necessary before the machine can operate again. When the "Green" period is within half-an-hour of the beam-on time, audible warning announcements will be made using the pre-recorded tapes and people will be told to leave. After a further 5 minutes those persons still outstanding (i.e. according to tally or key) will be warned over the loudspeaker system by name. As soon as all the keys and tallies have been recalled the machine condition will change to "Yellow".

The "Yellow" condition denotes that the beam is off but expected to come on within half-an-hour. During this period a thorough search will be made of all relevant areas and loudspeaker announcements and audible warning notes will be transmitted at frequent intervals. Entrance to the machine will be limited to a few doors and any semi-authorised person entering must be accompanied by an authorised person. This reduced number of doors will be controlled remotely from the main control room. After all the checks of the areas are complete, final warnings to leave the areas are given, all keys are returned to the key exchange boxes and all interlocks are closed. A "one-minute" warning is given over the public address system, followed by an interrupted 1000 c/s note. Half the main lights are turned off and the machine condition changes to "Red".

The "Red" condition does not necessarily signify that a beam is actually being produced but that all conditions and interlocks are correct for the production of a beam. The red flashing lights around the machine occur for 1 minute before the machine can be switched on and any person left in the area under these conditions must immediately operate an "Emergency Off" push button.

The safety interlocking and radiation protection system for Nimrod is more fully described in a Nimrod Design Note (NDN/600/1).

ANCILLARY PLANT

10.1 Introduction

The Nimrod ancillary plant provides the services of water and air for Nimrod. Many of the main components of Nimrod generate heat and require cooling, for example, the heat generated in the magnet is dissipated by cooling the conductor coils with water and by passing air between the magnet sectors to give forced convection. The cooling water must, of necessity, be of low electrical conductivity and, before use, the raw water from the mains is treated in a special plant to demineralise it and give it a low oxygen content. For most items of Nimrod equipment, the cooling water also needs to be temperature controlled; in some instances this involves the use of refrigeration plant. Where low electrical conductivity is not important, the water used for cooling purposes is only softened to reduce scaling.

The magnet room temperature is controlled to ensure that the magnet does not tilt beyond the acceptable limit due to differential temperature gradients across the foundation monolith. The relative humidity is also controlled to reduce electrical breakdown and to minimise condensation. This is effected by means of a large air conditioning plant employing refrigeration units and steam heaters.

Commissioning and development of much of this ancillary plant has of necessity proceeded in parallel with the commissioning of the main machine, rather than preceding it. One reason was because of the impracticability of simulating the heat loads put out by Nimrod and associated experimental equipment. The ancillary equipment is now functioning reasonably well, but a full knowledge of component plant capacities and reliabilities is not yet known.

10.2 Cooling Towers

The four towers dissipate the whole of the heat output from Nimrod. There are three induced draught, evaporative units each of 320,000 Btu/min and 120,000 gal/h capacity, and one smaller unit of 160,000 Btu/min and 60,000 gal/h capacity. The cooled temperature of the water will depend on the heat input and climatic conditions but is not expected to exceed 79°F under the worst conditions. A schematic diagram of the water cooling system is shown in Fig. 10.2(i).

The geographical position of the towers is such that strong cross winds caused large amounts of water to be swept out of the towers against the air draught induced by the fans located above the cooling matrix. Under gusty conditions the waves formed on the ponds, lapped over the retaining walls. These troubles were overcome by detail modifications to the wooden air inlet louvres which improved air inlet flow conditions and by the addition of a vertical baffle across each pond normal to the direction of air inlet.

Considerable airborne debris is present in the locality of the Rutherford Laboratory; some is due to adjacent construction work but most is caused by the light soil conditions and at times the high insect population. The original pot type filters in the feed lines to the pumps were inadequate in area and necessitated a shut down and drainage of each pond in order to change a filter. Larger filters of 40 mesh (60μ) have been fitted and no shut down is required to service them. A specific flow rate of 45 gal/min/ft^2 is satisfactory. A special washdown area has been constructed alongside the cooling towers to clean these filters.

The original design of the water system pipework did not allow the small cooling tower to be taken out of commission without shutting down all equipment served by it. As the small cooling tower distribution pump gives a slightly higher head than the other tower pumps, a pipework system was evolved which allowed the water to the small tower to be diverted to and from the other towers, thereby achieving the required maintenance facility. Various other similar modifications have been made to improve the operational flexibility.

Considerable work has been done to guard against frost damage to the cooling tower complex. This has included the application of heater tapes, controlled bleeds, repositioning of stop valves to eliminate dead legs and additional lagging. The main water stop valves to each tower are of the direct acting, hand operated type and require the effort of two men for operation. This is an extremely difficult job in very cold weather and geared drive units have been purchased but are not yet fitted.

Evaporation results in a steady increase in the total solid content of the water. An overflow and drain connection added to each tower will allow sufficient bleed off (about 1/40th of the system makeup water) to reduce the content to an acceptable level. At the present time, the need to clean the ponds of airborne and constructional debris (concrete dust, rust etc.) at least once a month renders this system inoperative.

Sodium pentachlorophenoxide (Algicide) was added to the towers at a concentration of 80 parts/million when algea was observed. To prevent a strain of algea developing resistance to Algicide, a shock dose of 100 parts/million is now added once a month. As Algicide is only effective in high concentrations, is toxic and does not protect against slimes, a more suitable material is being sought.

When magnet loading and ambient weather conditions have allowed, heat balance

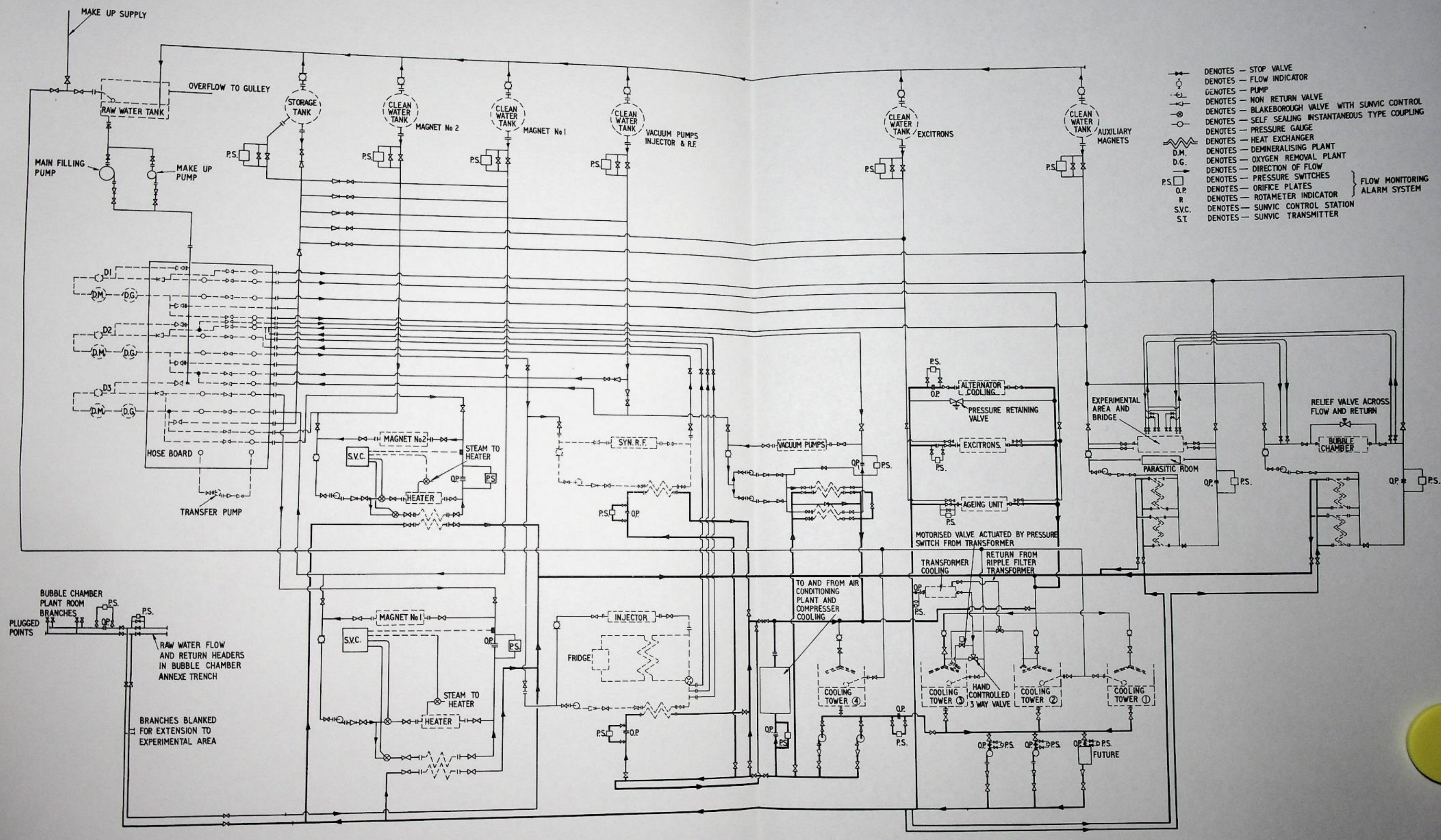


Fig. 10.2(i) Diagrammatic Arrangement of Water Cooling System.

trials have been performed on the towers. To date it has only been possible to check and confirm the performance at full heat load and fairly low ambient relative humidities.

