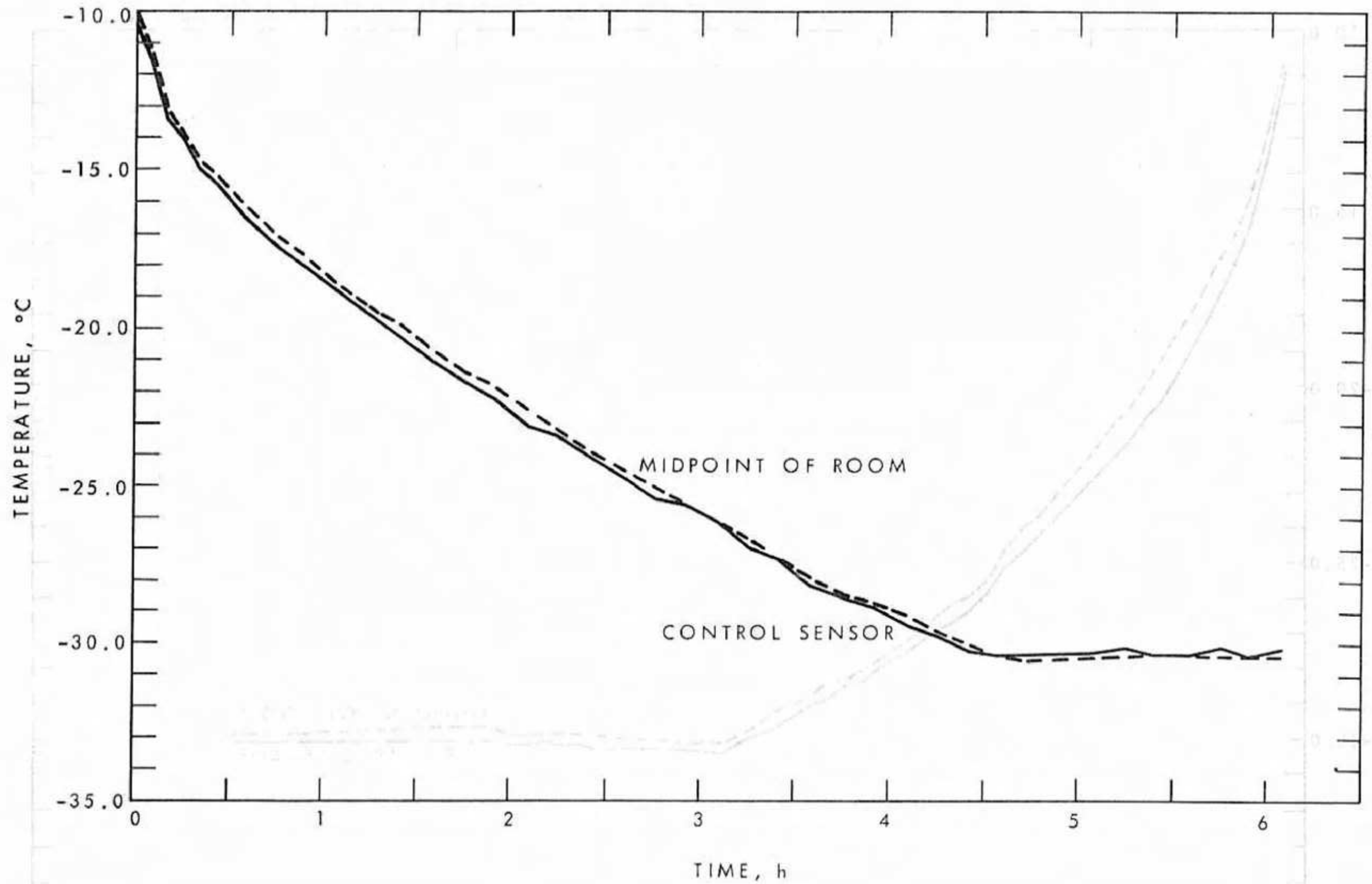

FIGURE 14

TRANSIENT EVENT, -10°C TO -30°C IN ICE COLD ROOM

BR 5455-12

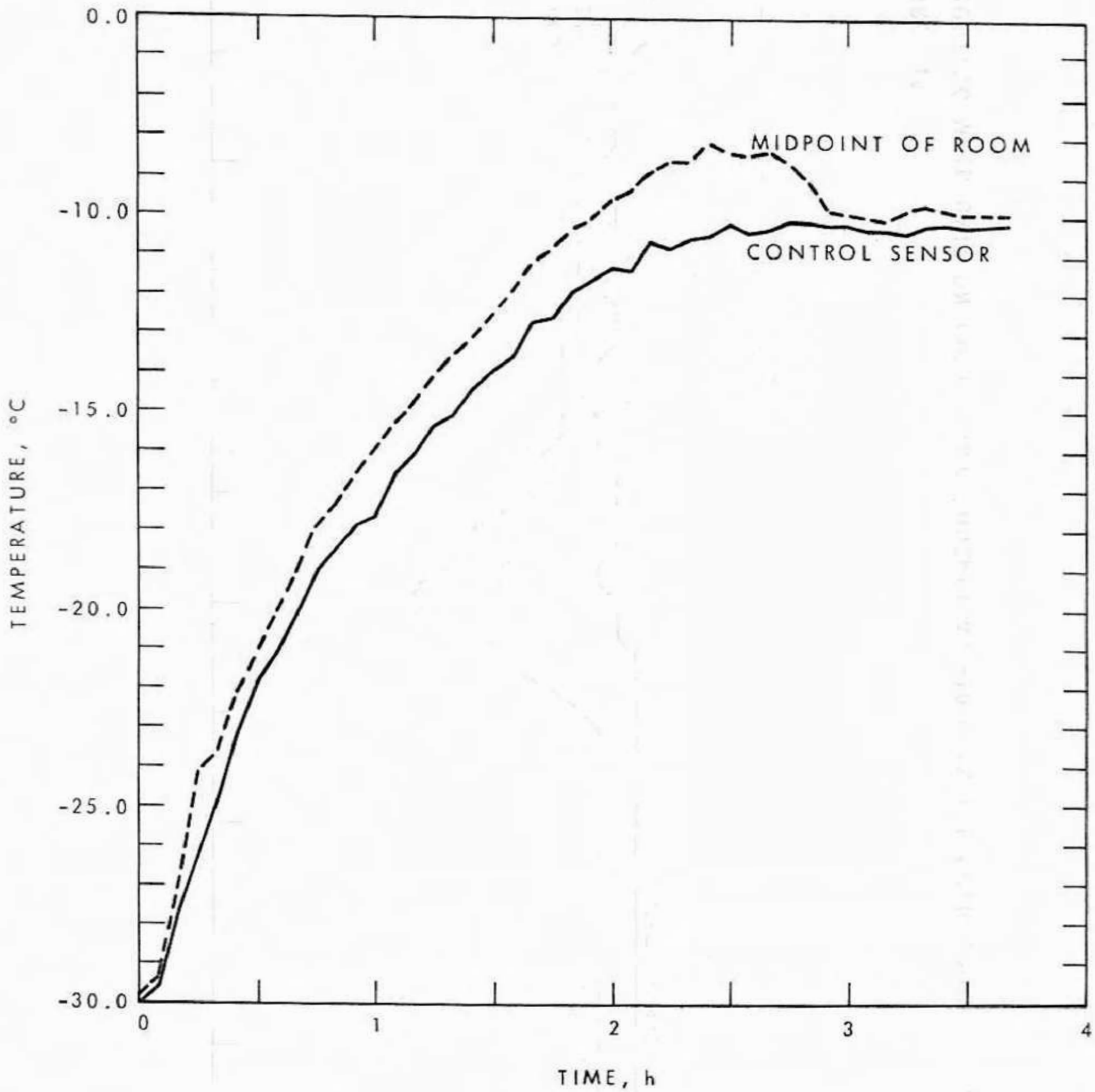

FIGURE 15

