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AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS

REACTOR HIFAR – THE SPACE CONDITIONER SYSTEM

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Revised April 1975

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ABSTRACT

This manual describes and gives the operating details for the Space Conditioner System of the reactor HIFAR. The system was considerably modified during the latter half of 1970 and subsequently classified as an engineered safety feature.

For the benefit of reactor operators, a typical refrigeration circuit associated with the Space Conditioner System and an air conditioning process are briefly discussed.

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1. INTRODUCTION

During the latter half of 1970, the HIFAR space conditioner system was considerably modified. Hopkinson [1970] has explained the reasons for the modifications and the principles involved. The modifications separated the original single system into three independent sub-systems.

The modified HIFAR space conditioner system is designed to accommodate anticipated temperature and pressure conditions within the reactor sealed building after a loss of coolant accident. The control and maintenance of comfortable air conditions within the reactor sealed building (RSB) are of secondary importance. However, provided that sub-system 3 and either of the other sub-systems are operable, adequate facilities exist for the normal control of dry bulb temperature and relative humidity throughout the year. If sub-system 3 is not available, adequate control of dry bulb temperature can be maintained by the use of the other sub-systems. Sub-system 3 is capable of carrying the normal air conditioning load by itself on all but exceptionally hot days of the year.

The relative positions of the space conditioner units and their association with the respective refrigeration plant are illustrated in Figure 1. Note that the chilled water coil of the weathermaker in the auxiliary plant room is not cross-connected to the other sub-systems in anticipation of a break down in sub-system 3. Such cross-connection would infringe the principle of independence and tend to degrade the overall reliability of the system. Every reasonable effort has been made to prevent defects in one sub-system affecting the performance of the others; this applies to refrigeration, chilled water, electrical and instrumentation.

The modifications to the original system were carried out under a contract let to Thomas Clark & Son Pty Ltd. Official drawings relating to the space conditioner system are issued in the name of this contractor.

The instrumentation was installed by Honeywell Pty Ltd and reference is made to this sub-contractor in Section 3, Instrumentation.

2. CHILLED WATER CIRCUITS

2.1 Pipework within the Reactor Sealed Building

With some very minor deviations, the chilled water pipework inside the reactor sealed building conforms to the layout described by Hopkinson [1970] and AAEC Drawing BE 31523.

The highest points on sub-systems 2 and 3 are on the respective space conditioner units themselves where pet-cocks are located on the uppermost positions on the cooling coil manifolds for air bleed-off purposes.

On sub-system 1, where there are three rising and three falling sections, brought about by the necessity to keep this pipework as far away from the pipework of sub-system 2 as practicable, three bleed-off points are installed as follows:

(i) On the space conditioner units as for sub-systems 2 and 3.

(ii) Behind No.1 storage block in the reactor sealed building (one each for flow and return).

(iii) Above the cooler of No.1 refrigeration system in the auxiliary plant room (one each for flow and return).

On inspection, these positions are obvious.

Provision has been made for possible additions to each of the three sub-systems by blanked tee-pieces in each chilled water line just after it enters the reactor sealed building.

All chilled water pipework and fittings are insulated with 50 mm thickness 'Styrene', vapour sealed and sheathed with heavy-weight calico.

All chilled water pipework joints are either flanged or butt welded with the exception of connections to the 3-way and 2-way chilled water regulating valves in the auxiliary plant room and the coupling connections to the space conditioner units. The screwed regulating valves were not seal welded because of the possibility of distortion of the valve bodies. The space conditioner units are connected to the flanged isolating valves by a screwed coupling which facilitates unit removal for cleaning and maintenance.

Figure 2 shows the detail of the chilled water pipework passing through the reactor shell. This design was adopted to permit *in situ* local leak testing of each chilled water pipework penetration.

2.2 Pipework External to the Reactor Sealed Building

Drawing 4477/9 (Clark) schematically shows the chilled water circuits and site water make-up *via* the head tanks for each sub-system. A typical chilled water circuit is as follows:

The Ajax CMH-2 pump (nominally 360 litres per minute) delivers the chilled water *via* isolating valves and a non-return valve to the Carrier 10T3 cooler, the refrigeration side of which was described by Hopkinson [1967]. A differential pressure switch monitors the flow through the cooler and is directly associated with the freon compressor control circuit. As the chilled water leaves the cooler its temperature is monitored by a thermostat with a set point of 7°C which controls the operation of the evaporative condenser fan. This fan must be in operation before the refrigeration plant can start (see Section 8, Electrical).

En route to the reactor sealed building, the chilled water passes through an orifice plate whose tappings are connected to a differential pressure cell and transmitter with electrical output. The flow rate is displayed in the control cubicle in the auxiliary plant room and the override panel in the emergency control room (ECR). After return from the reactor sealed building the chilled water passes through a 3-way mixing valve operated by a modulating motor which is in turn controlled by either:

(a) two thermostats located in the reactor sealed building adjacent to the respective space conditioner units; or

(b) a valve positioning switch located in the override panel in the emergency control room.

The chilled water pipework in the auxiliary plant room is 64 mm i.d.; within the reactor sealed building it is 50 mm i.d. except for the space conditioner off-takes which are 38 mm i.d.

Upstream of the 3-way valve on the return pipework the feed line from the make-up tank joins the line. Resistance thermometers are located in pockets in the chilled water pipework inlet and return lines. The temperatures are displayed in the control cubicle in the auxiliary plant room and the override panel in the emergency control room.

A resistance thermometer is also located in the pump delivery line to the cooler and this temperature is shown only on the control cubicle.

The chilled water pump pressure indication is converted from hydraulic to electrical output for display on the control cubicle.

The Normal Input weathermaker joins the main lines of sub-system 3 on the pump/cooler side of the 3-way valve. The 2-way regulating valve in the weathermaker return line is operated by a modulating motor, controlled either by a thermostat in the weathermaker unit or by a valve positioning switch located in the override panel in the emergency control room. Because the thermostat in the weathermaker will normally call for full cooling, this 2-way valve should always be fully open. The setting of the isolating valve above the 2-way control valve is such that approximately 140 ℓ/min flows in each branch of the circuit.

2.3 Head Tanks

The head tank for each sub-system is located on the external walk-way at the top of the reactor sealed building.

All have a common site water supply *via* a 32 mm i.d. isolating valve and a copper line to the 100 mm o.d. site water main running across the roof of the auxiliary plant room. This is the only aspect of the overall space conditioner system where independence is not provided. There are no further isolating valves in the water make-up supply which reduces the number of valves which could be inadvertently left shut.

3. INSTRUMENTATION

This includes the flow, pressure and temperature indicating equipment. In this respect all sub-systems are identical and Figure 3 illustrates a typical wiring diagram. Honeywell Pty Ltd are responsible for the complete servicing and maintenance of the equipment (refer Section 7). Literature fully explaining the construction and operation of the instrumentation is held by the HIFAR Maintenance Supervisor.

For any sub-system this equipment comprises the following:

3.1 Flowmeter

(a) *Sensor* The primary flow element is an orifice plate inserted between flanges on the chilled water line to the reactor sealed building downstream of the offtake for the central port (B) of the 3-way valve. The design gives a differential pressure of 0 to 7.5 kPa for a flow range of 0 to 360 ℓ/min on a non-linear scale. The pressure tappings are connected *via* isolating valves to a model ND122 electric differential pressure transmitter which converts the hydraulic signal into a proportional electric signal of 4 to 20 mA d.c. This is fed direct to the flowmeters in the control cubicle and the emergency control room override panel. The indicating instruments are graduated in litres per minute.

(b) *Power Supply* Power for the flow metering installation is *via* a 240 V/115 V 60 VA Henderson type DW transformer feeding a model NAX 422 solid state Currentpack 42 V d.c. power supply unit. This unit supplies the required constant voltage for operation of the transmitter mentioned above. It also incorporates a current limiting circuit that prevents output current from reaching excessive values.

3.2 Pressure Indicator

Continuous indication of chilled water pump outlet pressure is provided at the control cubicle. The primary element, a L91B hydraulic pressure-to-electrical-output transducer, is in series with a 500 ohm resistance slide-wire and actuates the electrical pressure indicator *via* a model W620A bridge module. The power supply for these components is derived from a model W619A power supply converting 240 V a.c. to 12 V d.c. There are two bridge module adjustments:

(i) Span - which is factory adjusted to calibrate the bridge span with the meter scale span.

(ii) Zero - final adjustment which is made during commissioning to calibrate the monitoring element with the meter reading.

These settings must only be varied by authorised personnel.

3.3 Temperature Indicators

Resistance thermometer temperature elements are installed in the chilled water line:

(i) at the inlet to the cooler;

(ii) at the inlet to the reactor sealed building; and

(iii) at the outlet from the reactor sealed building.

The meters associated with these sensors provide continuous indication and are located within the control cubicle. The indications for points (ii) and (iii) are repeated in the emergency control room override panel. The temperature indicating system uses the same power supply unit as the chilled water pressure indicator but has its own bridge module, model W620A, with similar bridge adjustments to those stated for the pressure indicator.

4. CONTROL ROOM

One set of indicator lamps for each sub-system is located on reactor control room panel No.3 and comprises:

(a) duplicated *POWER ON* lamps, and

(b) duplicated *LOW LEVEL HEAD TANK* lamps.

No control or other indicating facilities have been brought to the reactor control room (CR) because the system is designed basically for emergency operation controllable from the emergency control room.

However, the operation of the *POWER ON* lamps will be an indication to shift staff in the control room of those sub-systems capable of operation and of any sub-system not available for service.