10.3 Pump House

10.3.1 Pumps

The pump house contains the Kennicott softened water (raw water) plant, two 2500 gal/min pumps serving the three large cooling towers and two 500 gal/min pumps serving the small auxiliary cooling tower. An additional twin pump set has been installed to provide a raw water supply to laboratories. These are each of 800 gal/min capacity and the circuit is required to dissipate about 1200 kW. The two small pumps together provide the total flow from the auxiliary cooling tower to the air conditioning plant, injector and magnet room. One duplicate pump of 1000 gal/min capacity is being fitted to provide a maintenance facility and to guard against breakdown and loss of water supply.

The noise from the existing pumps was extremely high, over 100 dB at the worst azimuthal position. Sound absorber hoods were constructed and the level was reduced to 92 dB at the same position. The air cooling of the motors is now more directional and a lower running temperature is recorded.

The relative heights of the raw water pumps to the tower ponds is such that on pump start up there is insufficient head to give positive suction to start the pumps without cavitation. A priming system has been installed so that the raw water pump No. 1 of the Kennicott softening plant may be used to prime all raw water pumps. Rotameter flow indicators installed in the suction lines are inoperative due to air locks attributable to the low local suction pressures. No satisfactory alternative has yet been fitted.

10.3.2 Kennicott Plant

The Kennicott plant (shown schematically in Fig. 10.3.2(i)) is the treatment plant for the cooling tower water system. It consists first of an alkaliminator section where the temporary hardness of the water is converted to carbonic acid. After passing through a scrubber tower, where the carbonic acid dissociates to form carbon dioxide, the water only contains permanent hardness. This is removed in the base exchange section where the calcium, magnesium, etc., is converted to sodium salts which (in solution) are non-scale forming. The difficulties associated with this plant were of a mechanical nature; chemically it fulfils its function.

The acid measure system gave considerable trouble. Initial leakage from the acid measure sight glass and the acid flow rotameter resulted in spillage of concentrated sulphuric acid. Sticking of the rotameter bobbin on the lower lead stop resulted in a low flow of the sulphuric acid to the primary dilution vessel, causing the water supply tank to be corroded through by dilute acid. The lower stop material was changed to P.T.F.E. (polytetrafluoroethylene), a spring buffer was fitted, and the lead lined steel tank was relined with Penton. Various rubber lined pipes were attacked by dilute acid; these were relined. A barometric loop, a non-return valve, a larger water trap and a larger air admittance solenoid valve were fitted to prevent water being sucked back into the primary acid measure tank. The vent for the acid secondary measure tank was altered so that if the tank is overfilled, acid flows into the acid storage tank bund and not outside the building. The lead bung for the drain from this bund is kept in position to allow acid spillage to be adequately diluted before release into the trade waste drain.

Failure of the constant level float valve on the caustic injection system flooded the plant room with a 5% caustic soda solution. The operation of the caustic dosing (before the base exchangers) became erratic due to coarse flow control and sticking of the solenoid valves. This resulted in resin being lost from the base exchanger due to high back wash flow. A high rate of corrosion of the base exchange tank was attributable to the erratic caustic dosing. The caustic injection system

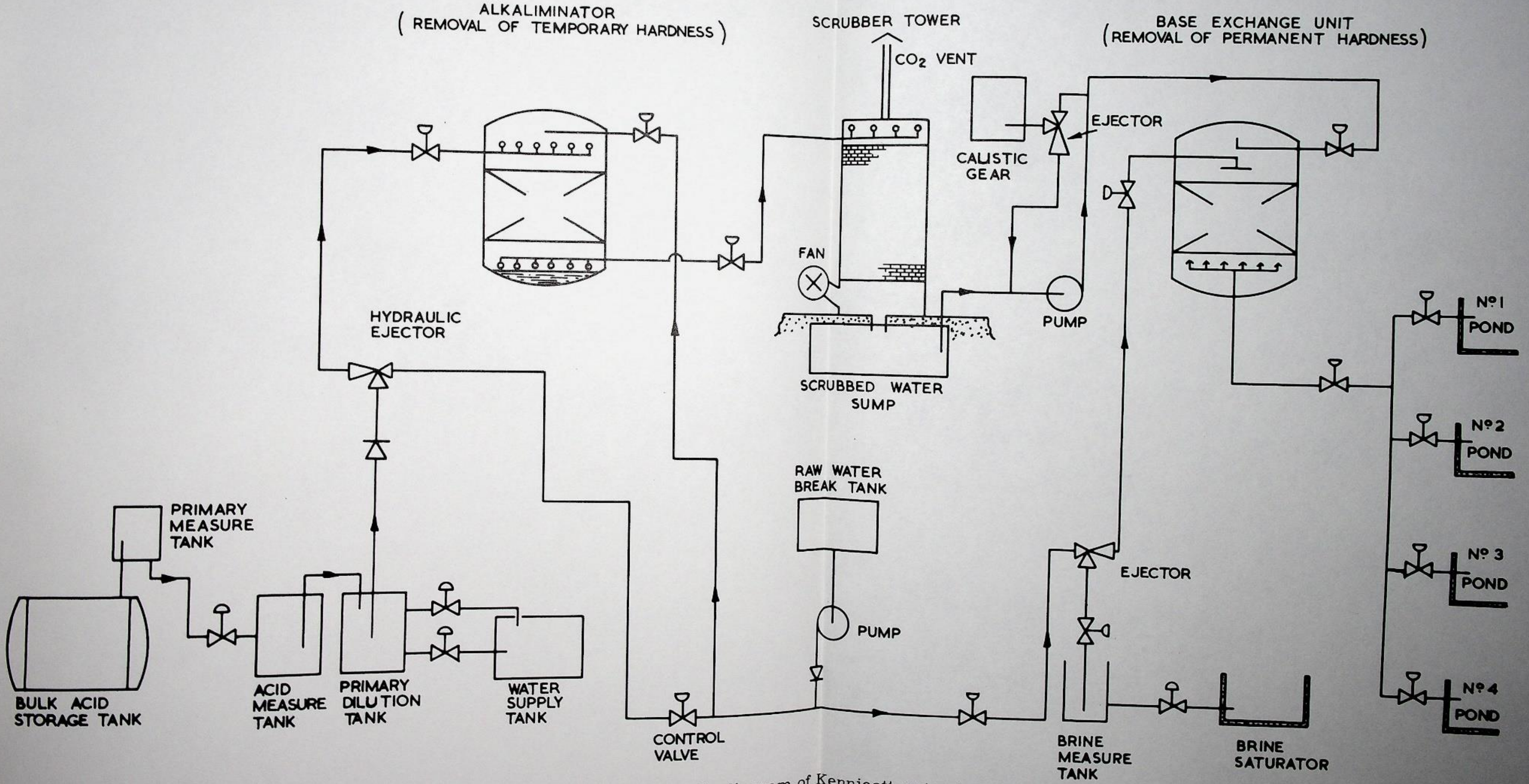


Fig. 10.3.2(i) Schematic diagram of Kennicott water treatment plant.

was re-designed and all other affected parts renewed. Solenoid valves now operate Saunders pneumatic diaphram valves which have positive limit stops to prevent jamming at the end of the travel. One interesting failure occurred to the external diaphram of a pneumatic valve by, presumably, the action of paint which had in error been applied to the diaphram.

Compatibility of materials is always a problem on chemical plant. The bitumen paint on the degassed water sump and on the brine tank peeled off, exposing the concrete. The water sump was repainted successfully but the brine tank was coated with a glass fibre. The concrete bund of the acid storage tank was also lined with glass fibre but dilute acid broke this up and it had to be lined with glazed ceramic tiles. The use of incorrect grades of rubber on diaphram valves has caused much trouble. To protect the concrete floor of the plant room a bund has been built around all acid measuring system equipment.

The cooling tower pond has capacitance type electrodes which control the plant. These were unsatisfactory due to excessive splashing from falling cooled water. They were repositioned and protected by splash covers and the electrodes were changed from mild steel to stainless steel because of corrosion.

