Diesel Engine Power for Microwave Relay Stations

by R. A. Ford
A.M. Inst. B.E.

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P R E F A C E

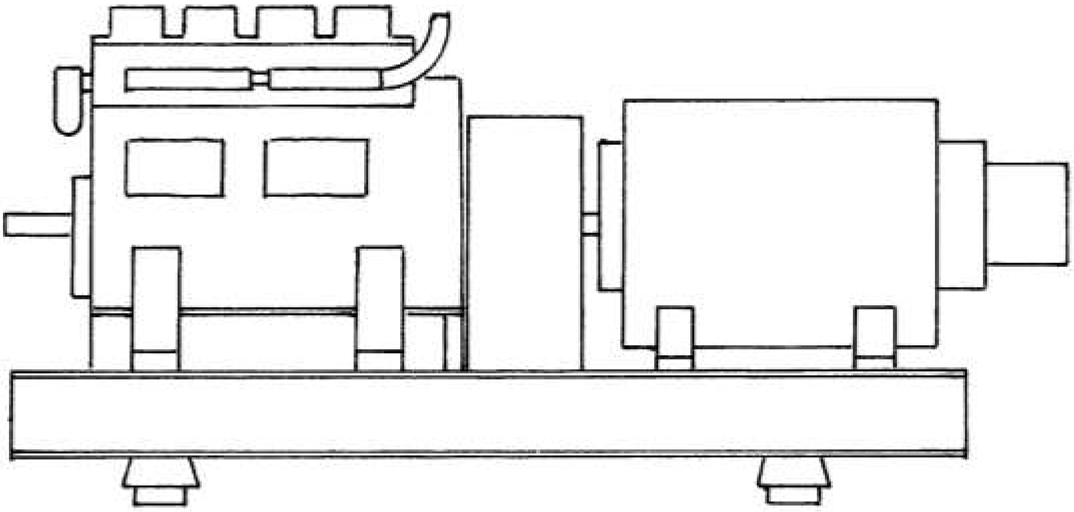
In the early 1930's progressive manufacturers of radio communications equipment were beginning to explore the possibilities and problems of using the higher frequency ranges to provide a system of transmitting and receiving messages. Their work evolved into a complete new science from which has grown the industry of Microwave radio.

A microwave radio network today is an extremely complex system that carries not only voice communications, but teleprinter circuits, television channels and computor data. On a small scale, it may serve the demands of an operator such as an oil company or railway system - on a larger scale, it may serve a whole nation and tie in with a great international and world wide system.

Intrinsically, the distance over which a high frequency radio signal may be transmitted and received is limited - normally to a line of sight path with an average distance of about 45 miles. In areas where the distance between two terminal stations is too great to fall within this limitation a repeater station is installed to provide an efficient path.

Frequently, these repeater stations have to be situated in remote isolated sites where no power supply is available and the need arises to provide a small self-contained and efficient generating station. These prime power sources, by virtue of their very existence, are required to be reliable and able to operate unattended for extended periods of time.

Hand in hand with the ever increasing complexity and sophistication of the modern radio relay station has gone the demand for more reliable and efficient methods of providing electrical energy.



DIESEL ALTERNATOR SET ON

FABRICATED STEEL BASE

Chapter One.

THE APPLICATION OF DIESEL POWER.

The importance of any telecommunications system is such that due consideration must be given to every aspect of its component parts, not the least of which is an efficient and reliable source of electrical power. The project engineer asked to design equipment that is to be an integral part of a telecommunications network has an important function to perform in providing this power and will require considerable information on which to base his proposal. The radio engineer, in his turn, is obliged to provide as much information as he has at his disposal and this should be at all times both specific and accurate.

Let us consider a simple brief that calls for power equipment for a single radio station. The project engineer will require information in detail on as many of the following aspects as possible:-

1. Geographic location including height above sea level and relative humidity. Accessibility of the proposed site and any restricting factors in regard to weight that may be transported.
2. Ambient temperature at the site.

3. Power requirements and type of load, permissable tolerances of Voltage, Frequency, Cyclic Variation and Waveform. Is the equipment to be Standby to mains or prime power source? Is no-break power required? Is any form of electrical power available at the site - how reliable is it?
4. Is the estimated loading of the equipment likely to be increased?
5. Is an existing building to be used - is an engine room design required? Is the radio equipment situated adjacent to the engine room or is transmission of the electrical energy required?
6. Availability of local fuel and lubricant types? Are any fuel storage facilities available?
7. Is the site to be attended by maintenance personnel? How remote and what is the quality of the staff?
8. Are any preferences given in regard to the proposed equipment generally? Are any special facilities such as remote signalling required?
9. Any other relevant facts.

Before we examine in greater detail the various technical implications of the foregoing we may use the above guidelines to prepare a specific example to assist our understanding of the problems.

The brief then, as presented to the power engineer might appear in this form:-

" Specification for one Standby to Mains Station located in Quito, Ecuador.

The station is to provide standby power for one Microwave Multi-Channel VHF station.

The station is located on a hill on the outskirts of the city and accessable by paved road. It is an addition to an existing system where adequate space is available adjoining the radio room. A fuel storage tank of one thousand litres capacity is located on the outside of the building and may be piped into the new installation. The fuel currently in use conforms to BSS 2869; 1957 Class A. This station is attended by fully-trained diesel fitters and electricians.

The incoming mains supply is 120/208 volts three phase four wire at 60 hz., the supply is reliable and free from transients.