The *LOW LEVEL HEAD TANK* lamps will immediately indicate to shift staff in the control room a fall in the head tank water level. This may not be noticed by the plant room technician because of temporary preoccupation with other duties.

5. EMERGENCY CONTROL ROOM

An override panel for each sub-system is located in the emergency control room. Each override panel contains the following:

(a) Flowmeter.

(b) Temperature indicator (chilled water *TO* reactor sealed building).

(c) Temperature indicator (chilled water *FROM* reactor sealed building).

(d) *STOP* button.

(e) *START* button.

(f) *POWER ON* lights.

(g) *LOW LEVEL HEADTANK* lights.

(h) *MANUAL/AUTO* switch for 3-way chilled water valve.

(i) *MANUAL VALVE POSITIONER* for 3-way chilled water valve.

NOTE: (a) to (e) are duplicated in the auxiliary plant room control cubicle, (f) and (g) are repeated in both the control cubicle and control room panel 3.

In addition the override panel for sub-system 3 contains:

(j) *MANUAL/AUTO* switch for 2-way chilled water valve.

(k) *MANUAL VALVE POSITIONER* for 2-way chilled water valve.

The override panel for each sub-system permits an estimation and corresponding regulation (if necessary) of the heat removal performance of the sub-system by operating staff in the emergency control room (refer Section 11.2).

For normal automatic operation, all *MANUAL/AUTO* switches must be in the *AUTO* position when all chilled water regulating valves will operate only under the influence of their respective controlling thermostats. Because the thermostats in the reactor sealed building could themselves be damaged as a result of an accident and induce an undesirable functioning of the chilled water regulating valve, the arrangement in the override panel in the emergency control room allows the thermostats to be by-passed by placing the *MANUAL/AUTO* switch to *MANUAL*. The adjacent *MANUAL VALVE POSITIONER* then takes up the control of the positioning of the chilled water regulating valve and the flow can be adjusted over the full range of the flowmeter. Note that the flowmeter indicates only the chilled water flow to the reactor sealed building. For sub-system 3, the *MANUAL VALVE POSITIONER* for the 2-way valve would be utilised to render this valve fully shut so that, if required, all available chilled water would be available for the space conditioners in the reactor sealed building.

More importantly, this override facility in the emergency control room will allow the anticipation of the point of refrigeration over-loading of any sub-system. The heat removal capacity of the space conditioners can then be correspondingly reduced by manually reducing chilled water flow.

The work carried out by Thompson & Read [1970] relating to performance tests of HIFAR space conditioners established two significant points:

(i) The space conditioners develop a relatively very high heat removal rate at the elevated relative humidities that might be expected from a loss of reactor primary coolant.

(ii) Above approximately 88 kW capacity, the operation of the refrigeration circuits tends to become unstable and rapidly approaches the point of high pressure cut out.

Also established was that on approaching refrigeration overload the temperature of the chilled water leaving the cooler was approximately 18 to 19°C. As the refrigeration plant becomes more and more loaded, the compressor suction pressure rises and the compressor delivery pressure also rises (although not uniformly) despite operation of the condenser spray until the point of high pressure cut out 1790 kPa is reached. It is then necessary to press the *RE-SET* button on the cut-out component in the auxiliary plant room control cubicle before the plant can be restarted. As this procedure may not be immediately possible in an abnormal situation, the emergency procedure as outlined in Section 11.2 is to be adopted.

6. CHEMICAL CONTROL

Initially, chemical control of the chilled water circuits will involve the following:

(a) As an anti-corrosion measure, one per cent borax will be added to the chilled water circuits to increase the pH of the solution.

(b) As an anti-freeze measure, ten per cent ethylene-glycol will also be added to the chilled water circuits. This is regarded as a back-up to the mechanical/electrical anti-freeze devices described in Section 8, and will allow the temperature of the chilled water to drop to approximately -3°C before the onset of freezing.

Chemical control is being implemented and maintained by the Reactor Chemistry Section and, because very little evaporation is involved, a three-monthly check by this Section will be adequate. Each circuit will be drained out, flushed, and refilled with fresh coolant annually by the HIFAR Maintenance Group.

7. MAINTENANCE AND ROUTINE TESTING

As an engineered safety feature, the complete system will regularly be subjected to tests and maintenance services to demonstrate that the system is capable of reacting to an abnormal situation if called upon, and that performance has not deteriorated to an unacceptable degree.

A maintenance and routine testing schedule has been drawn up and is now being implemented along the following lines.

(1) The four-weekly reactor pre-start up check as described in Section 11.3 is to be performed by shift personnel. The authority of the Reactor Operations Engineer or his deputy will be required to start up the reactor if

more than one sub-system is not immediately available for service while the reactor core contains Mark 4 fuel elements.

(2) All mechanical and electrical equipment not incorporated in the Honeywell twice-yearly service and maintenance contract, that is, head tanks, sprays, screens, filters, motors, pumps, *etc.*, are included in the reactor maintenance schedule.

(3) At least every three months the air flow through each space conditioner will be determined. Nominally a flow of 2 m^3/s passes through each space conditioner and, provided that the chilled water inlet temperature does not rise excessively, the heat removal capacity is largely determined by the air flow through the unit. Despite substantial air filtration at the entry point to the Normal Input Ventilation system considerable dust and dirt particles are present in the reactor sealed building. These particles ultimately deposit on the fins of the space conditioner coils presenting an impedance to air flow and reducing heat removal capacity. This effect will be assessed by the HIFAR Maintenance Group for determining the frequency for cleaning the cooling coils in each unit.

(4) Every six months:

(i) Each sub-system is to be operated for at least 4 hours on its emergency electrical supply as described in Section 8.1. These tests will be programmed and supervised by the DRSS.

(ii) All equipment of Honeywell manufacture which forms part of the system will be serviced and maintained by Honeywell Pty Ltd.

(iii) The heat removal capacity of each sub-system will be tested. The specification of this test has not yet been prepared.

(5) It is anticipated that the chilled water and refrigeration circuits will have a complete overhaul every three years by taking one sub-system out of service each year for major maintenance.

It is expected that reactor maintenance personnel will handle the chilled water aspect of the major overhaul while the freon circuits will be covered by contract with refrigeration specialists.

(6) The chilled water circuits will be checked by the Reactor Chemistry Section every three months and the coolant changed annually (refer Section 6).

8. ELECTRICAL

8.1 Supply to Control Cubicles

Hopkinson [1970] has described the position of the control cubicles for the three sub-systems and their normal power supplies. These are illustrated in AAEC Drawing BE 31517.

The most significant feature of the electrical supply is that of the standby facility such that in the event of a prolonged site outage of power each sub-system can operate from a completely independent source of electrical energy.

Under power failure conditions, sub-system 1 can be operated from its normal supply board DBR6 in the rig diesel plant room, fed from either one or both rig diesel-alternators in accordance with McIlwraith [1965], (Section 5, Rig Diesel Plant Room).

Other essential loads may also have to be carried by these units under conditions of general power failure. However, in the event of a reactor accident requiring its use, it is expected that the space conditioner system will take priority.

Sub-system 2 is connected to a 100 amp switch-fuse located at the rear of Section 3 of the low tension switchboard in No.1 Substation. The switch-fuse is fed *via* an automatic changeover contactor in the No.1 Substation Standby switchboard DBS1-HIFAR, and is normally supplied from Section 3 of the low tension switchboard. Under power failure conditions, it automatically switches to the standby supply. The standby board DBS1-HIFAR is fed from a similar changeover contactor in No.2 Substation where, if a coincident normal supply failure occurs, emergency loading can be accommodated by supply from the 430 kVA diesel alternator in Building 4.

Under power failure conditions sub-system 3 can be fed from the McLaren diesel-alternator in the auxiliary plant room in accordance with McIlwraith [1965], (Section 3.5, The Diesel-Alternator). Other essential loads may also have to be carried by this unit under conditions of general power failure, but again, in the event of a reactor accident requiring its use, it is expected that the space conditioner system will take priority.

8.2 Control Cubicles

Drawings 4477/4-5-6 (Clark) illustrate the control cubicle layout for sub-systems 1,2, and 3 respectively. Also detailed are the makes and ratings of the electrical switchgear installed.

Apart from the associated override panel in the emergency control room and the indicating panel in the reactor control room, all switchgear, temperature and pressure indications, safety circuitry, instrumentation, power supplies and refrigeration plant controls are accommodated within one cubicle for each sub-system.

The compressor suction and discharge gauges, the high pressure/low pressure cut-out switch connected into the compressor control circuit and the condenser pump pressurestat, and the freon lines to these components, are housed in compartments separated from the electrical components. This also applies to the compressor lubricating oil pressure and control oil pressure gauges as well as the oil failure safety switch also connected into the compressor control circuit. This arrangement considerably reduces the possibility of freon or oil being sprayed onto electrical equipment should any of these components, or the associated pressure lines, leak.

The freon pressure gauges include a temperature scale corresponding to the pressure scale. These two parameters only correspond under saturated conditions, therefore on the compressor delivery side the indicated temperature relates to the evaporative condenser where the gaseous freon is being liquefied at saturation temperature. Immediately after leaving the compressor, the compressed freon gas is 17 to 22°C hotter and therefore superheated. In this case, the temperature/pressure relationship on the gauges does not apply.

The mimic diagram situated on the upper portion of the control cubicle is intended only to indicate to the operator the major components of the sub-system involved, their positions relative to each other and the source of electrical supply. For these reasons, no illumination has been included on the mimic diagram.