The plant was originally intended for use with 80% B.O.V. acid. In order to minimise corrosion of the storage tank 96% C.O.V. acid is now being used.

The Neckar water hardness meter is troublesome mechanically. Regeneration is triggered off too frequently as the raw water hardness changes due to a change in the source of supply (Thames, deep well or local authority). A time switch is fitted to the control gear to control the frequency of regeneration of the alkalimeters to not less than once per hour.

10.4 Permutit Plant House

10.4.1 Heat Exchanger and Pump Systems

The Permutit plant house contains the Permutit water treatment plant, circulating water pumps and heat exchangers and all other equipment needed to supply the Magnet and associated equipment with demineralised water.

Four large and two small heat exchangers transfer heat from the demineralised water returning from the machine and experimental equipment, to raw water circulated back to the induced draught cooling towers. The demineralised water serving the magnet is kept substantially at a constant temperature of 90°F by passing the flow across two water/water coolers when the magnet is energised, and by heating a proportion of the flow by a subsidiary steam heater coil when the magnet is not energised. The demineralised water serving the experimental equipment, bubble chamber and vacuum system is not temperature controlled.

10.4.1(a) Magnet Circuit. Two pumps each delivering approximately 720 gal/min serve the magnet. Temperature transducers in the feed line to the magnet, pass a pneumatic signal to a controller where suitably amplified pneumatic signals are fed to three valves; one controlling the steam supply to a heat exchanger across which demineralised water is by-passed, one controlling the demineralised water through the demineralised raw water heat exchangers and the third controlling the water across the steam heater.

Considerable instability was experienced when this closed loop system was subjected to full magnet heat load conditions (it had been impractical to attempt to simulate such conditions). The system was stabilised by:-

(i) repositioning the temperature transducer to such a position that it sensed a mean of the outlet water temperatures from the steam heater and main exchanger

(ii) redesigning the valve trim of the three control valves to obtain a more linear flow characteristic

(iii) increasing the proportional band of the positioners to counter instability (the positioners were changed for a new type to allow more latitude in control)

(iv) reducing the speed of response of the control valves by heavily damping the air supply to the diaphram motors

(v) setting the response of the two valves controlling the water so that one valve always led another, thus ensuring that lags in the system did not result in the effective area for water flow being reduced.

The magnet is protected by thermistor temperature monitors set to shut down the pumps when the inlet water drops to 28°C. It is difficult to prevent small slugs of water at about this temperature being passed into the system due to the action of the control circuits. The very high speed of response of these thermistors caused frequent shut down of the plant and thermal damping (provided by mounting the thermistors on copper blocks) was necessary.

It was found that the pump installed to supply water to the experimental area delivered insufficient head to overcome adequately the losses in the system. A new pump has been installed.

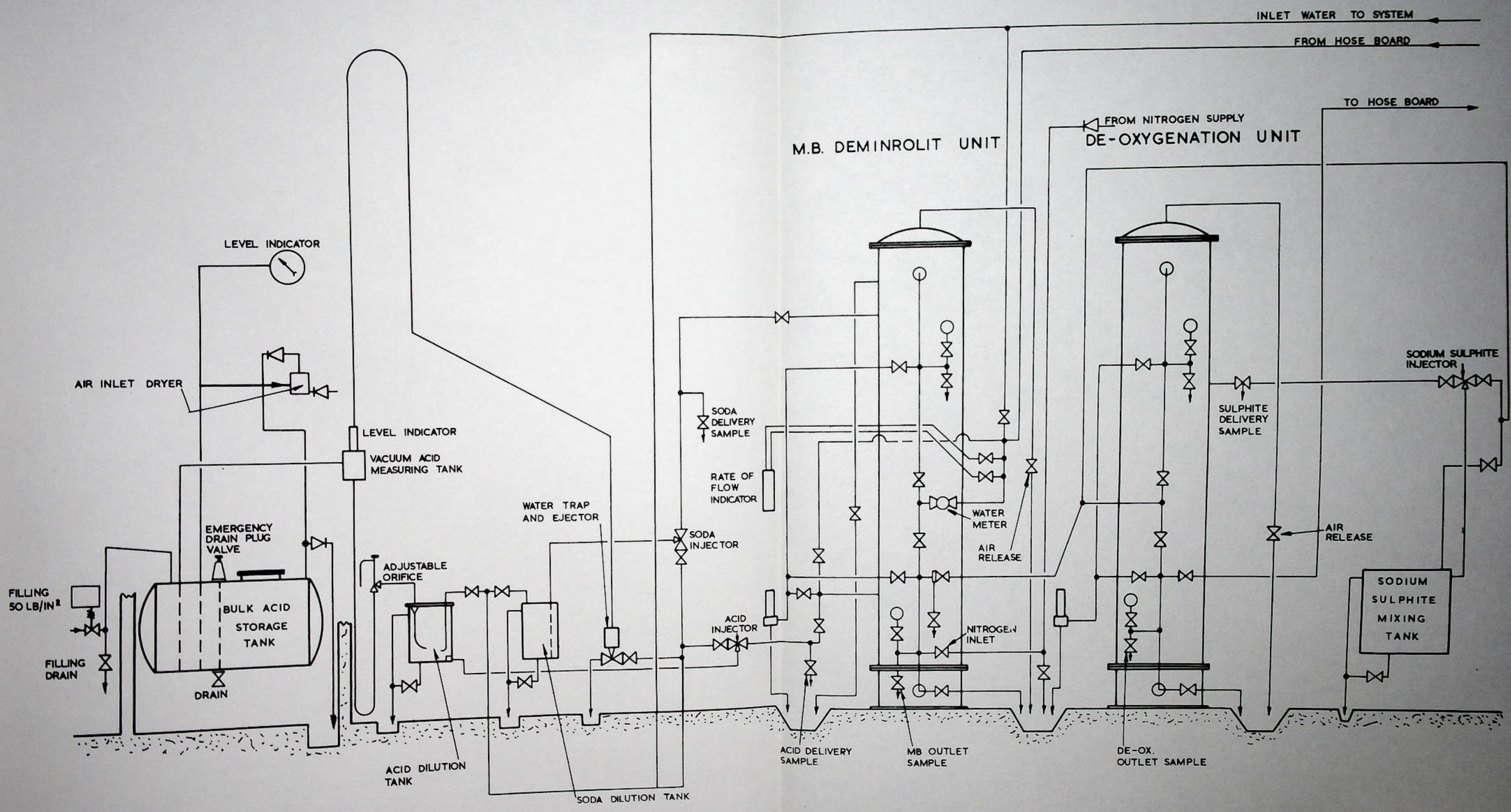


Fig. 10.4.2(i) Permutit water treatment plant.

Each pump has a visual flow sight glass at its inlet but with the instrumentation necessary to run the plant (rotameters, pressure gauges and thermometers), such sight glasses are superfluous.

The pipework between the two small pumps and the double tube heat exchangers for the vacuum cooling circuit had to be modified to allow inspection of one exchanger nest without shutting down the other. This type of facility is most desirable to achieve efficient operation.

An additional pump and heat exchanger was installed to provide cooling for the ripple transformer amplifier in the magnet power supply plant.

10.4.1(b) Steam Heaters. These are of a double coiled tube design. Hydraulic vibration quickly fatigued the copper coils where they were braced to the main shell. A new design of 'U' tubes will be fitted since thicker coils and stiffer bracing have not completely cured the problem. It was also necessary to fit an automatic shut off valve in the steam supply line so that if a demineralised water circulating pump trips out, the steam supply is shut off.

10.4.2 Permutit Plant

This installation comprises three mixed bed demineralisation plants each associated with an ion-exchange de-oxygenation unit. Each pair of units (demineraliser and de-oxygenator) is capable of treating raw water for filling the circuits at a rate of 60 gal/h and 160 gal/h when operating on a recirculation basis. Fig.10.4.2(i) is a schematic diagram of the Permutit plant.

Initial tests on the mixed beds showed the plant capacity to be up to specification. When treating mains water the demineraliser produced water with a conductivity of 0.1 μmho/cm (specification < 1.0 μmho/cm) with a capacity measured over a regeneration-exhaustion-regeneration cycle of 1700 gal (specification 1400 gal). Two de-oxygenator columns met the specification in delivering water at 0.2 parts/million O_2 after a throughput of about 2800 gal. One column needed modification to the sodium-sulphite regenerant injector dilution system before it met the specification.

Low capacities experienced at one time, were rectified by cleaning the caustic injection system which was partially blocked by wood pulp from a wood stick used for mixing the caustic solution. Operating instructions were issued to prevent a recurrence.