The site conditions are as follows:- Altitude above sea level 10,800 ft., ambient temperatures: maximum 38 degrees C. to minimum minus 5 degrees C., humidity 80%.

As the engine room is situated adjacent to a wooded area, adequate precautions in exhaust spark arresting must be made.

Preference should be given to conform to equipment currently in use on this system to avoid duplication of spare parts. The proposed equipment should include Lister series HA engines direct coupled to Transicon generators.

Power requirements: Eight KVA at .8 power factor, 120/208 volts 3 phase 4 wire, 60 Hz.

An electrical control panel should be provided with mechanical and electrical interlocks.

Provision should be made for charging the engine starter batteries and the following alarm functions with remote signalling contacts should be included:- engine fail to start; engine under and overspeed; voltage out of limits; frequency out of limits; oil pressure low and engine temperature high. In addition, an engine over-run circuit should be included to permit the engine to continue to run for an adjustable period of up to fifteen minutes after mains restoration. "

The above example is not too rigidly defined and the power engineer is at liberty to draw on his experience and imagination to design an equipment that will satisfy the various aspects of the brief. During the course of events the specification will be modified and amended as circumstances dictate and last minute changes and additions may be made as late as final testing on the shop floor. A successful project is one in which installation and commissioning are carried out with the minimum of problems and where efficient and trouble-free performance follow. Close liaison, not only between the relevent departments of engineering, but with the ultimate customer are essential to achieve these ends.

Power equipment for telecommunications systems falls into two basic categories, Standby Power and Prime Power. In addition, the refinement of no-break power is called upon where breaks of even a few milli-seconds can not be tolerated. Standby Power is defined as being a supply available to take over the station load in the event of a total or partial failure in the prime power - normally the public mains supply. The equipment is arranged to start up automatically when such a failure occurs and, by way of suitable circuitry and contactors, connect itself to the load until the prime supply returns in an acceptable and stabilised form. The control panel for such an equipment would contain voltage and frequency sensing circuits which detect variations in the incoming supply. If these variations fall outside pre-determined limits - say, 2½% of nominal - the main supply contactor would de-energise and disconnect the supply from the load and at the same time initiate a start circuit to the engine. The engine would be cranked and run up to speed and, if its alarm conditions were normal, the plant contactor would close under the influence of the generator output and connect the plant to the load. A well-maintained diesel alternator set may be expected to reach stabilised generating conditions within six seconds or less. The standby set will now run and continue to supply the load until, (a) the mains supply returns to within the accepted limits and is restored to the load with the diesel shutting down after a suitable cooling off and stabilisation period, or (b) until the diesel develops a fault and shuts itself down on an automatic alarm failure circuit. In this condition a total power failure will exist. In situations where the mains supply is known to be extremely unreliable - and where heavy demands may be made on a single standby set - an additional engine may be installed for extra security. In this type of dual standby equipment both sets may be arranged to start up when a power failure occurs, the first up to speed and nominal output taking the load and - in conditions of prolonged power failure - subsequently sharing the load at 24 hourly intervals. In this situation one engine would shut down and remain at standby to the other until called upon to supply power either at a scheduled changeover time or when the other shut down under an alarm fault condition.

All equipments of this type are arranged to shut down and isolate themselves in the event of certain undesirable conditions developing. These fault conditions may be summarised as follows:-

Failure to Start. In the event of an engine failing to start before a predetermined time the start circuit is locked out and indicator lamp illuminated on the panel. Most modern control circuits provide a refinement that allows the starter three attempts to engage and crank the engine for about fifteen seconds before isolating and locking out the circuit.

Low Oil Pressure. In the event of the oil pressure dropping below an acceptable limit the engine is shut down and locked out of duty. An indicator lamp on the control panel records the condition.

Engine Temperature High. In the event of the engine temperature rising to an undesirable level the engine is shut down and locked out of duty. An indicator lamp on the control panel records the condition.

Engine Over/Underspeed. In the event of over or underspeed the engine will be shut down and locked out of duty. An indicator lamp on the control panel records the condition.

Electrical Faults. Sersing devices connected to the generator output continually monitor its voltage and frequency; in addition, an overload trip may be fitted to disconnect the generator from the load in the event of sustained overload. The operation of any of these fault circuits will result in the engine being shut down and locked out of duty. Relevant indicator lamps will record the condition on the control panel.

The above fault conditions, with the possible exception of engine temperature high, will be instantaneous in action and will shut down the engine immediately the malfunction occurs. In the case of high temperature where no immediate danger of damage to the engine exists, the equipment may be allowed to run on for a short period to allow a standby set to start up and assume the load. (If the rise in engine temperature is the result of excessive overload this short over-run period may be a definite advantage as it will permit the engine to cool down a little before coming to rest. It should be remembered that cylinder head temperatures rise considerably when a hot engine is stopped and, if excessive, could result in a cylinder head cracking.)

Prime Power Equipment. Prime power - or repeater stations - embody many of the features discussed above. The engines, generators and ancillary fittings may be very similar, if not identical. It is more usual for standby engines to run at higher speed than repeater engines - the former normally being rated at 1,500 to 1,600 RPM, the latter at 1,000 to 1,200 RPM depending on frequency requirements.

A repeater station may contain two or three diesel generator sets, in some isolated cases more, depending upon circumstances. As there is no public mains supply available at these sites one engine is required to run and supply power continuously while the others remain idle until called upon to run (a) in the event of the duty set expiring its duty run or (b) in the event of the duty set developing a fault.