TRANSIENT EVENT, -30°C TO -10°C IN PERMAFROST COLD ROOM

BR 5455-13

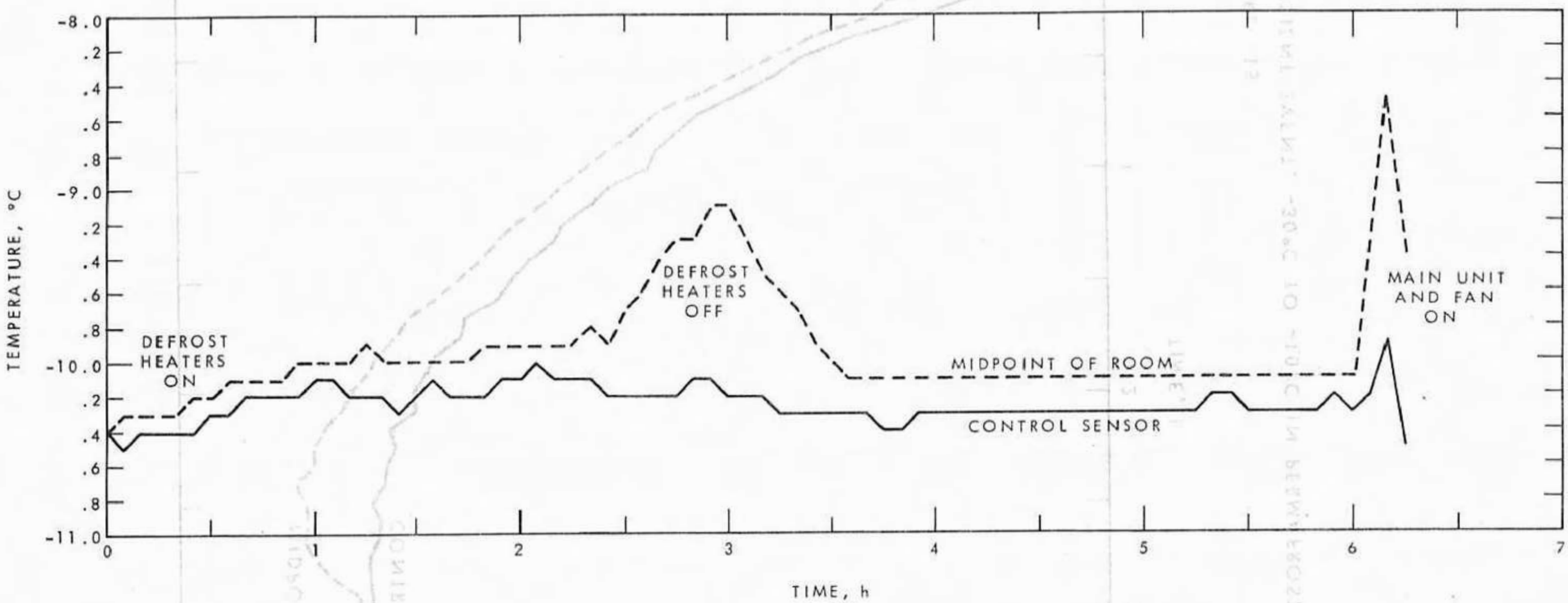

FIGURE 16

DEFROSTING MAIN UNIT ON AUXILLIARY CONTROL AT -10°C IN ICE COLD ROOM

BR 5455-14