Strainers were fitted to the mixed bed air release lines to avoid loss of resin when backflowing the beds with nitrogen during the regeneration cycle. The resin bed of one demineraliser unit, which is used for continuous circulation of the magnet system water, was found to be compacted when it became exhausted after being in use for three months. Regeneration once a month is now necessary to avoid this trouble.

The capacity of the mixed bed units was often only 50% of that specified. The cation resin usually exhausts first. The acid measure was dismantled and found to contain a quantity of ferrous sulphate which decreased the volume available in the measure of sulphuric acid. This is partly due to attack on mild steel by sulphuric acid which has become diluted by water vapour from the acid vacuum injector. Poor separation of the resins for regeneration will reduce the efficiency of regeneration and the backwash flow rate is being increased in easy stages to find an optimum condition.

Ceramic and cloth bag filters were fitted at the inlet to the mixed bed columns to prevent the resins acting as filters for system debris.

A secondary system of conductivity checks was installed, using a cell and standard meter. Existing conductivity cells were extremely unreliable due to faulty internal sealing against water. They have since been modified and now give no trouble.

A dissolved oxygen meter for monitoring the mixed bed units and the main demineralised water circuits was constructed in the Laboratory. This meter is based on an existing dissolved oxygen meter and has an electrolytic calibration unit.

10.4.3 Demineralised Water Storage Header Tanks

Five 1000 gal and one 500 gal mild steel tanks provide a static head of some 18 lb/in2 on the whole demineralised water system. After a few months of operation three tanks were opened up because of leakage at the inspection hole flanges between the mild steel shell and the P.V.C. lining. The linings were found to be badly split, several sections having fallen away. It was considered that failure was due to physical, not chemical causes - bad bonding and operational thermal stress. The water temperature at no time exceeded 100°F but the coefficient of linear expansion of P.V.C. is some eight times that of mild steel. The strength of the P.V.C. welds on the lining was high and no failure occurred on them. This failure resulted in a large rise in the demineralised water conductivity.

Investigation of suitable tank linings led to the adoption of a vulcanised neoprene. After the tanks were lined, they were acid treated with boiling 5% sulphuric acid followed by alkali treatment with boiling 5% sodium hydroxide. The 500 gal tank was filled with water from the Permutit plant at a conductivity of 0.8 μmho/cm and after standing for four days, this increased to 1.4 μ mho/cm. Subsequent inspection after six months use showed that the linings were in good condition but inspection of two tanks after twelve months revealed defects. Repairs were effected and inspection will again be necessary after a further nine months.

Modifications to the method of filling and control of level in these tanks were necessary. The original design was based on constant topping up and overflow but for better use of the Permutit plant, the tanks are now filled through the mixed bed units to a set level; the Permutit column is then available for other duties. A simple visual sight glass has been installed on each tank and it is an operator's responsibility to observe the level a few times a day to check against system leaks. An alarm system was fitted, using a bellows switch, to warn of a leak occurring in any demineralised system by registering the rate at which tank levels dropped compared with a predetermined maximum. With the differential heads available to register a small flow, the setting of this switch was difficult and, since it was possible to damage the bellows by excess pressure on filling the tanks if certain isolating valves were not closed, the use of this device was discontinued. Experience will dictate whether an automatic alarm system should be reconsidered.

10.5 Water Distribution System

All water systems are commissioned but modifications are continually being made to suit various experimental conditions. The greatest trouble, and not an uncommon one with these systems, has been the filtration of constructional debris. To counter this, all new pipework is fitted under scrupulously clean conditions with careful supervision. It takes many months to clean up a new closed loop circuit, which has been installed under normal constructional conditions, to a standard where in-line filters are little needed. Debris in the system (concrete dust, spelter, bitumen, metal chips, etc.) does not necessarily worsen the conductivity of the water.

One problem has arisen because the whole demineralised water system is made from copper pipe. On the machine itself only pure aluminium is used for the water systems because of radiation problems. The copper ions in the water can react unfavourably with the aluminium and sacrificial aluminium pipes have been fitted in the external feed pipes to the machine in the hope that this pipework will bear the brunt of corrosion. As corrosion can occur in a random manner consideration is now being given to the fitting of small ion exchange columns in place of the sacrificial pipes, to take out the copper ions from the water entering the machine.

With the raw water distribution system it is physically impracticable to filter out the fine debris that is deposited by the scrubbing action of the cooling towers. The raw water to the magnet and injector rooms is fine filtered to about 80 mesh and individual items of equipment are fitted with individual filters if necessary. Too low a margin on circulating water pump heads, limits the standard of filtration on raw and demineralised systems to the minimum necessary.

Corrosion problems exist in the water distribution systems due to differences in the anti-corrosion treatment of the pipe bores. Some sections of mild steel pipework containing cooling tower water are unprotected, much is bitumen coated and sections that have been welded 'in situ' are painted. The cooling tower pond water is slightly corrosive due to sulphates and chlorides from the make-up water and the high chloride content may attack the small section galvanized pipework. The use of inhibitors is not practical in this installation and a large bleed-off of pond water to reduce chloride levels would be too much for the effluent disposal facilities and the site water supply. Corrosion of pipework is being carefully watched.

The ebonite foam insulation for the pole face winding chilled water system was found to be releasing hydrogen sulphide. Since concentrations of 50 parts/million were measured in the magnet room, the insulation was encased with impermeable material, to prevent possible effects on personnel and electrical contacts.

Chilling units are used for various systems on the machine. The steel tanks containing demineralised water were painted with an epoxy paint which blistered. The relative inaccessibility of some of these units for repair work led to their rubber lining being scrapped and the tanks were reconstructed in copper. Corrosion of the tinned copper refrigerant coils was experienced on one unit and the cause attributed to attack by cement dust before the unit was put into commission. After thorough mechanical cleaning no further corrosion has occurred.

10.6 Air Conditioning Plant House

10.6.1 Air conditioning Plant

This plant, shown schematically in Fig.10.6.1(i), provides conditioned air for the magnet and injector rooms; nominally at 65°F ± 2°F and at a specified relative humidity of 60%. It consists of two self-contained air conditioning sets, one acting as a master to the other. Each set has a refrigerator plant with a refrigerant capacity of 120 ton and a flow and extract fan capable of 51,000 ft^3/min air flow. The two sets can be run together or singly and, with reservations, at half capacity. The refrigerant plant chills demineralised water to about 40°F which is stored in an insulated steel tank. Chilled water is supplied from this tank to the injector room subsidiary air conditioning plant and to the cooling batteries of the main air conditioning plant.

Air is extracted from the magnet room by an extract fan discharging 10% of the air and taking in 10% fresh air as make-up. The air then passes over a heat exchanger where chilled water precipitates moisture. The required temperature is then re-established by passing the air over a steam heater. Filters are installed to filter the incoming air and the re-circulated air.

Slight instability of the temperature control system occurred on commissioning, which adjustment of the control equipment did not eliminate. The fault was traced to excessive backlash and lost motion in the steam control valves giving rise to a relatively long delay in response between the two sets.

Vibration is often a problem on reciprocating and rotary plant. On the compressors in the refrigerator plant repeated failures of small bore copper pipes forming part of the system unloading the cylinder heads, occurred on change from full to half load, or vice versa. Changing to thicker gauge Tungum cured the problem. (It is pertinent to report that a large number of failures of small pipes have occurred due to the use of copper which is often insufficiently annealed. Tungum is a much better substitute). Flutter of a metal dividing plate in the steel air ducting to the fans necessitated some stiffening. Vibration also caused the pipework from one compressor set to crack at the weld neck of an oil separator when the compressor was on half load. A change of pipe support has lessened the severity of vibration but further investigation may be necessary.

10.6.1(a) Capacity of the Plant. Two full scale heat balance trials have been conducted to check that the plant meets the specification. It is reasonably clear that the heater bank and fans are satisfactory but the cooler bank is of insufficient capacity. It is possible to hold 65°F air inlet temperature for the relatively short time that the magnet has been pulsed at maximum load but it has, as yet, been impossible to check for a long period. The specified relative humidity of 60% is not met. Although this may not in itself be important at the higher air inlet temperatures, it is hoped to achieve an inlet temperature of 60°F (63°F has been achieved) when the margin between the wet bulb temperature and the dew point will be much smaller. It is relatively easy to increase the performance of the cooler bank but if the refrigerator plant proves incapable of meeting a high sustained load, it may be difficult to improve its performance. The matter is now being considered by outside consultants.