In a dual repeater station the engines would be arranged to duty cycle for a time clock controlled period which might vary from 24 hours to seven days.

At the end of this period, the time clock would initiate a start to the standby engine and it would be cranked and run up to speed. After a suitable timed period to allow the output to stabilise within acceptable limits the load would be transferred from the duty set. The expiring set would either shut down or run on for a short period. (This run on period serves two functions (i) it remains available to re-assume the load if the incoming set is unable to carry it, and (ii) it allows for a short cooling period.) When the expiring set comes to rest it will remain on standby until called upon for further duty which - as in (a) and (b) above - will be at the termination of the duty cycle or when the current duty set develops a fault. The sequence of events in a triple or quadruple repeater would follow the same pattern.

As typical repeater stations are required to run for periods of long duration without attention, they are equipped with special features that are not applicable to standby stations. Details of long duration lubricating facilities and auto-transfer fuel tanks will be discussed at length in the next chapter.

When a fault does occur at a repeater site, the sequence of events outlined under standby power takes place, i.e. the faulty plant shuts down, the load is taken by the next set and the fault recorded by a panel light. In addition, the alarm is relayed through the radio system and the terminal station attendants are immediately aware of it and can take appropriate action.

It is normal to provide additional fault alarm circuits on a repeater station and facilities to signal low fuel level will definitely be fitted. More sophisticated systems may even call for an alarm to be signalled when the engine room door is open - others may require indication of when a control switch has been incorrectly set. All alarm indicator systems are useful and help considerably to ease the burden of the control and maintenance staff. However, the project engineer should avoid the pitfalls that accompany an over-complicated and cumbersome system of protection - things have got out of hand when an alarm has to be incorporated to report on another alarm!

No-Break Generating Equipment. It has been seen that in conventional type standby or repeater station generating equipment a short duration break in the supply circuit occurs when load contactors change from one to another. Further, it will have been seen that a break of several seconds occurs when a failure has taken place and an engine has to be started from standby condition to assume the load.

Modern day demands on telecommunications systems are such that even a load contactor break of only a few milliseconds is intolerable and it has become increasingly more necessary to specify some form of no-break equipment as an integral part of the power supply.

No-break power may be provided in many forms and a chapter dealing with this subject is included. In its simplest form a no-break set may comprise several diesel generator sets rated at less than full station load and each able to continue the supply if one of the others shuts down. Each set would be provided with synchronising facilities and able to rejoin the load circuit without interruption. In this system incoming plants could be brought on to the line and expiring sets shut down with 'no-break' to the essential load. At any given time, two diesel generator sets would be running on full duty cycle with additional sets at rest on standby duty.

Chapter Two.

THE DIESEL ENGINE AND ITS ACCESSORIES.

Before deciding upon a suitable engine the project engineer will consider very thoroughly the use to which it will be put and the environmental conditions under which it will operate. His first consideration however, will be the actual power requirement under site conditions.

Let us consider the requirements of a diesel engine that is to be installed at a height of 3,500 ft. above sea level and where the maximum engine room temperature is 115 degrees F.

Using BSS 649/1958 we should derate 3.5% for every 1,000 ft. after the first 500 ft. to obtain a derating figure of 10.5%. Subtract a further 2% for every 10 degrees above 85 degrees F. to obtain minus 6% and give a total derating of 16.5% An engine rated at 120 horse power would only develop 100 HP located in the above conditions.

Where power requirements are asked for in terms of electrical energy as would generally be the case for a diesel generator set, the calculation should be worked back from the required output in kilowatts or kilo volt amps. Here let us consider the power factor of 0.8 and an efficiency of 87%. The required calculation is:-

50 KVA. x 0.8 equals 40 KW.
40 KW divide by .746 equals 53 BHP.
53 BHP divide by .87 equals 61 BHP.
(746 watts equals 1 horse power)

In the foregoing examples the effect of relative humidity has been ignored. It is, in fact, a difficult thing to assess, but should be considered as it may well have to be taken into account. Let us assume that a specification quotes a relative humidity of 95% where the temperature varies between 130 and 55 degrees F. In practice, the maximum humidity occurs when the temperature is at its minimum - as the minimum temperature is less than 85 degrees we could, therefore, derate for humidity only. Using a derating factor of 4% for every inch of mercury above 0.6 inches vapour pressure the total derating for the above example would fall between 3 and 4%. However, at the hottest period when the temperature reaches 130 degrees, a derating factor of about 11% would apply against the temperature factor, but now the humidity would be at a minimum and could reasonably be ignored. In this case a total derating of 11% would be adequate unless the sum of the two factors has been specifically asked for.

It is rarely necessary to calculate derating figures as most engine manufacturers' manuals give this information in table form.

When the horse power requirement has been calculated the project engineer can narrow the field in choosing an engine to suit his needs. It should be remembered at this stage that the power output of an engine is always quoted at a certain speed; the generator frequency requirement will be known and an engine may be selected to turn at either 1,000 or 1,500 rpm for a 50 Hz. supply, or at 1,200 or 1,600 rpm for a 60 Hz. supply. As has been shown in Chapter One, a repeater station will normally use an engine turning at 1,000 rpm while a terminal standby to mains set will normally turn at 1,500 rpm. Reference to engine manufacturers' tables will readily indicate what engines are available to produce the required horse power at the required speed.

The many other factors that will be relevant to the eventual choice of an engine will now be considered in detail.