8.3 Circuits from Control Cubicles

8.3.1 General

AAEC Drawing BE 31542 indicates the routes taken by the wiring for the sub-system from the control cubicles. As far as is practicable, the wiring from any one sub-system has been separated from the wiring associated with either of the others. This principle has been applied particularly within the reactor sealed building where all wiring associated with the space conditioner system is in mineral insulated cable. The wiring for each sub-system enters the reactor sealed building *via* a separate shell penetration. Provision has been made to facilitate *in situ* local leak testing of the shell penetrations. The design of the penetration is illustrated in Figure 4.

Figures 5, 6 and 7 show the power and control circuit wiring diagrams of space conditioner sub-system 3. The wiring diagrams for sub-systems 1 and 2 differ from sub-system 3 only by the absence of the weathermaker components and different numbering of units and switch gear. The following sections refer to sub-system 3.

8.3.2 Main switch

With power supplied to the control cubicle, closing the 75 amp main switch will:

(a) Make power available to each of the contactors of the system's motors *via* their respective protection fuses.

(b) Energise low level relay LLR in series with the head tank float switch provided the head tank is full.

(c) Energise the oil separator heater and compressor crank case heater. A contact of relay LC disconnects these heaters when the compressor starts up, as heating for these parts is then supplied from the operation of the compressor itself. However, it is important that the oil separator and compressor crank case are heated at all times and *THE MAIN SWITCH SHOULD ALWAYS BE CLOSED WHETHER THE SYSTEM IS OPERATING OR NOT.*

(d) Energise the 240 V/24 V 100 kVA transformer which supplies:

  (i) The *POWER ON* lamps in the control cubicle, the control room panel, and the emergency control room override panel.

  (ii) The *HEAD TANK* lamps in the control cubicle, the control room panel and the emergency control room panel. These lamps are lit by a contact of relay LLR when the water level falls in the head tank and the float switch breaks the circuit to this relay.

  (iii) The modulating motor actuating the 3-way chilled water regulating valve and its associated controls:

  - One pair of averaging thermostats located in the reactor sealed building. One of each of these is adjacent to the air inlet of each space conditioner.
  - A *MANUAL/AUTO* switch and a *MANUAL VALVE POSITIONER* located in the override panel in the emergency control room.

  (iv) The modulating motor actuating the 2-way chilled water regulating valve and its associated controls:

  - A thermostat located in the weathermaker unit after the chilled water coil.
  - A *MANUAL/AUTO* switch and a *MANUAL VALVE POSITIONER* located in the override panel in the emergency control room.

  (v) The modulating motor which actuates the 2-way valve controlling the flow of high pressure hot water to the after-heater coil in the weathermaker, and its associated controlling thermostat which is located in the ductwork of the Normal Input Ventilation system.

(e) Energise the 240 V/115 V transformer which supplies power to the Honeywell NAX422 42 V d.c. power supply unit for operation of the flowmetering equipment.

(f) Energise the power supply unit for pressure and temperature indicating units located as follows:

- Chilled water pump pressure indicator at the control cubicle.
- Chilled water to cooler temperature indicator at the control cubicle.
- Chilled water to reactor sealed building temperature indicator at the control cubicle and the override panel in the emergency control room.
- Chilled water from reactor sealed building temperature indicator at the control cubicle and the override panel in the emergency control room.

(e) and (f) above are more fully described in Section 3.

8.3.3 <u>Normal operation</u>

If the chilled water circuit is prepared for service, the motor isolating switches are closed, conditions (a) to (f) above (Section 8.3.2) are fulfilled (that is, the main switch is closed), no overloads or safety switches require re-setting, the *MANUAL/OFF/AUTO* switch on the panel of the control cubicle is turned to *AUTO*, all *AUTO/TEST* switches within the control cubicle are on *AUTO*, and the *AUTO/MANUAL* switch on the override panel in the emergency control room is also on *AUTO*, the system is ready for automatic operation by depressing the *START* button at either the control cubicle or the override panel in the emergency control room.

Depressing either *START* button will energise relay SC5, contacts of which will close to:

(a) Start the fan motor on space conditioner unit No.5.

(b) Bridge out the *START* button so that this circuit remains energised when the *START* button is released.

(c) Energise the control circuit to relay SC6 and time delay relay TDR1.

Contacts of relay SC6 will now close to start the fan motor on space conditioner unit No.6.

After 5 seconds time delay relay TDR1 will energise the control circuit to relay SAF*.

Contacts of relay SAF will now close to:

(a) Start the motor of the supply air fan in the weathermaker.

(b) Energise the control circuit to relay SAP and time delay relay TDR2.

Contacts of relay SAP will now close to start the recirculating water spray pump of the weathermaker.

After 5 seconds' time delay relay TDR2 will energise the control circuit to relay CWP provided that:

(a) The auxiliary switch on the modulating motor which actuates the 2-way valve controlling the chilled water to the weathermaker is not open, that is, the 2-way control valve is not fully shut, and simultaneously

(b) the auxiliary switch on the modulating motor which actuates the 3-way valve controlling the chilled water to the reactor sealed building is not open, that is the 3-way valve is not fully diverting.

Contacts of relay CWP will then close to:

(a) Start the motor of the chilled water pump.

(b) Energise the control circuit to relay CF provided that the L426A thermostatic controller, monitoring the temperature of the chilled water delivered to the reactor sealed building, is in the closed position, that is the chilled water is calling for refrigeration cooling.

Contacts of relay CF will then close to:

(a) Start the motor of the evaporative condenser fan.

(b) Prepare the control circuit to relay CP. If and when the delivery pressure of the freon compressor exceeds 1450 kPa the closure of the condenser pump pressurestat contacts will start the condenser pump.

(c) Supply power in readiness for the operation of the freon compressor safety and starting circuits.

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* At this point in sub-systems 1 and 2 (where the weathermaker is not involved) TDR1 will energise the control circuit to relay CWP *via* the auxiliary switch on the modutrol motor actuating the 3-way valve.

8.3.4 Compressor protection

The compressor and refrigeration system safety features are described by Hopkinson [1967]. Briefly they are as follows:

An anti-freeze thermostat L426A whose bulb is located in the liquid freon in the base of the cooler. The temperature in this location should be above 2°C before the compressor can operate.

A differential pressure switch P406B across the chilled water inlet to and outlet from the cooler. This prevents compressor operation unless chilled water flow is established.

A high pressure/low pressure cut-out. Should the compressor delivery pressure exceed 1790 kPa or the suction pressure fall below 385 kPa the compressor is switched off. The high pressure cut-out is a lubricating and high temperature safety feature and the low pressure cut-out is a low temperature safety feature.

A duplicated low pressure cut-out sensing the pressure of freon in the cooler will stop the compressor. This is an anti-freeze safety feature.

An oil failure switch which permits the compressor to run only with adequate lubricating oil pressure.

8.3.5 Compressor operation

Provided then that all the plant safety requirements listed above are met the compressor and its auxiliaries will start up as follows:

Relay LC will be energised by closing of contact of relay CF and its contacts will:

(a) Disconnect the oil separator heater and crank case heater as previously described.

(b) Energise the level master heater attached to the side of the cooler. This controls the operation of the expansion valve regulating the flow of liquid from the evaporative condenser to the cooler.

(c) Energise the cooler return solenoid valve, the oil return solenoid valve and time delay relay TDR3.

(d) Start the compressor motor as follows:

A contact on time delay relay TDR3 will initially energise relay SC *via* a normally closed contact of relay DC and the compressor will start with its motor windings star connected. After 7 seconds, relay TDR3 will de-energise relay SC and energise relay DC *via* the normally closed contact of relay SC. The compressor will now run with its motor windings delta connected. A normally closed contact of relay DC which has energised the unloader solenoid valve to unload the compressor during the starting up period opens to load the compressor by de-energising the unloader solenoid.

9. REFRIGERATION CIRCUIT

The brief description of a refrigeration cycle which follows applies to all sub-systems.

The refrigerant used, approximately 140 kg in weight, is Freon-22, chemically designated monochlorodifluoromethane ($CHClF_2$). Apart from the usual requirements of any refrigerant, *i.e.*

(a) Convenient evaporation and condensation pressures,

(b) High latent heat of evaporation,

(c) Chemical and physical inertness under operating conditions,

(d) Non-corrosive characteristics,

(e) Very low explosive hazard,

it also has the very desirable characteristics of being non-toxic, non-irritating and non-flammable. Small traces of this refrigerant in air can be readily detected by the vivid green colour imparted to a flame by its presence; this considerably assists in the safe detection of leaks from any system.

With reference to Figure 8 'Freon-22 Cycle' it will be seen that the refrigeration cycle is as follows. (The pressures indicated on the chart are typical average operating values.)

1 → 2 Saturated freon gas is drawn from the cooler (evaporator) at 585 kPa and compressed to 1480 kPa. It is important to note that:

(1) Work is done on the system between points 1 and 2 by the compressor equivalent to the difference in the enthalpy, i.e. 291-251 = 40 kJ per kilogram of refrigerant. The expenditure of this work is necessary to maintain the cycle.

(2) Because this compression in practice cannot follow the line of constant entropy to obtain maximum efficiency of compression, point 2 is located further out into the superheated region. It is this temperature that limits the delivery pressure because at higher temperatures the lubricating qualities of the compressor oil deteriorate.

2 → 3, 3 → 4, 4 → 5 All carried out in the evaporative condenser.

2 → 3 The relatively hot high pressure gas is de-superheated and at point 3 is saturated vapour.

3 → 4 During this part of the cycle, the vapour is condensed into liquid at constant pressure.