10.6.1(b) Temperature control. An investigation has been made into what parameters could practicably be used to control the air inlet temperature to the magnet room under various load conditions. Calculations relating the differential temperature gradient between the top and bottom surfaces of the magnet room concrete monolith with tilt of the magnets have established the required relationship between air inlet temperature and magnet load to restrict the tilt to acceptable

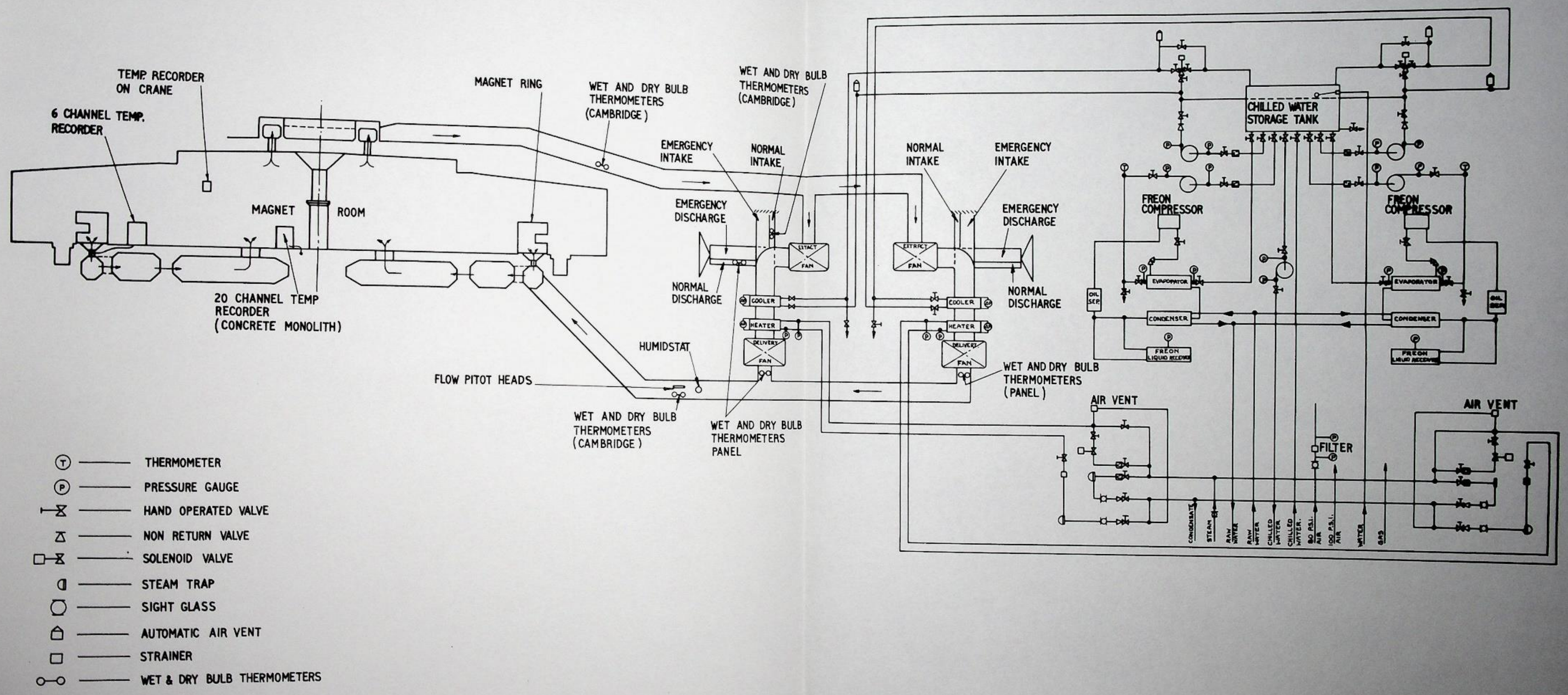


Fig. 10.6.1(i) Air Conditioning System.

limits (0.0035 in over the 120 in width of the magnet). Remote recording tilt meters positioned on top of the magnets have been considered but as these would require considerable development, simple spirit levels will be used. The thermal inertias of the magnet room structure are large, therefore periodic visual checks of these levels will be adequate.

10.6.2 Chilled Water Storage Tank

This galvanised steel tank was initially filled with untreated mains water. The tank carries mild steel pipework and heat exchangers of brass and copper. Considerable corrosion of the mild steel parts of the tank resulted in filter blockage.

Tests conducted to find the most suitable corrosion inhibitor included adding: (i) 10 parts/million calgon (ii) an alkali (iii) 0.5% sodium chromate at pH 8. After thoroughly cleaning the system, the circuit was flushed and filled with mains water containing 0.25% sodium chromate at pH 8.5-9.0, and the suspended solid content reduced from 8 to 1 part/million by the use of 7 thou. filters in circuit.

The inhibitor has reduced corrosion but to reduce it further it is intended to provide means of filling the system with demineralised water.

10.7 Air Distribution System

Air from the air conditioning plant is supplied to the magnet room via an underground tunnel to an annular space which is located underneath the magnet ring. A proportion of the air is then passed through stack pipes and carried up in between the magnet sectors where it absorbs heat. The remaining air is distributed into the cavities within the magnet monolith, the mass flow of air to each cavity being proportioned according to the heat output of the installed equipment. This air then passes into the magnet room via 4 ft diameter holes in the ceiling of each inner cavity. Air is returned to the plant room via a tunnel running from an annular duct in the roof of the magnet room.

Attention has been given to the cleanliness of these air ducts in which a considerable amount of dust was precipitated, particularly where a thin cement had been floated on the base concrete, and was carried into the magnet room. The concrete was treated with 'Lithurin' and the ducts are periodically cleaned with a vacuum cleaner. Water leaks at subsidence joints required attention.

The return duct from the magnet room roof has a steep slope of about 1 in 4, which requires a 'life-line' rope to assist ascent and descent, particularly when air is flowing.

The design of the ducts gives rise to relatively high aerodynamic losses since large areas of re-circulation occur, reducing the effective flow area. It is considered, as with the water systems, that the capacity of the air conditioning plant may be marginal and therefore some attention will be given to simple streamlining in certain parts of these ducts to improve, however little, the total head pressure delivered and hence the volumetric flow.

The proportion of air fed to the magnets and to the cavities has been determined experimentally, using anemometers to measure flow. More equipment has been installed in the cavities since this work was done, which has increased resistance to flow and, more significantly, requires the flow in the cavities to be reapportioned to suit the new heat loads. Some doubt exists as to the validity of the early measurement because of strong circulations in the cable ducts between the cavities and the magnet room. The magnet room pressure will also change when the shielding bridge is completed. To assist in circulating air through the cavities and out into the magnet room, all ducts not required for air flow have been blanked off and extract fans installed in the 4 ft outlet holes. As might be expected recirculation occurred around these fans and they now are being adequately ducted. A recheck of the air distribution and a re-setting of controlling dampers will be done at the first available opportunity.

10.8 Injector Room

10.8.1 Injector Cooling System

Heat is transferred from injector components to demineralised water and then, vi a local cooling plant within the injector room, to the Nimrod raw water system. The raw water plant incorporates the cooling towers and the water softening plant. The raw water is fed back to the local cooling plant at 80°F maximum.

The major portion of the injector cooling plant is situated in the south east area of the injector room, and occupies a floor area of about 260 ft^2. A platform over this area is provided for non-rotating components of the plant and flush panelling with an entry door forms a neat screen around the area. The components to be cooled are grouped into one of four circuits according to the operating temperature as follows:-

Circuit 1: vacuum diffusion pumps (upper circuit) and liquid air machines. (See Fig.10.8.1(i))

A total of 26 kW of heat can be extracted, raising the demineralised water temperature to 50°F. This is then cooled and returned by the plant at 40°F ± 3°F and 15 gal/min flow (89,000 Btu/h).

Circuit 2: r.f. liner, drift tube shells, buncher, debuncher, S.A.M.E.S. EHT set and r.f. modulator. (See Fig.10.8.1(ii))

A total of 8 kW of heat can be extracted, raising the demineralised water temperature to 70°F. This is then cooled and returned by the plant at 68°F ± 1°F and 23 gal/min flow (27,360 Btu/h).

Circuit 3: drift tube quadrupole magnets, external quadrupole magnets, steering magnets and inflector system magnets.

A total of 270 kW of heat can be extracted, raising the demineralised water temperature to 108°F. This is then cooled and returned by the plant at 90°F ± 2°F and 85 gal/min flow (920,000 Btu/h).

Circuit 4: high vacuum pump (lower half circuit), targets, roughing pumps and four - jaw boxes.

A total of 30 kW of heat can be extracted, raising the demineralised water temperature to 100°F. This is then cooled and returned by the plant at 90°F maximum, and 17 gal/min flow (102,500 Btu/h).

Circuits 1 and 2 are provided with refrigerated circuits between the demineralised water and raw water circuits. Circuits 1 and 2 are functioning correctly and were up to specification, but an increase in the number of liquid air units on Circuit 1 increased the load above the capacity of the plant. A Thames Valley Unit was installed to cope with the liquid air units and the vacuum pump circuit left on the existing plant.