<u>Aspiration</u>. Engines will be either normally aspirated or turbo-charged. The former relies on the manifold depression for the quantity of air that can be effectively induced at the cylinder.

The function of a turbocharger is to increase the power output of an engine by mechanically increasing the amount of air in the cylinder at the commencement of the compression stroke. When the exhaust gases leave the cylinder at the end of the power stroke they still have a substantial amount of energy; this energy is capable of driving a turbine which is straight coupled to an impeller. The impeller delivers the air directly to the cylinders.

To quote an example, the Napier Turbo-blower delivers between 11,000 and 19,000 cu. ft. of free air per minute, maximum continuous rating, with a nominal pressure ratio of 1.5 : 1, sea level delivery pressure 7.35 lb/sq. inch at 6,400 rpm. This unit comprises a single stage centrifugal blower driven by a single stage axial flow turbine.

Turbo-chargers have been developed to an efficiency capable of carrying out the dual function of evacuating (scavenging) and pressure charging the cylinders of two stroke diesel engines. Modern turbo-chargers are manufactured in a range of seven sizes to fit engines of 400 up to 4,000 BHP. For engines of larger capacity, more than one unit may be fitted.

The advantages of turbo-charging may be summarised as follows:-

1. A substantial increase in output power from a given size of engine or a substantial reduction in the physical size of an engine for a given power output.
2. An appreciable improvement in specific fuel consumption.
3. Lower initial cost.
4. Less maintenance costs with better reliability.

Cyclic Variation. The effect of an imprecise or erratic waveform on modern communications equipment may be very critical; it is, therefore, of the greatest importance that cyclic irregularity be kept to a minimum. Cyclic variation will result from such factors as number of cylinders and number of firing strokes per minute, engine speed and the weight of flywheel fitted to the engine. It is usually expressed as a fraction and indicates the degree by which the flywheel varies from uniform rotary motion and is calculated by subtracting the minimum speed from the maximum speed and dividing the result by the mean speed (taken over one engine cycle.).

Engine manufacturers will provide tables giving this data for their products, it should be ascertained whether their figures include an allowance for generator rotor inertia as this will obviously have an effect also.

Engine Cooling. After about 200 horse power capacity the task of deciding between water and air cooling becomes irrelevant, for the higher power ranges are predominantly water cooled. The choice below that range, however, may be difficult for there are many advantages and disadvantages that merit careful consideration.

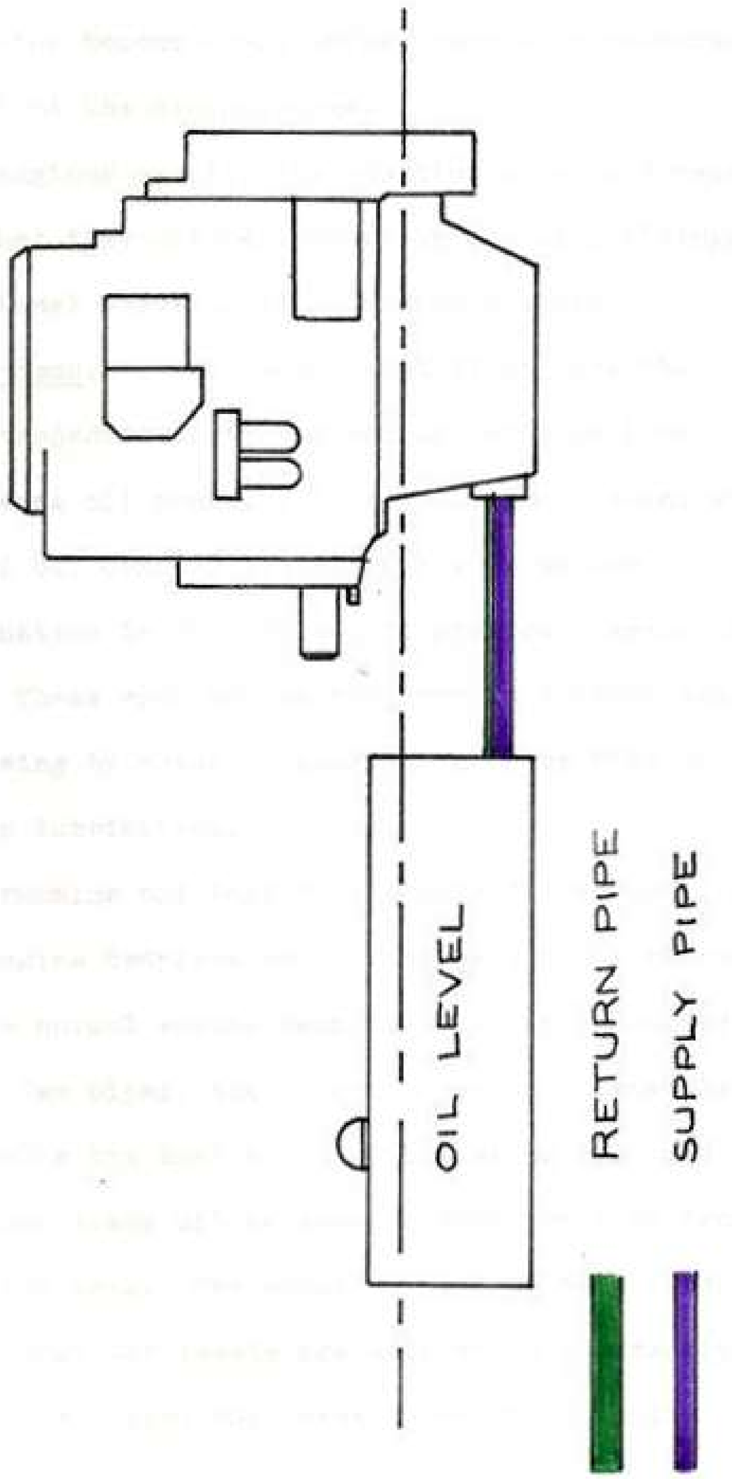
Air cooled engines may be somewhat cheaper and lighter although this may not be an important consideration in microwave applications. Generally speaking they may be more easily maintained and dismantling and rebuilding is more quickly and easily carried out. Apart from what may sometimes be rather cumbersome air ducting they are generally easier to install. The air ducting itself may prove easily adaptable to heating adjacent accommodation by way of shutters controlled by thermostats.