As the refrigerant leaves point 3, it becomes a mixture of gas and liquid whose dryness fraction proportionately reduces to zero as it approaches the condition at point 4, *i.e.* the condition of saturated liquid. During this period, it must necessarily release its latent heat.

4 → 5 The saturated liquid is subcooled to ensure that the refrigerant is fully liquefied before it enters the cooler (evaporator) *via* the expansion valve. The heat released here is in the form of sensible heat.

All heat released in the evaporative condenser (super, latent and sensible) is absorbed and dispersed by air and/or water flowing over the outside of the evaporative condenser tubes.

5 → 6 During this part of the cycle, the subcooled liquid freon is introduced into the cooler (evaporator) *via* the expansion valve whose setting is controlled by the level master heater described in the electrical control circuits. The process across the expansion valve is one of constant enthalpy (*i.e.* throttling) involving a pressure reduction and also a temperature reduction due to evaporation of some of the liquid. The latent heat for this process is drawn from the remaining liquid, thus cooling it to the saturation temperature at the reduced pressure.

6 → 1 As the refrigerant in the cooler (evaporator) moves from condition 6 to condition 1, its dryness fraction increases proportionately to unity at condition 1, that is, saturated vapour. For this to occur, it must necessarily absorb latent heat and does so by deriving heat from the water on the other side of the cooler tubes. Thus, the chilled water is reduced in temperature as required for space conditioner operation.

The refrigerating effect of the system relates to the enthalpy difference between points 6 and 1 and amounts to 251-70 = 181 kJ per kilogram of refrigerant in this case. As the nominal rating of each sub-system is 84 kW it follows that approximate mass flow rate of refrigerant is

$$\frac{84}{181} = 0.46 \text{ kg/s.}$$

As with any refrigeration plant, the system can be likened to a heat-pump. Heat is absorbed at a low temperature (latent heat in the cooler), 'pumped up' the temperature scale by the compressor (only because work is done on the system) and then dissipated from the system at a comparatively high temperature (super, latent and sensible heat released from the evaporative condenser).

The motor driving the refrigeration compressor is rated at 18.6 kW. This gives a coefficient of performance of about 4.5 which is normal for this type of mechanical refrigeration.

Because Freon-22 is expensive, any suspected leakage from any of the sub-systems must be immediately reported to the HIFAR Maintenance Supervisor.

10. NORMAL AIR CONDITIONING

Because it is expected that the weathermaker unit will be permanently associated with No.3 space conditioner sub-system and have no connection to the other sub-systems, it is anticipated that, by appropriate adjustment of the thermostats in the reactor sealed building, No.3 will predominantly carry the cooling load, with either of the other sub-systems as alternative back-up.

A reasonable degree of air conditioning control within the reactor sealed building can be attained by the single operation of space conditioner sub-system 3. Referring to Figure 9, a typical air conditioning process is as follows:

Point 1 is taken in this case as average outdoor conditions on a normal summer day, that is 29°C dry bulb temperature and 50 per cent relative humidity. 1 → 2 represents the continuous spray cooling in the weathermaker and, because of the so-called adiabatic saturation inherently associated with this process, the air conditioning process will follow the line of constant wet bulb temperature to the saturation line of 100 per cent relative humidity where the dry bulb temperature will fall to 21°C. This process is automatic.

In passing over the fins of the chilled water coil in the weathermaker, the air will undergo primary cooling and come down the saturation line to point 3 and have its dry bulb temperature further reduced to 16°C. This process is controlled by the thermostat in the weathermaker above the chilled water coil which operates the modulating motor actuating the 2-way valve in the chilled water line. Primary after-heating, that is 3 → 4, is carried out by high pressure hot water regulated to the after-heater coil by a 2-way valve whose actuating motor is controlled by a thermostat in the ducting of the Normal Input Ventilation system.

4 → 5 represents the secondary after-heating that is provided within the reactor sealed building itself from the operation of the reactor, lighting and instrumentation.

3 → 5 is considered as direct sensible heating with the automatic reduction of relative humidity. Nominally the conditions within the reactor sealed building would be 24°C dry bulb temperature and 60 per cent relative humidity before the air receives its secondary cooling from the space conditioners.

The thermostats controlling chilled water flow to the space conditioners are set at 20°C dry bulb temperature at which temperature the relative humidity will tend to decrease because of the drop in moisture per kg of dry air to the optimum condition of 50 per cent which, however, could vary as much as plus or minus 10 per cent. At a steady dry bulb temperature of 20°C, this relative humidity variation is acceptable for comfort air conditioning.

Extreme winter conditions involve a negligible amount of both primary cooling (weathermaker) and secondary cooling (space conditioners) with a corresponding increase in primary after-heating (secondary after-heating is relatively constant throughout the year). For an external atmospheric dry bulb temperature of 7°C, provided that the accompanying relative humidity was not below 60 per cent, conditions within the reactor sealed building would be a minimum of 35 per cent at 20°C dry bulb temperature. This is illustrated by line A, B, C, D on the psychrometric graph (Figure 9).

If space conditioner sub-system 3 is out of service and either of the other sub-systems are operating (or both as would be expected if the external atmospheric temperature exceeds about 24°C dry bulb) the final relative humidity within the reactor sealed building will largely depend on the relative humidity of the external atmosphere. However, in the reactor sealed building the dry bulb temperature of approximately 20°C will be maintained. If the initial relative humidity is high, sensible cooling with the space conditioners will saturate the air within the reactor sealed building and moisture will be precipitated on further cooling. This would be accompanied by secondary after-heating which will reduce the relative humidity from the saturation condition. From a comfort point of view, however, comparatively high relative humidities are tolerable if the dry bulb temperature is maintained at around 20°C.

11. SYSTEM OPERATION

11.1 Auxiliary Plant Room

The plant is designed to operate in the fully automatic condition and according to the following procedures:

11.1.1 Starting up

Ensure electrical supply (see Section 8). Close the Main switch and check that the power lights are burning on the control cubicle, on the override panel in the ECR, and on the panel in the control room and also that the electrical instruments are indicating on both the control cubicle and the override panel in the ECR.

Place all *MANUAL/OFF/AUTO* switches to *AUTO*.

Press all reset buttons (inside control cubicle, on relays and pressure switches).

If starting from cold allow at least 12 hours for compressor crank case and oil separator to warm up via their respective heaters.

Check that *AUTO/MANUAL* switch in the ECR override panel is on *AUTO*.

Check water supply to the evaporative condenser sump. Check all motor isolating switches closed (Figure 5). Check for correct oil level in the compressor sump. Push the *START* button and, assuming the RSB is calling for cooling, check that in turn:

(a) the space conditioner fans are running and that the weathermaker fan and spray pump are running in the case of sub-system 3;

(b) the chilled water pump is running and its ammeter indicating about 8.5 A;

(c) the compressor is running and on normal loading with its ammeter reading about 26 A;

(d) the compressor discharge pressure lies between 1000 kPa and 1450 kPa;

(e) the compressor suction pressure lies between 400 and 550 kPa;

(f) the compressor oil pressure lies between 800 and 1100 kPa;

(g) the control oil pressure is approximately 70 kPa below the compressor oil pressure;

(h) the chilled water flow as indicated is appropriate to the indicated setting on the 3-way valve;

(i) the temperature of the chilled water flow to the reactor sealed building after about 10 min operation is 7°C ± 2°C; and

(j) condenser spray pump operates at about 1450 kPa compressor discharge pressure.

11.1.2 Normal running

At least every two hours, the operating plant generally should be inspected for normal running and any irregularities reported. No manual adjustments should be necessary.

Until further notice, sub-system 3 will operate continuously together with either sub-system 1 or sub-system 2. Sub-systems 1 and 2 will alternate between operational and idle on a weekly basis. The weekly changeover procedure is described in Section 11.2.1.

11.1.3 Shutting down

Depressing the *STOP* button on either the main control cubicle or the override panel for any sub-system will render that system idle. Unless maintenance is to be carried out on the shut down sub-system the main isolator should be left in the closed position (refer Section 8.3.2).

11.2 Emergency Control Room

11.2.1 Normal operation

The weekly changeover procedure which, until further notice, is to be carried out on each Monday day shift, should be as follows:

(a) At the emergency control room for the operating sub-system 1 or 2;
  (i) turn *AUTO/MANUAL* switch to *MANUAL*;
  (ii) turn valve positioner switch to *CLOSE*;
  (iii) check that flow meter reading falls to zero;
  (iv) check with the control room that space conditioner fans are still running;
  (v) check that light indicators are normal;
  (vi) check that the plant is idle in the auxiliary plant room.

(b) At the emergency control room for the sub-system 1 or 2 (previously idle):
  (i) turn *AUTO/MANUAL* switch to *AUTO*;
  (ii) check that light indications are normal;
  (iii) check that eventually chilled water flow is established with consequent operation of refrigeration plant as required.

11.2.2 Emergency operation

(a) Put all *MANUAL/AUTO* switches on *MANUAL*.

(b) Put the 2-way valve to fully shut with the *MANUAL VALVE POSITIONER* (sub-system 3 only).

(c) Estimate the heat removal performance of each sub-system from the water flow and temperature difference.*

(d) Adjust the water flow with the *MANUAL VALVE POSITIONER* for a heat removal rate of 100 kW maximum for each sub-system.

(e) Check that the temperature of the chilled water to the reactor sealed building does not exceed 18°C. If this value is approached, further reduce the chilled water flow to prevent its attainment. (The temperature difference will tend to increase but overall heat removal will drop.)