Circuit 2 is controlled to 68°F ± 1°F. The control of the refrigeration plant is as close as possible and, although the tolerance of ±1°F is achieved, there is too high a frequency of oscillation of temperature within this tolerance band. It is intended to increase the thermal inertia of the temperature controlled water system by installing a heat sink in the form of a large sealed tank in the supply line. Lack of thermal inertia is a fault common to all circuits of the plant: it results in frequent stop and start conditions and has made the optimum setting of the control systems difficult. To protect the plant the installation of similar heat sinks will be considered.

Circuits 3 and 4 use one heat exchanger between the demineralised water and raw water circuits, with a temperature controlled mixing valve to by-pass the heat exchanger (on the demineralised water side) as necessary. The heat exchanger for circuits 3 and 4 is of sufficient capacity for a 30% increase in duty.

When tested, the water/water heat exchanger serving both circuits 3 & 4 cooled the demineralised water to within $\frac{1}{2}$°F of 90°F. If fouling resistance of the heat exchangers was taken into account this was 3°F from design point and did not allow for the specified 30% overload capacity. The low performance was attributed to the fact that the drainage notches at the bottom of internal baffles in the heat exchanger were machined too large and hence too much water was by-passed along the internal nest of tubes instead of across them. An additional heat exchanger was installed in parallel with the existing one to make good this 30% deficiency.

All circuits have water pumps for recirculating the demineralised water. A stand-by pump is provided in parallel, with suitable valves, so that maintenance does not interfere with the use of the plant. Similarly, refrigerator compressors and motors are duplicated. Materials throughout the demineralised water circuits are substantially zinc-free.

Copper pipework from the circuits of the cooling plant is run in the floor services trenches, and terminates in valves at appropriate points near the items to be cooled. Flow switches and thermistors are also included, and these, together with automatic monitoring equipment installed in the local control room, permit continuous observation of flows and temperatures in the various cooling circuits. High pressure hoses and fittings and self sealing couplings make the final connections between the copper pipes and the equipment to be cooled.

R.F. Valve Cooling Circuit A separate, free standing cooling unit is used to supply very high purity demineralised cooling water to the last two r.f. valves in the power drive chain, removing about 20 kW (70,000 Btu/h). An insulated, copper tank of 400 gal capacity contains demineralised water and immersed evaporator coils. Refrigerator compressors, condensors and control gear are mounted over the lid of the tank; valves, motors, pumps, level alarm units, etc., are attached to the tank side. Two motor-pump sets for the circulation of demineralised water to the r.f. valve circuits are provided in parallel, one set being used as standby during maintenance periods. Each pump is capable of delivering 8 gal/min against 52 ft head and the temperature of the cooling water supplied to the r.f. valves is closely maintained at 68°F. Raw water from the Nimrod circuit is supplied to a manifold connected to the condensors of the refrigerating system. Two full flow ion exchange columns (in parallel) are interposed in the demineralised water circuit between the circulating pumps and the r.f. valve lines, with stop valves, flowmeter, sampling points, purity indicator, flow switches and temperature and pressure measuring devices. Indication of purity and of absolute temperature of the cooling water is available in the injector control room. For maintenance and for recharge of resin, one ion exchange column can be removed at a time without interrupting the use of the circuit. Typical analysis results show a conductivity of 1.2 μ mho/cm and 6.8 pH value.

One problem (occurring far too frequently on the cooling circuits) was the inadequacy of instrumentation, or provision for instrumentation, to display local

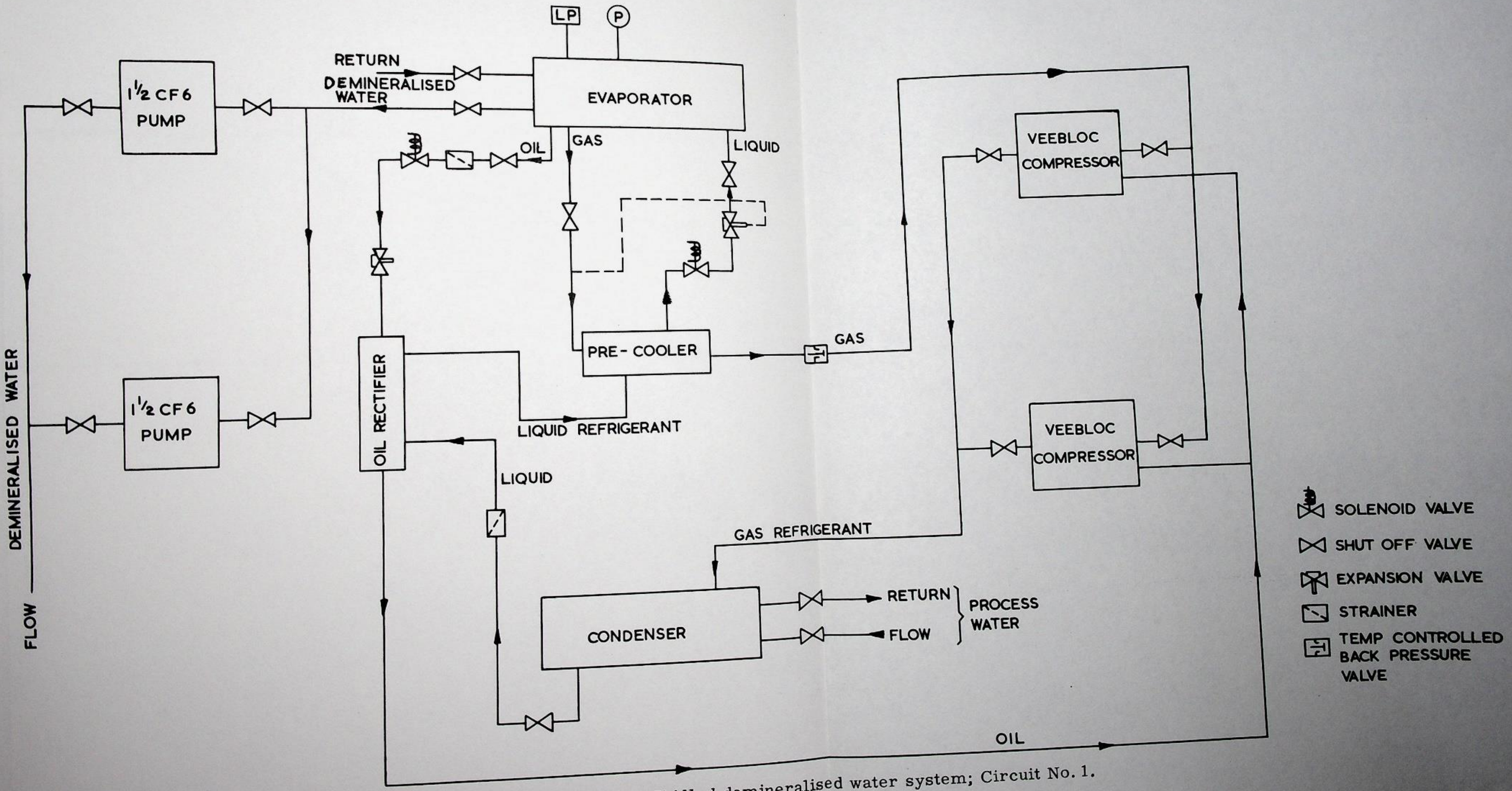


Fig. 10.8.1(i) Chilled demineralised water system; Circuit No. 1.