On the debit side it is almost always necessary to design an engine room specifically for an air cooled engine as many problems can present themselves in regard to obtaining sufficient cooling air. Great care has to be taken also to ensure that hot air is not recirculated giving rise to over-heating problems.

Water cooled engines are initially more expensive and carry the additional burden of expensive radiators or heat exchangers and piping. They require considerably more effort to install but can be installed readily in existing buildings due to the greater ease of piping water over long distances. The waste heat may be more easily used for secondary purposes than in air cooled engines.

A water cooled engine lends itself more readily to being kept warm during rest periods as immersion heaters may easily be installed in its cooling system.

Some installations employing water cooled engines may have engine mounted radiators. Although this type makes a



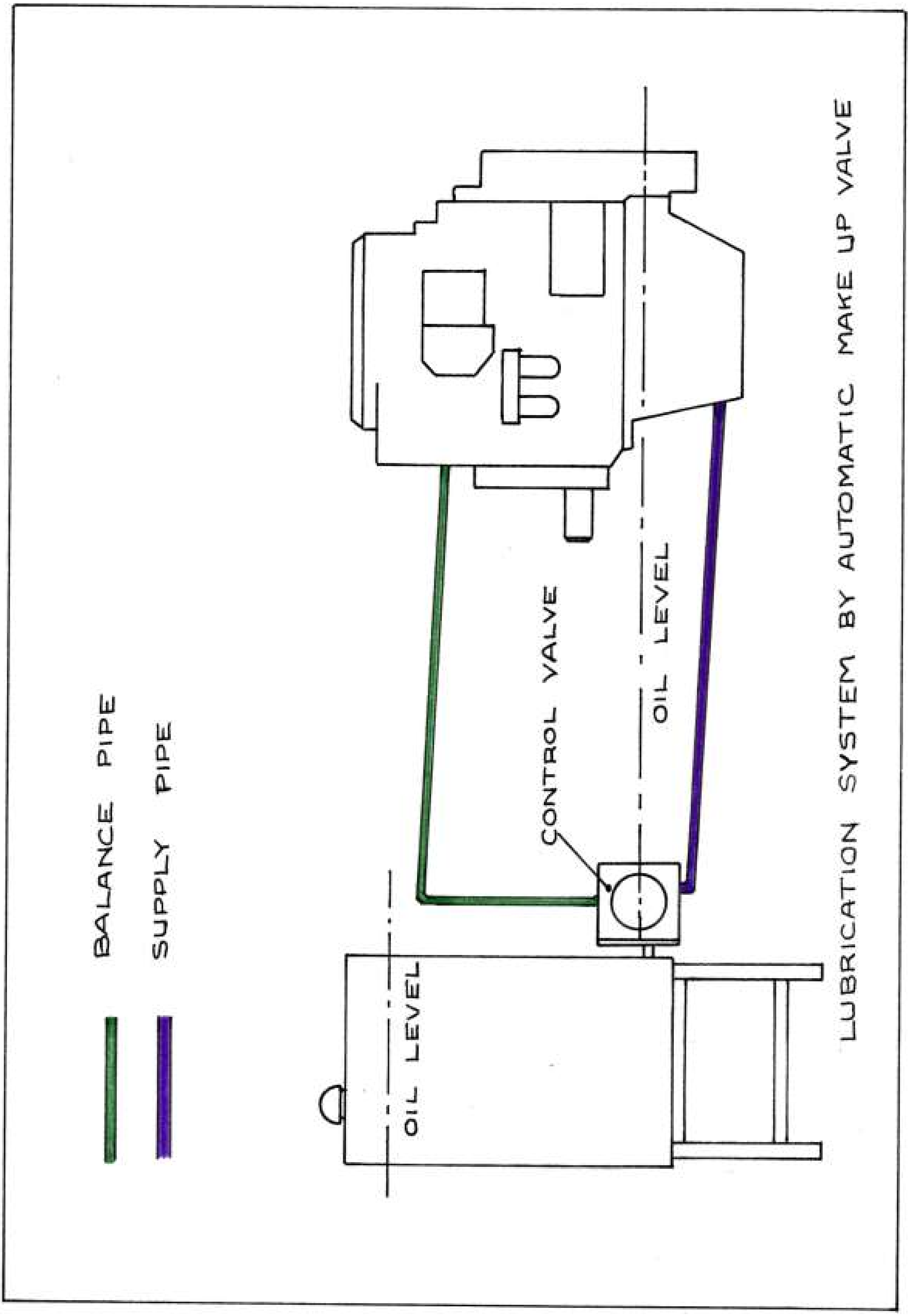
EXTENDED RUNNING LUBRICATION SYSTEM.

neat package in itself, the problems of ducting the hot air away from the radiator become great unless careful consideration is given to it at the design stage.