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* $H = 0.0698 \times F \times \Delta t$

where H = heat load (kW)

F = chilled water flow rate (ℓ/min)

Δt = chilled water temperature difference (°C)

A good approximation would be $H = \frac{7 \times F \times \Delta t}{100}$

Provided the above conditions can be achieved and maintained and also if the indicating lamps are indicating normal conditions it is reasonable to assume the following for any operating sub-system:

(i) Electrical supply is satisfactory.

(ii) The refrigeration plant is operating within normal limits.

(iii) The space conditioner fans are running.

(iv) The chilled water circuit is intact and the chilled water pump is operating.

(v) The head tank is full of water.

(vi) The space conditioners are removing heat.

(vii) The instrumentation is functioning.

11.3 Reactor Pre-startup Check

Before starting up the reactor at the commencement of each operating period, the following pre-startup check is to be carried out:

11.3.1 In auxiliary plant room

(a) Ensure power to available sub-systems (if not operating).

(b) Check that all available sub-systems are ready for operation (if not operating).

(c) Check indicating lamps as appropriate.

11.3.2 In emergency control room

(a) Check indicating lamps are appropriate.

(b) For each sub-system in turn:

- (i) If operating, press *STOP* button;
- (ii) press *START* button;
- (iii) turn *AUTO/OFF/MANUAL* switch to *MANUAL* and operate *MANUAL VALVE POSITIONER* control over full range;
- (iv) check for corresponding variation in chilled water flow;
- (v) check temperature indicator for normal readings;
- (vi) Return to normal operation.

12. ASSOCIATED DRAWINGS

The drawings by Thos. Clark & Sons Pty Limited applicable to the HIFAR space conditioner system are as follows:

Wiring diagram for No.2 a.c. system	4477/2
Wiring diagram for No.3 a.c. system	4477/3
Layout and construction details of space conditioner sub-system 1	4477/4
Layout and construction details of space conditioner sub-system 2	4477/5

Layout and construction details of space conditioner sub-system 3	4477/6
Wiring diagram for No.1 a.c. system	4477/7
Plantroom pipework schematic	4477/9
Wiring diagram and control panel details of ECR and CR	4477/10
Wiring diagram for electrical flow, temperature and pressure meters	4477/11

A full set of the above drawings is held:

(a) by the HIFAR Maintenance Supervisor, and

(b) in the plant room technician's office in the auxiliary plant room, HIFAR.

13. REFERENCES

Hopkinson, J.B. (1967) - HIFAR Reactor Sealed Building Normal Ventilation System. AAEC/M79.

Hopkinson, J.B. (1970) - Modifications to the HIFAR Space Conditioners. AAEC Internal Report.

McIlwraith, J.R. (1965) - Plant and Operations Manual for HIFAR Electrical Power System. AAEC Internal Report.

Thompson, N.E. & Reed, N. (1970) - Performance Tests of HIFAR Space Conditioners. AAEC Internal Report.