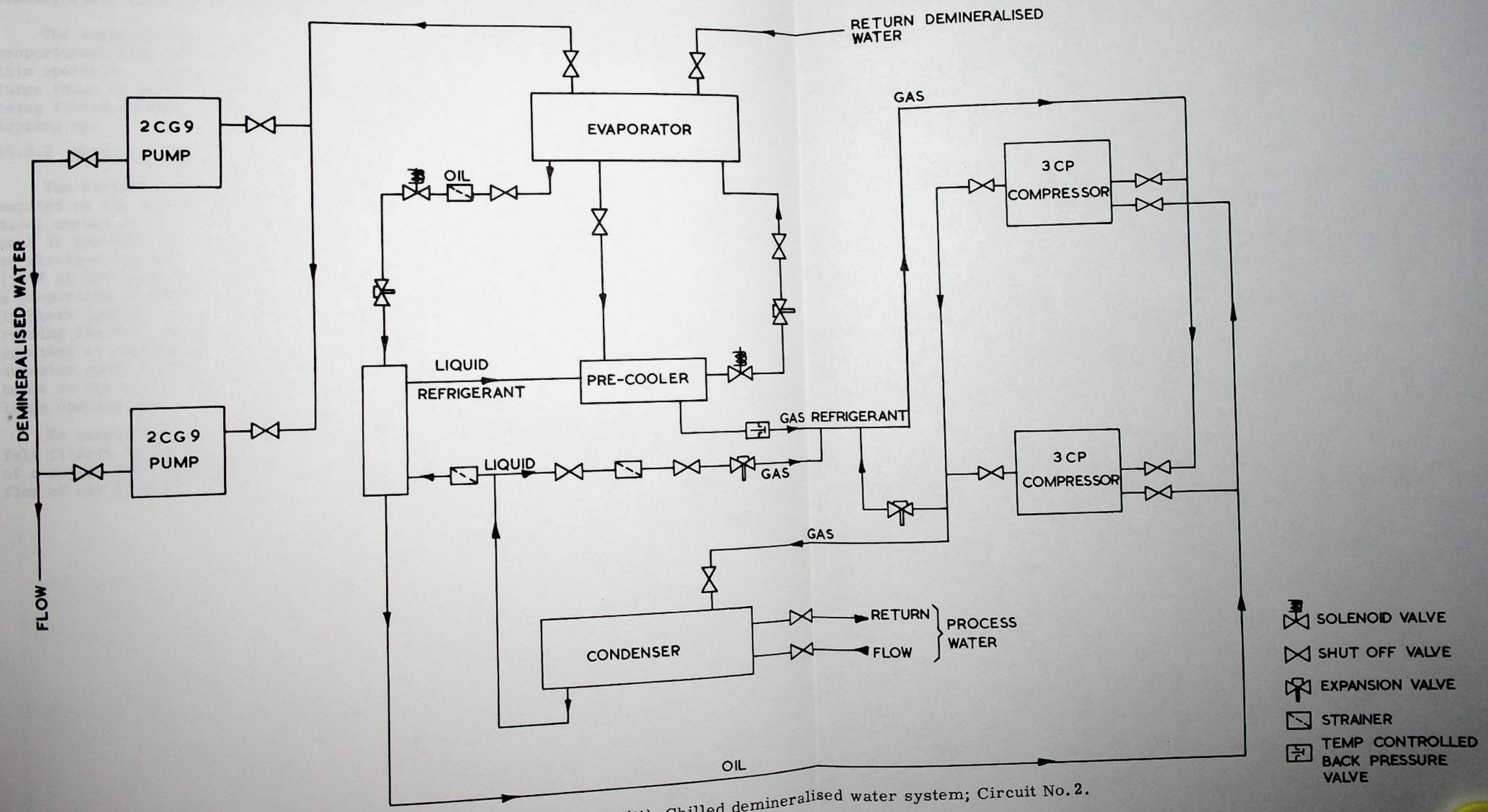


Fig. 10.8.1(ii) Chilled demineralised water system; Circuit No. 2.

conditions and assist in assessing performance or in fault finding. Once equipment is in operation it is often difficult to find time to fit missing instrumentation. It must be strongly emphasised that provision for instrumentation, by T pieces, bosses, etc., should be generous.

The conductivity of each circuit was designed to be controlled by a proportional flow through the Permutit plant. Experience has shown that in attempting this operation, temperature control of each circuit becomes impossible due to the large input of water at an uncontrolled temperature. Small ion exchange columns are being fitted to each circuit and the Permutit plant will only normally be used for topping up.

10.8.2 Injector Room Ventilation

Two similar sets of equipment are provided for ventilation purposes, one mounted on the north wall and the other on the south wall of the injector room. The total amount of heat to be extracted is estimated as 130 kW maximum. On each circuit, heat is removed from the injector room by means of an axial flow fan drawing air over an air-to-water heat exchanger which is connected to the Nimrod chilled water supply (50°F at the injector room). This air (5,500 ft^3/min on each circuit) is mixed with a proportion of warmed air 2,500 ft^3/min each circuit) drawn from the magnet room and is blown down an aluminium distribution duct mounted beneath the crane corbel and running the full length of the injector room. A supporting platform for each set is provided at high level, close to the curtain wall between the magnet room and injector room, so that air from the magnet room can be conveniently drawn in through holes in the wall. A small proportion of air returns to the magnet room through the large opening under the curtain wall.

No commissioning problems have arisen on this plant, other than the need to fit felt filters to the air inlet of the air to water heat exchangers. The installation of a shield wall between the magnet and injector rooms has seriously impeded the flow of air from the injector room and hence the mean temperature tends to rise.

10.9 R.F. Chilling Equipment

This plant is designed to control the temperature of the ferrite in the accelerator unit of the r.f. cavity to a mean temperature of 77°F. The equipment comprises a triple compressor refrigerator unit capable of handling 218,000 Btu/h. The refrigerant is Freon 12 and the primary coolant is transformer oil. The condensors are water cooled. A schematic diagram of the equipment is shown in Fig.10.9(i).

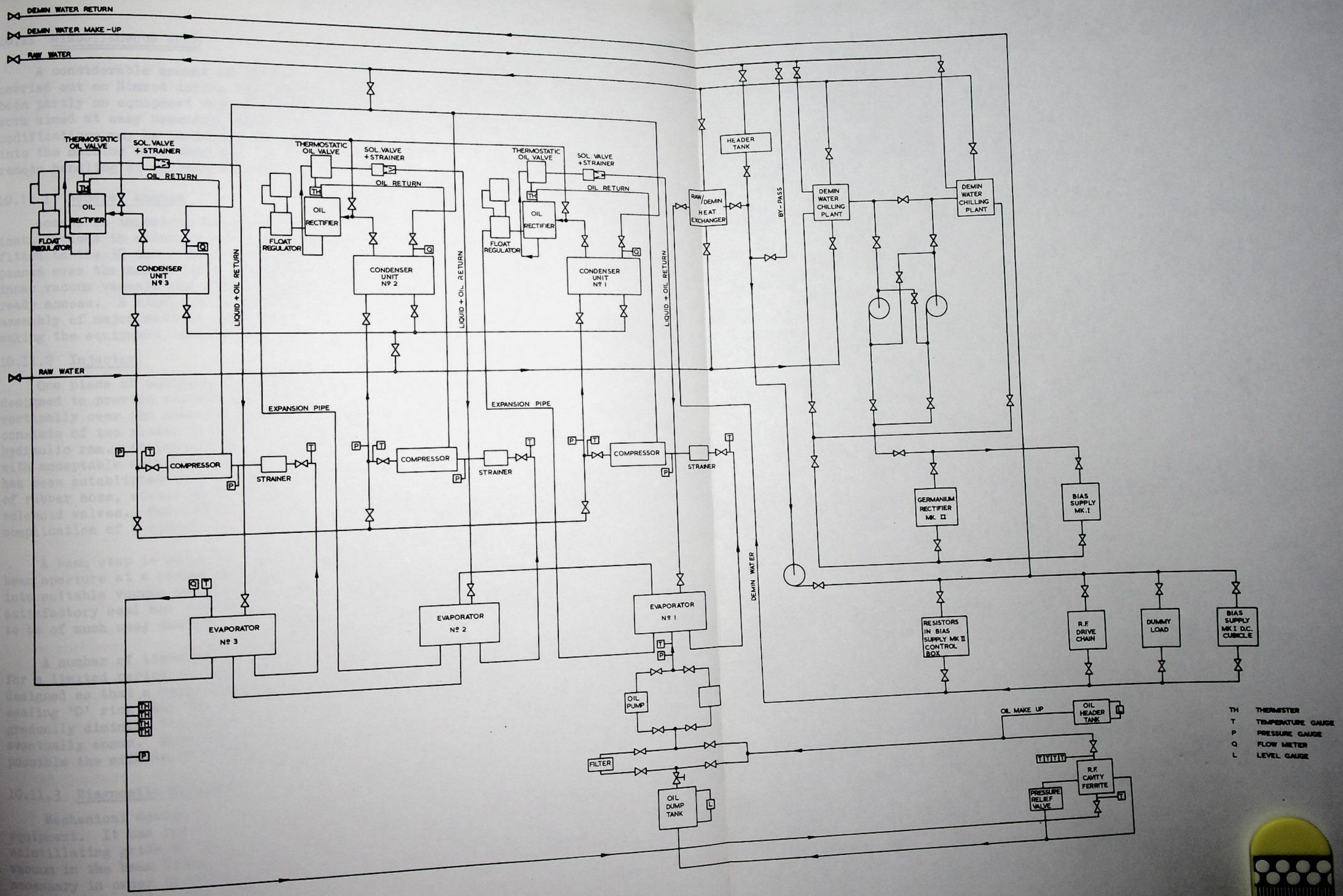
The refrigeration plant was commissioned with little trouble. Minor modifications have been made to both water and oil systems to obviate the need for venting these systems of air on start up. The main changes have been raising the make-up header tanks of each system, increasing the size of the main oil sump and providing means whereby oil from the sump can be pumped to the header tank (this provides a facility for priming the main circulating pump).