Water cooled engines require the addition of anti-freeze despite the fact that they may be located in heated buildings and have the additional security of immersion heaters.

Lubricating Oil Systems. It is essential that engines that are to remain unattended for extended periods of time have additional lubricating oil capacity provided. The reasons are to allow for normal oil consumption, to cut down on the percentage contamination in the oil and to provide a means of heat dissipation. These ends may be achieved in various ways, the more popular being by extended running tank, by Make-Up tank or by dry sump lubrication.

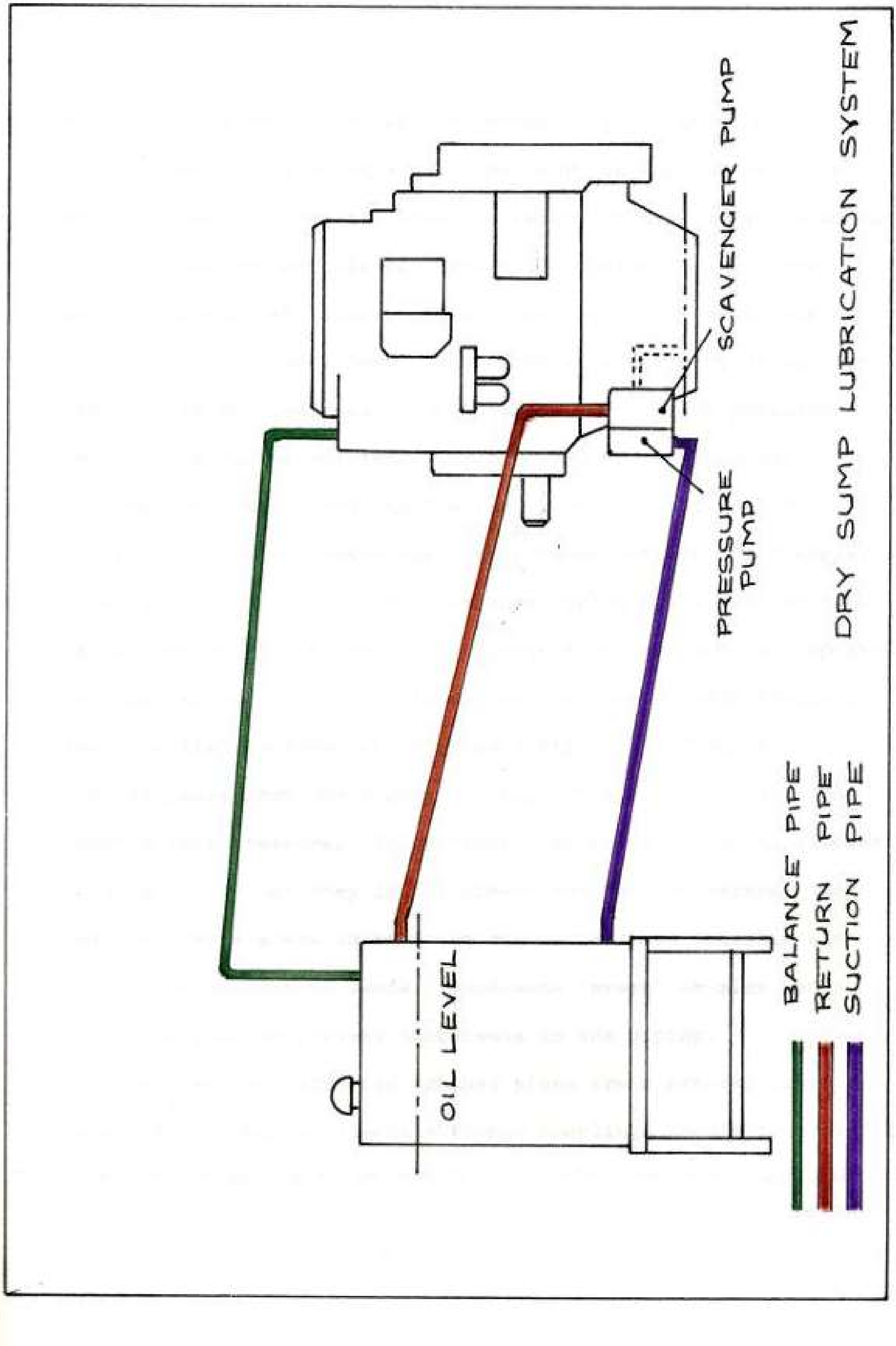
The extended running oil tank is normally fitted on to an extension of the engine bedplate and comprises a steel oil tank of about double the normal engine capacity. It is connected to the engine sump by two pipes, the larger of which enters the sump immediately below the duct to the lubricating oil pump. In practice, the pump draws oil in equal quantities both from the sump and from the tank. The second pipe acts as a level balancer to ensure that the levels are maintained constantly equal. In effect, the engine has three times its normal



LUBRICATION SYSTEM BY AUTOMATIC MAKE UP VALVE capacity of oil in circulation. Although appearing somewhat primitive this system has been successfully employed on many large systems without fault.