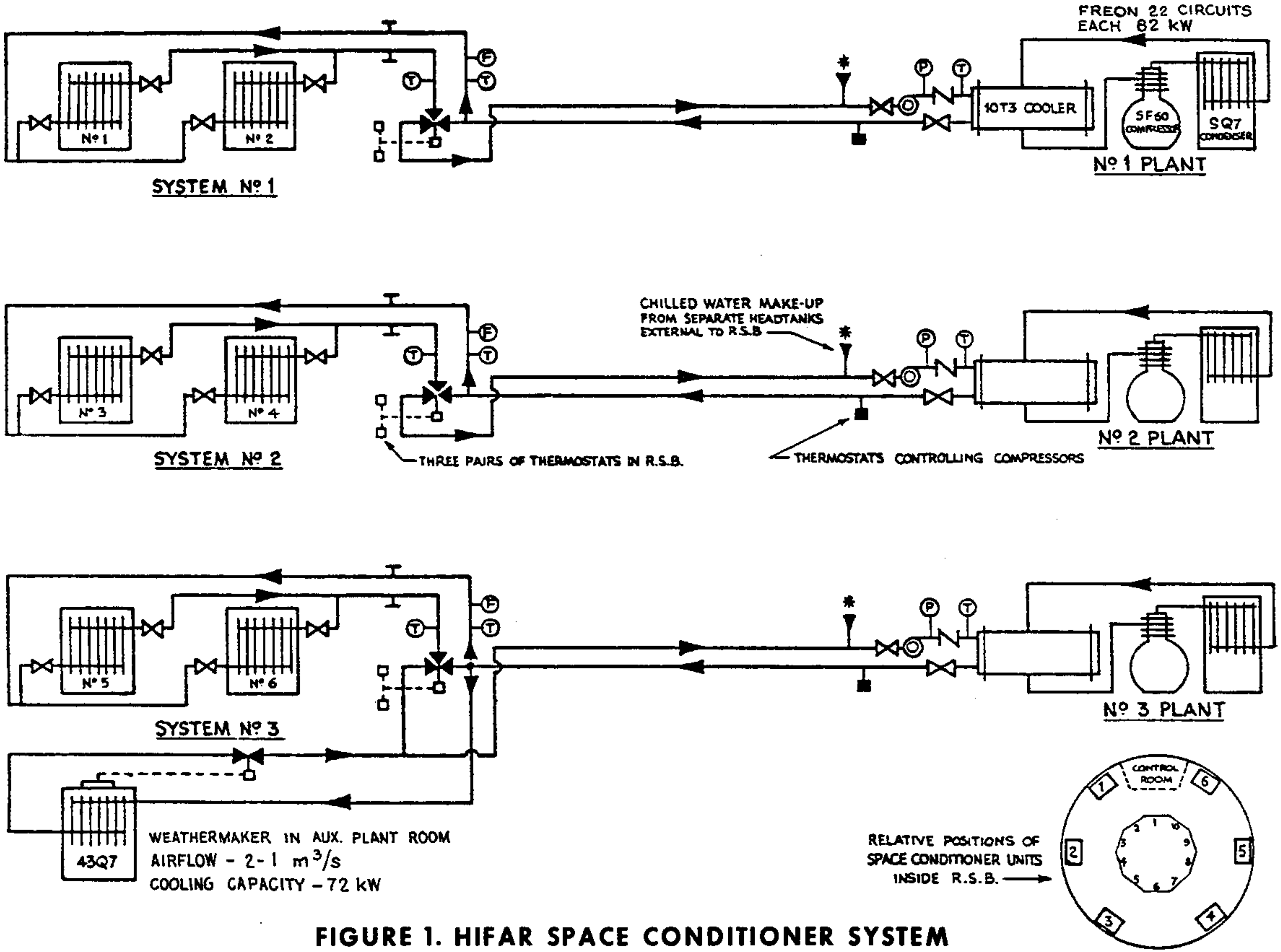

FIGURE 1. HIFAR SPACE CONDITIONER SYSTEM

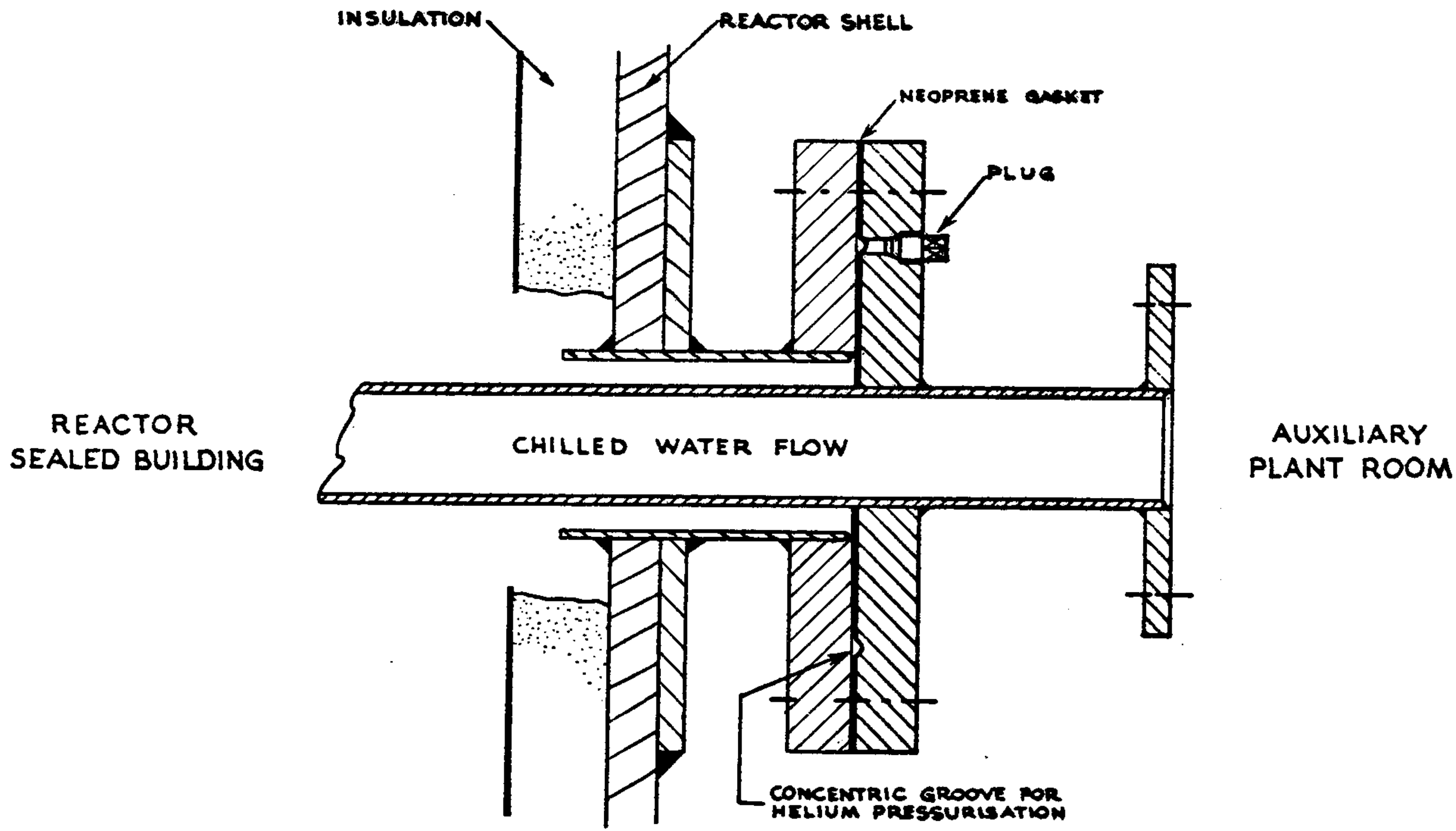

FIGURE 2. DETAIL OF CHILLED WATER PIPEWORK PASSING THROUGH REACTOR SHELL

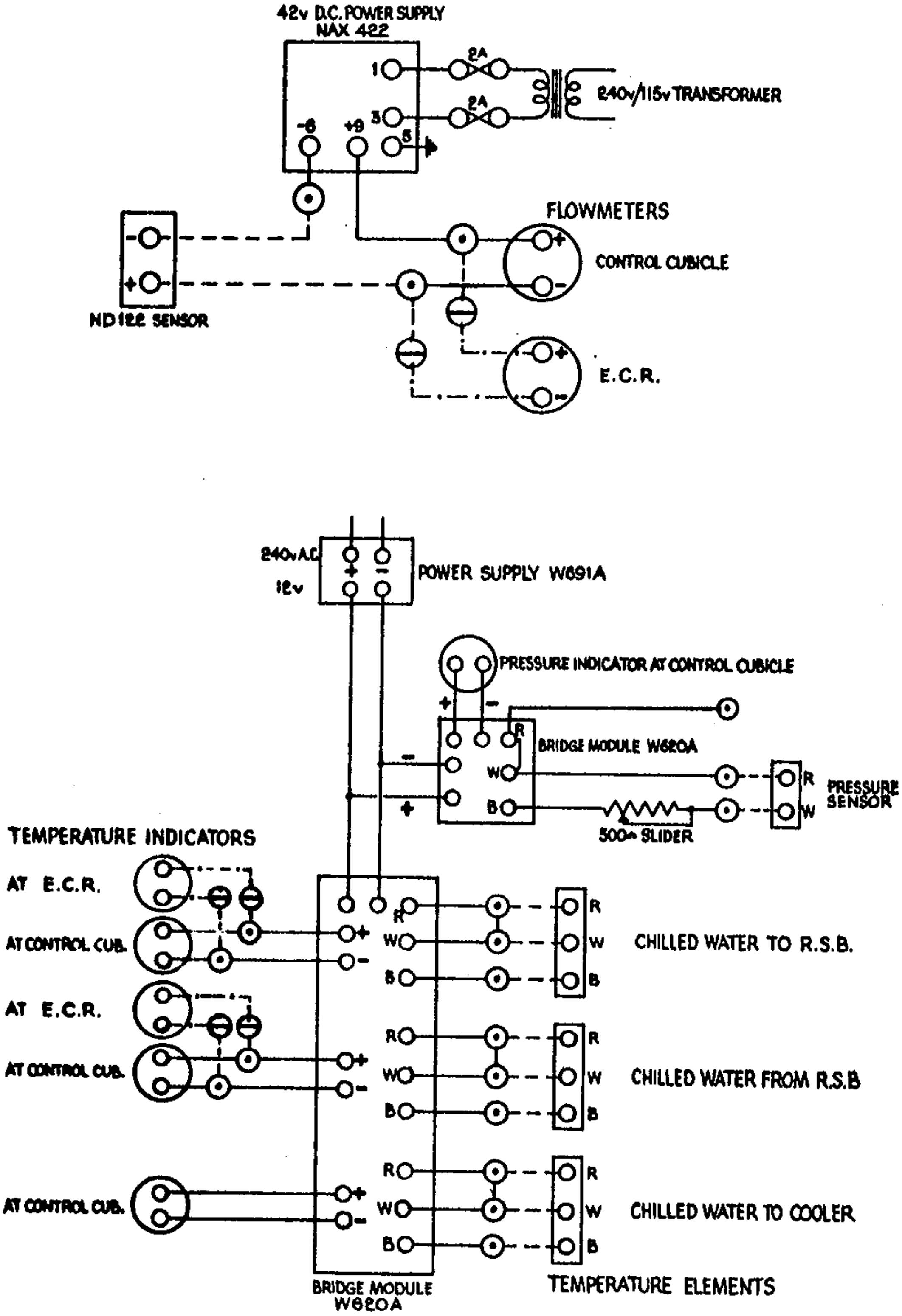

FIGURE 3. TYPICAL INSTRUMENTATION WIRING DIAGRAMS