The oil pumps, dump tank, and evaporators are housed in a fire proof box within outer cavern No. 8. Since a CO_2 fire extinguishing system is installed it is imperative that, if it is used, no CO_2 should be allowed to seep indiscriminately into other caverns or service ducts. With a sealed box a complete discharge of CO_2 will raise the internal pressure one atmosphere; therefore a vent system is required to allow a displacement of the encased air. A scheme for this is in hand.

10.10 Sumps and Tunnels

The main problem here has been to provide automatic priming of the sump pumps. For various reasons, such as faulty foot valves and header tanks of insufficient capacity, no pumps installed were completely satisfactory. In two instances it was possible to fit fully submersible pumps but elsewhere work continues on improving the automatic pumping systems.

With the exception of one cable tunnel, all service tunnels are vented naturally. With the future use of heavy gases for experimental work (e.g. propane) the ventilation of these tunnels is being reconsidered since they are all at the same height as, or lower than, the experimental area.



i . 10.9(i) R.F. Chilling Equipment.

10.11 Miscellaneous Work

A considerable amount of detailed development of a mechanical nature has been carried out on Nimrod during the constructional and commissioning phase. This has been partly on equipment designed as part of the diagnostic system but mainly on work aimed at easy assembly, easy maintenance and improved reliability. Further modifications may be necessary to assist mechanical handling, due to limited access into the machine area when the shield wall is closed and due to the future need for remote handling of certain equipment.

10.11.1 General Access

Access is important since it is undesirable to dismantle experimental installations in order to service the machine. A 5 ton hoist and crab is being fitted to the 30 ton radial crane in the magnet room to enable bulky equipment to be passed over the magnet by utilizing the space between the crane girder frames. Spare inner vacuum vessels and poleface windings are stored within the magnet ring for ready access. A study is in hand to rationalise the equipment used for handling and assembly of major machine components by making as many items as possible common and by making the equipment demountable.

10.11.2 Injector

One piece of equipment requiring development is the 'four-jaw box', a device designed to provide variable dimension slits that can be traversed horizontally or vertically over the cross section of the beam. It is used to set up the beam and consists of two plates located edge on in a common slide, each actuated by a hydraulic ram. At present it is not possible to inch these plates across an aperture with acceptable accuracy and repeatability. The control system is open loop and it has been established that error is caused by hysteresis effects due to the flexibility of rubber hose, strain energy imparted to rubber piston seals and leaks across solenoid valves. Some significant improvement is possible without resorting to the complication of a closed loop system.

A beam stop is under development which is designed to plunge a plate across the beam aperture at a predetermined repetition rate. This has led to an investigation into suitable vacuum seals for reciprocating motion. Although a reasonably satisfactory seal has evolved, wear may reduce its effectiveness too rapidly for it to be of much use; therefore an alternative scheme for a rotary beam stop is in hand.

A number of items of equipment have been modified to make them work, if only for a limited period of time. As an example, one or two vacuum gate valves are designed so that a beryllium copper, leaf spring biases the valve gate away from the sealing 'O' ring when the valve is being actuated. Fatigue of this spring will gradually diminish the clearance between the gate and 'O' ring and damage will eventually ensue. Such designs are being critically examined to obviate as far as possible the effects of fatigue or wear.

10.11.3 Diagnostic Equipment

Mechanical design was undertaken within the Laboratory on most of this equipment. It has led to development work on three aspects - glass windows to allow scintillating grids in the vacuum vessel to be observed, thin diaphrams to withstand vacuum in the beam lines, and reciprocating seals. Windows, 11½ in by 38½ in were necessary in order to obtain an adequate field of view when observing the scintillating grids. The stress levels set up by the differential pressure of 14.7 lb/in^2 necessitated the use of two ½ in thick layers of toughened glass bonded together by polyvinyl butyral. Each layer is capable of taking the load imposed, but rudence dictated two layers in case one became damaged. These windows were horoughly tested in single and double layer form up to 75 lb/in^2. When the window as bolted into its carrier frame stress concentrations were found to be satisfactory y subjecting the assembly to photo-elastic stress analysis. The lifetime of these indows will be limited due to radiation and consideration is being given to the possibility of using a cerium stabilised glass.

Thin "windows" are required in certain beam lines to maintain vacuum when the line downstream is at atmospheric pressure. The material used must conform to certain physical requirements, three materials being suitable; aluminium, stainless steel and terylene (Melenix or Mylar). Investigation of the bursting pressure, fatigue and creep properties is being made with various thicknesses of window. A suitable method of supporting the windows has been evolved and tests on Melenix materials has progressed to the stage when installation of 4½ in diameter windows in beam pipes is now possible with some degree of confidence when using 0.015 in thick material. Testing of rectangular windows is now in hand and a report will be issued to cover this work.

A reasonably satisfactory seal has been developed for the plunging mechanisms which employ vacuum seals subjected to reciprocating motion. The mechanism reciprocates at the rate of 0.7 s per stroke for 7 GeV conditions. At the higher rate of 0.2 s per stroke for 2 GeV conditions the seal may not hold vacuum and in both cases it is considered that wear will be unacceptably high. The same conditions apply to the plunging beam stop used in the injector HEDS. A small rig is being used to develop this type of seal and it is hoped that by use of a suitable labyrinth seal, a reasonable life can be obtained without the need for inter-space vacuum pumping. A larger rig is being planned for further development.

10.11.4 Remote Handling

Work is in hand on the design of equipment for handling radioactive equipment. A mechanism has been manufactured that will allow the installation of a target into the machine without letting up the vacuum and a simple test rig is being constructed to prove this equipment without using the machine itself. An investigation is in hand on the methods of transporting this target from the machine to a 'hot' store yet to be designed. A suitable lead coffin has been designed.

A critical investigation is necessary throughout the machine to ascertain what equipment can be modified in detail to allow rapid installation or withdrawal, what materials need be changed to reduce the effect of radiation and what assemblies require duplicating to reduce the time taken for component replacement.

Methods of checking the radiation dosage for oils have been reported in private communication from the Research Department of Castrol Ltd. A check will be kept of the radiation dose received by the lubricating oils actuating plunging and target mechanisms since tests have shown that relatively low doses will cause the evolution of hydrogen in the oil, giving rise to spongy or erratic control.

10.12 Records Office, Storage and Workshop

10.12.1 Records Office

Operationally, much importance must be placed on the need for an efficient Records Office. Such an office has been set up for Nimrod to deal with planning and progressing of work, acquisition of equipment and spares, planned maintenance, running plant store and clerical duties of a technical nature.

The build, and change of build, of Nimrod is being controlled by collating in index form all relevant information, such as construction schedules, drawings, build instructions, test instructions etc. into log books covering various specified parts of the machine. From this information it is possible to rationalise the acquisition and storage of spares and miscellaneous equipment and it serves to record for posterity various build standards of the machine or associated equipment.

10.12.2 Storage

Some 7,000 ft^2 of heated store has been allocated for storage of equipment for Nimrod. It is essential to know exactly what spares and equipment exist and where they are available. It must also be made easy to obtain such equipment at all hours of the day and a suitable system has been devised so that, in emergency, relevant equipment can be obtained promptly. Equipment that is stored in unheated premises, is suitable treated against corrosion and then put on a care and maintenance basis. Some equipment is cocooned and some held in zip-up moisture proof containers. The value of certain materials and the difficulty of obtaining some materials for Nimrod has made necessary a small bonded store. A scheme is in hand for building a small 'hot' store to take targets and machine parts that become radio-active.

10.12.3 Test Area

A small area has been set aside as a mechanical test laboratory. Much ancillary equipment requires a brief functional check after overhauling before it is re-installed, and there is always a steady load of this work applicable to the machine. One item of equipment that has been constructed is a water flow test rig capable of dealing with up to 30 gal/min at pressures up to 150 lb/in^2 and with a variable temperature control of the circulating water. Another rig that has been constructed and found most valuable, is a portable unit designed for cleaning up any demineralised water system or equipment so that the conductivity of the treated water is brought down to an acceptable level before the main circulating demineralised water system is connected.

10.12.4 Workshop

A local workshop has been set up to deal with day to day maintenance and with the development work for Nimrod. General purpose machine tools have been installed but no equipment requiring specialised skills has been bought, since it is considered more appropriate to do such work in the main Laboratory workshop or by external contractor. It is, however, essential for the class of work required in the Laboratory, that welding equipment of high quality, capable of dealing with stainless steels and aluminium be readily available.

The potential work load of such a local workshop is high and care must be taken at all times to provide the capacity to deal with any emergency.