An oil Make-Up tank may be installed anywhere in relation to the engine and thus has the advantage that it does not interfere with accessibility. It employs a regulator valve that maintains the engine oil level at a constant height, the regulator valve itself being located in line with the sump oil level. The valve is fed from a reservoir tank which may be wall mounted above the valve. Two pipes are fitted between the valve and the engine, one to provide a supply line, the other to equalise the pressure difference that exists between the two. Although this system does not increase the effective quantity of oil in circulation it does keep down the percentage contamination as fresh oil is constantly being added to the sump, it thus permits full time between oil changes. It is not uncommon to use a combination of this and the previous system by connecting a make up valve to the extended running tank and, in doing so, considerably increasing the time periods between oil changes.

Dry sump lubrication is commonly used on all types of engines except those employing any form of splash lubrication. The actual oil reservoir - or dry sump tank - is located


DRY SUMP LUBRICATION SYSTEM
SCAVENGER PUMP
PRESSURE PUMP
OIL LEVEL
BALANCE PIPE
RETURN PIPE
SUCTION PIPE

remotely from the engine and connected to it by three pipes - a feed pipe, a return pipe and a pressure balance or vent pipe. Oil is drawn continuously from the reservoir tank by the engines own oil pump and circulated through the engine in the normal way. A second and larger pump returns the oil from the engine sump to the reservoir tank. The third pipe which is of smaller diameter is run overhead to balance out any unequal pressures between the engine and tank. This system provides excellent cooling for the oil and, as the reservoir does not need to be restricted in size, extremely long periods between oil changes.

Exhaust Systems. Although an exhaust system may appear to be a rather insignificant part of the project it does have an important function to serve and its design requires careful thought. The essential function of an exhaust pipe is to clear the exhaust gases from the engine quickly and efficiently without causing back pressure. In addition, the gases should be cleared in such a way that they do not create any form of hazard. The prime essentials are to keep the run as short as possible and to use the minimum of bends. Hand-made 'sweep' or slow bends should be used to prevent turbulence in the piping.

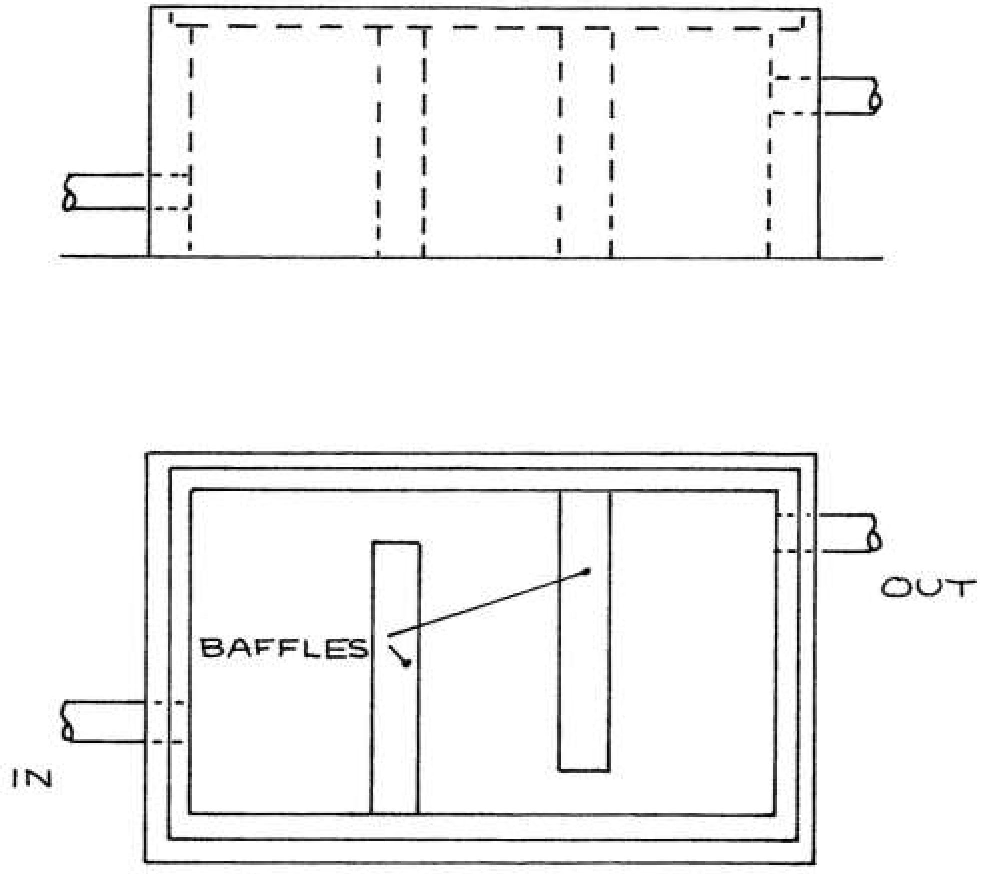
As clean unobstructed exhaust pipes are a pre-requisite of an efficient engine, adequate flange couplings should be provided to allow the system to be easily dismantled for cleaning. Exhaust silencers should be fitted as close to the engine as possible and all piping within the engine room suitably lagged with asbestos cord. Horizontal pipe runs should slope away from the engine to allow condensation to drain off to the outlet.

An exhaust run of over thirty feet should be increased in size to prevent back pressure, a good rule of thumb method is to double the area of the pipe for every ten feet after the first thirty feet.

Exhaust pipes should be adequately insulated where they pass through walls both to prevent heat and vibration from causing damage. Pipes passing through wooden walls should have air gaps of at least four inches.

Under no circumstances should rigid exhaust pipes be screwed directly into an engine manifold. A flexible connecting piece of at least three feet in length should be used at all times. This flexible should never be expected to carry the weight of any part of the run.