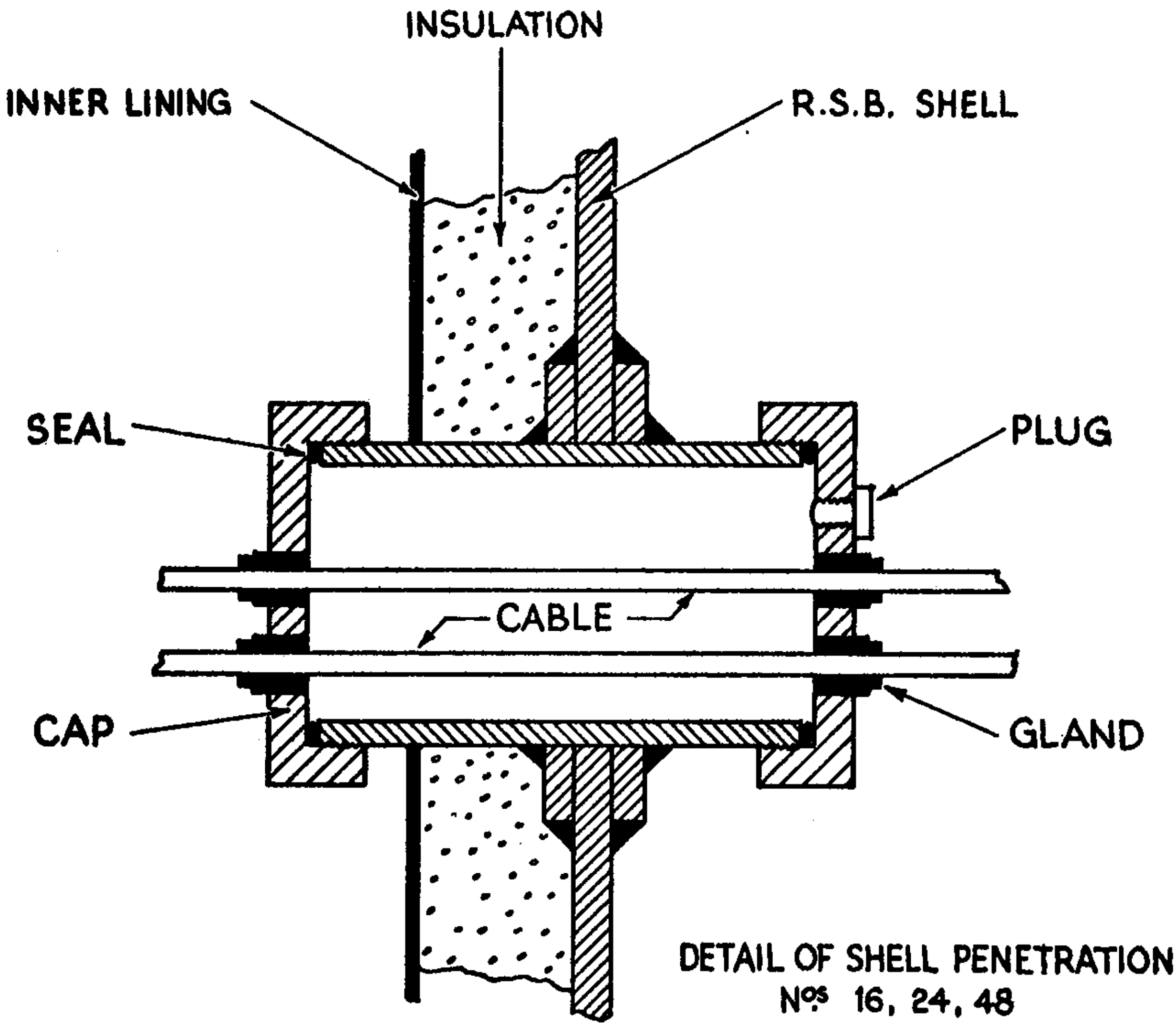

FIGURE 4. DETAIL OF ELECTRICAL WIRING PASSING THROUGH REACTOR SHELL

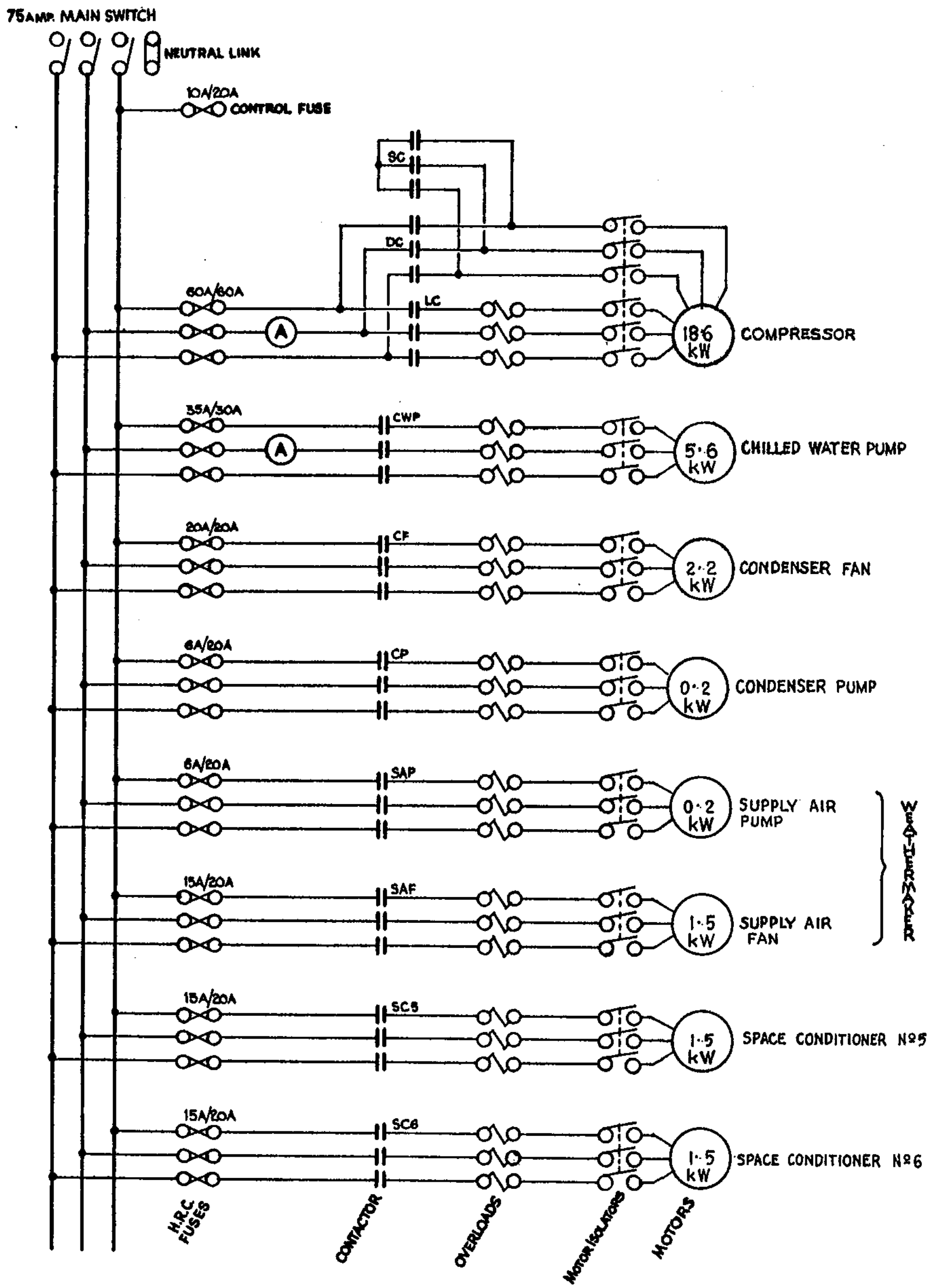

FIGURE 5. POWER DIAGRAM FOR SUB-SYSTEM 3

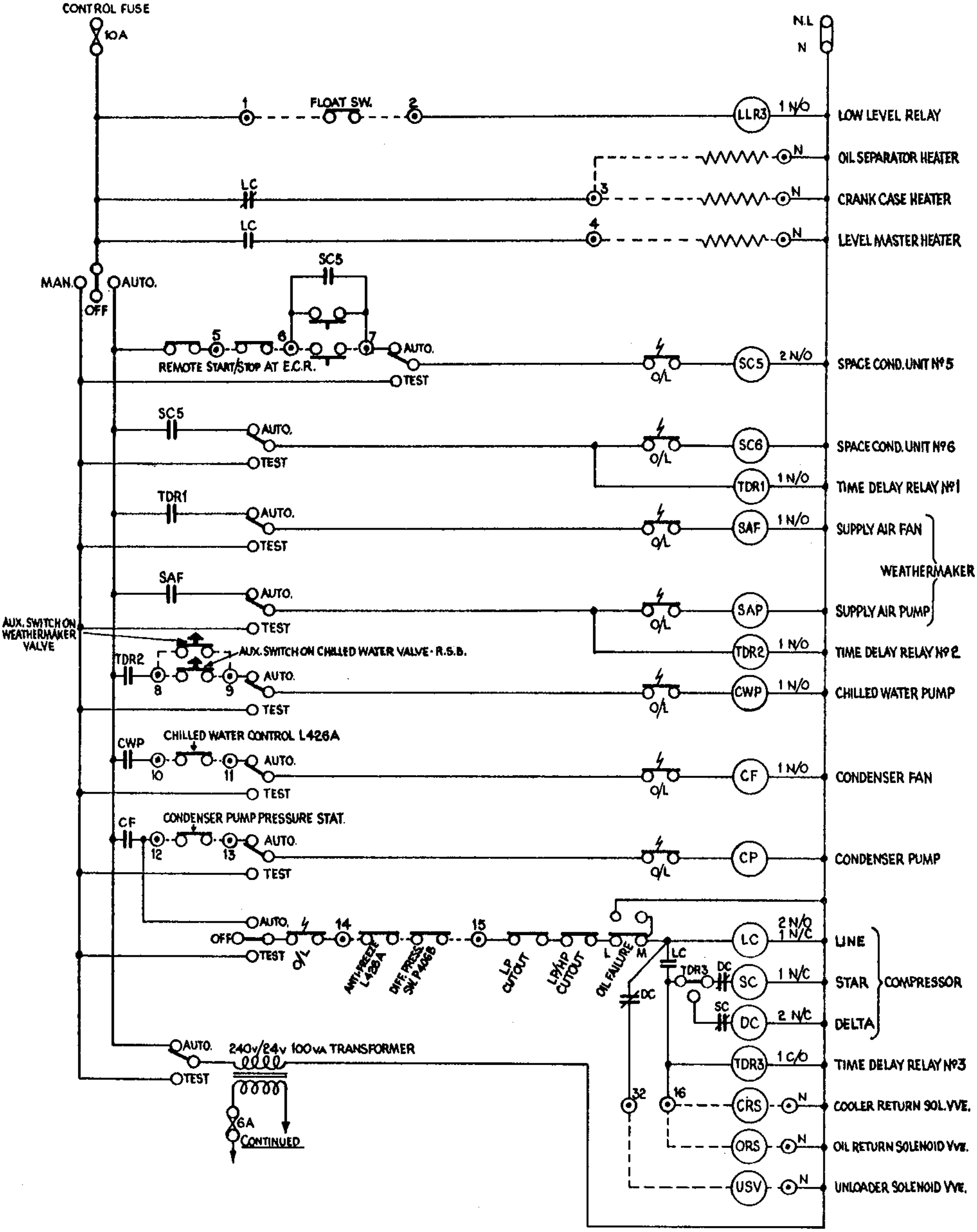

FIGURE 6. CONTROL CIRCUIT FOR SUB-SYSTEM 3

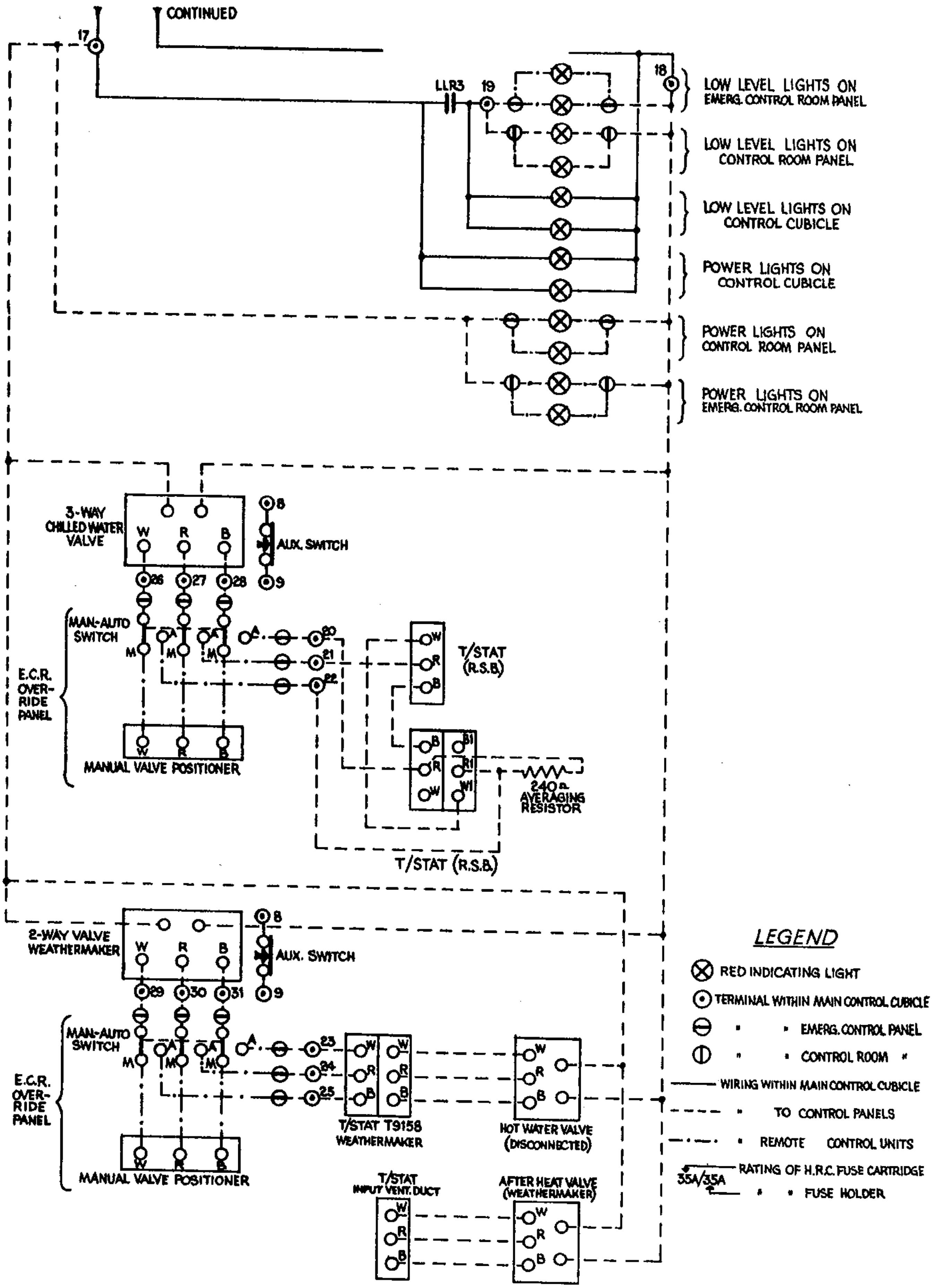

FIGURE 7. CONTROL CIRCUIT FOR SUB-SYSTEM 3 (CONTINUED)

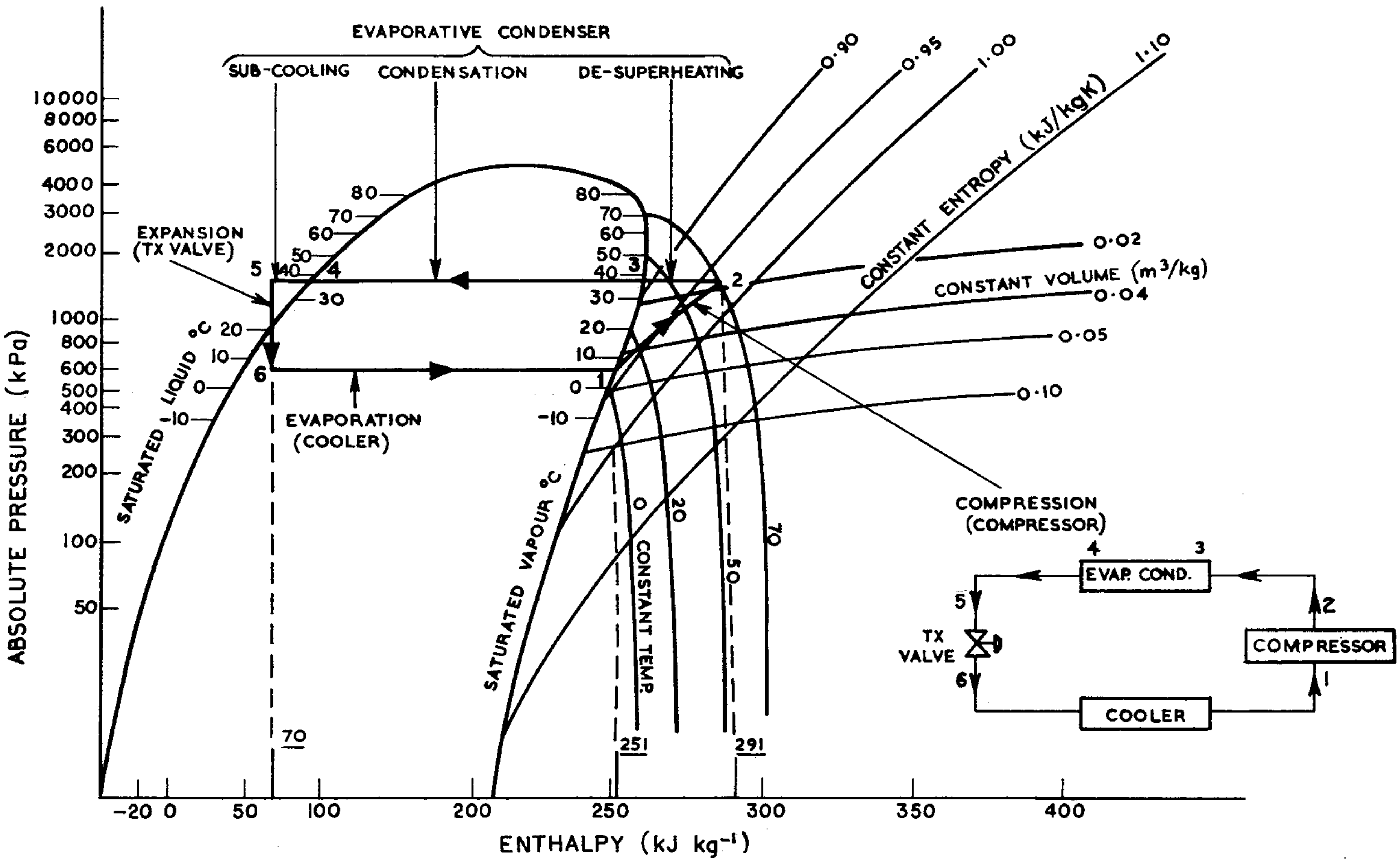

FIGURE 8. FREON-22 CYCLE

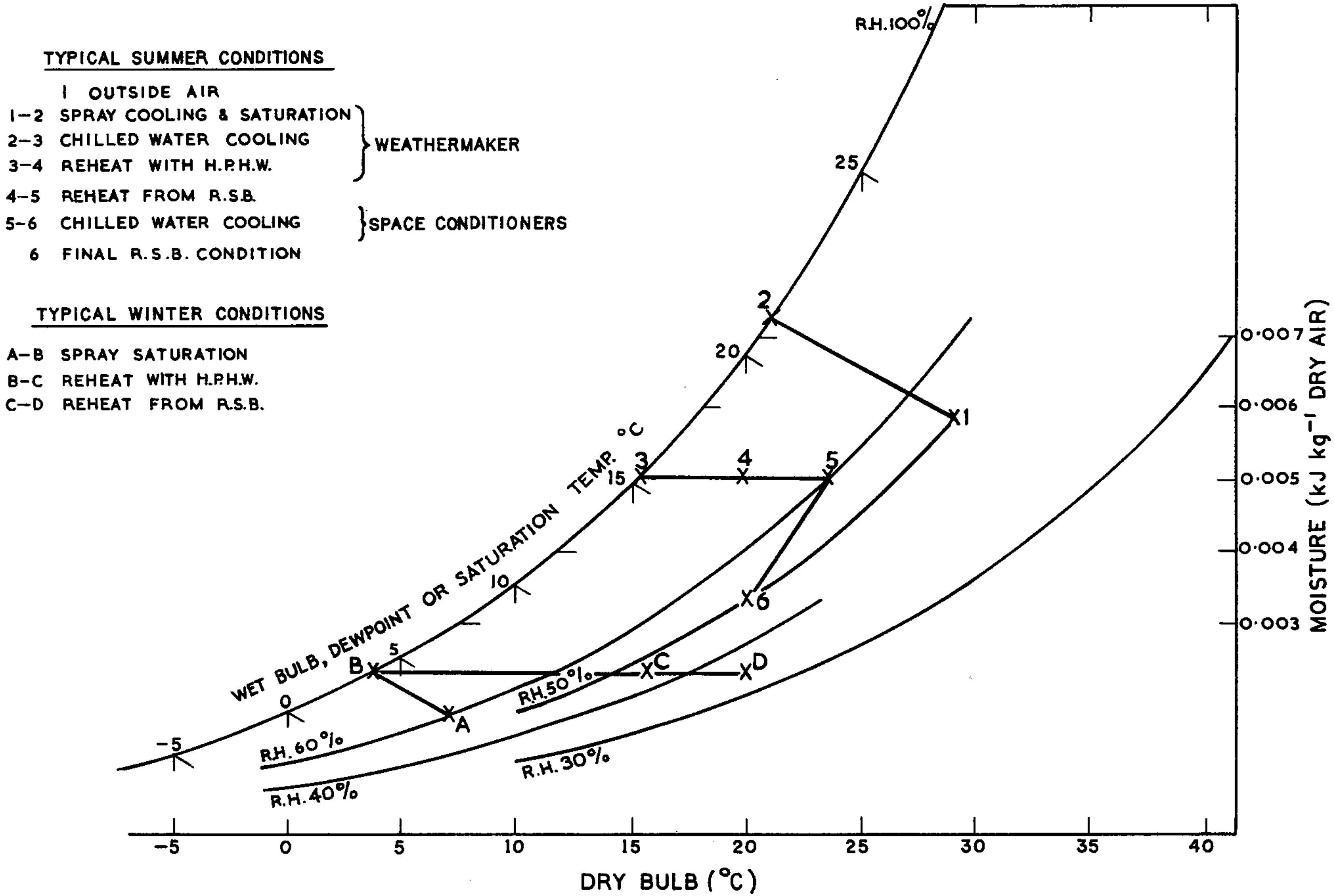

FIGURE 9. THEORETICAL PSYCHROMETRIC GRAPH FOR SPACE CONDITIONER SUB-SYSTEM 3