The problems of noise, smoke emission and spark arresting may be overcome by terminating the exhaust run in a suitable 'ground silencer' or expansion chamber. These may be designed in a variety of ways but in its simplest form would consist of a cement or brick lined hole in the ground into which the exhaust



TYPICAL GROUND SILENCER
EXPANSION CHAMBER.

pipe is terminated. Baffles may be introduced to increase the effective length to the outlet slot and a quantity of water put into the bottom to arrest sparks and soot.

Perhaps the last word on exhaust systems is still operating undetected in a large city in South America and, hopefully, as yet not offending National pride in any way.

I was confronted with the problem of installing an exhaust sytem from a basement engine room in a ten-storey public building. The location was awkward to say the least and it seemed the only way out would be via a devious horizontal pipe run terminating in an expensive and time consuming vertical shaft - if it could be done at all.

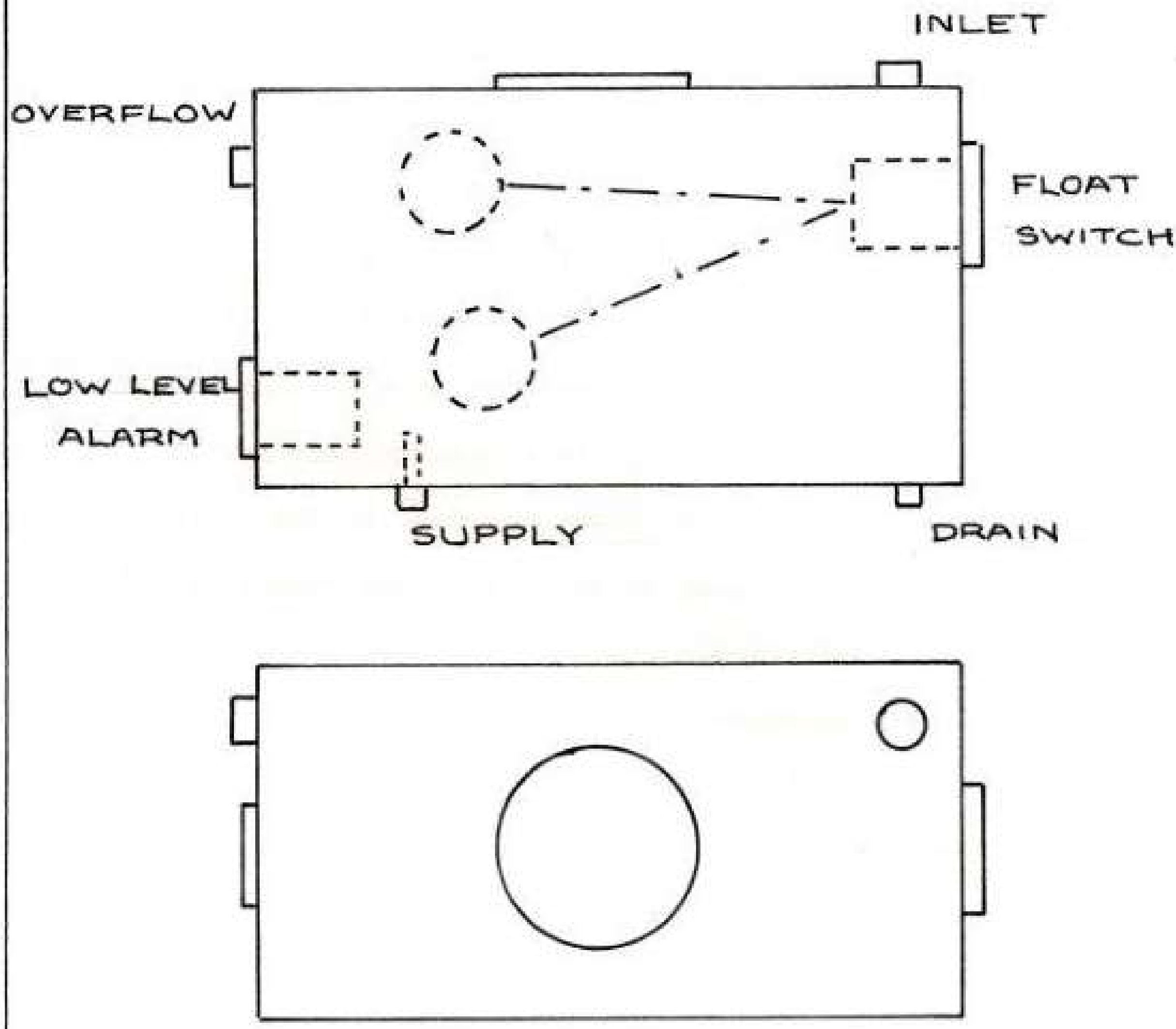
Then I discovered the National flag-pole standing serenely on its ornate cement base and proudly guarding the front entrance steps - within only a few feet of the engine room. Some rapid and ingenious civil works - executed while the President and his entourage were away on a state visit to Cuba - soon converted the ornate base into a ground expansion chamber and the steel flag-pole itself into a rising outlet! I left the country still hoping that a power failure would never coincide with a couple of faulty injectors during a State Trooping of the Colours!

Fuel Storage and Supply Facilities. There are two main methods of storing fuel in bulk - underground storage tanks and those that are supported above ground level and employ gravity as their feed to the engine day service tank. Both have merits which should be carefully considered.

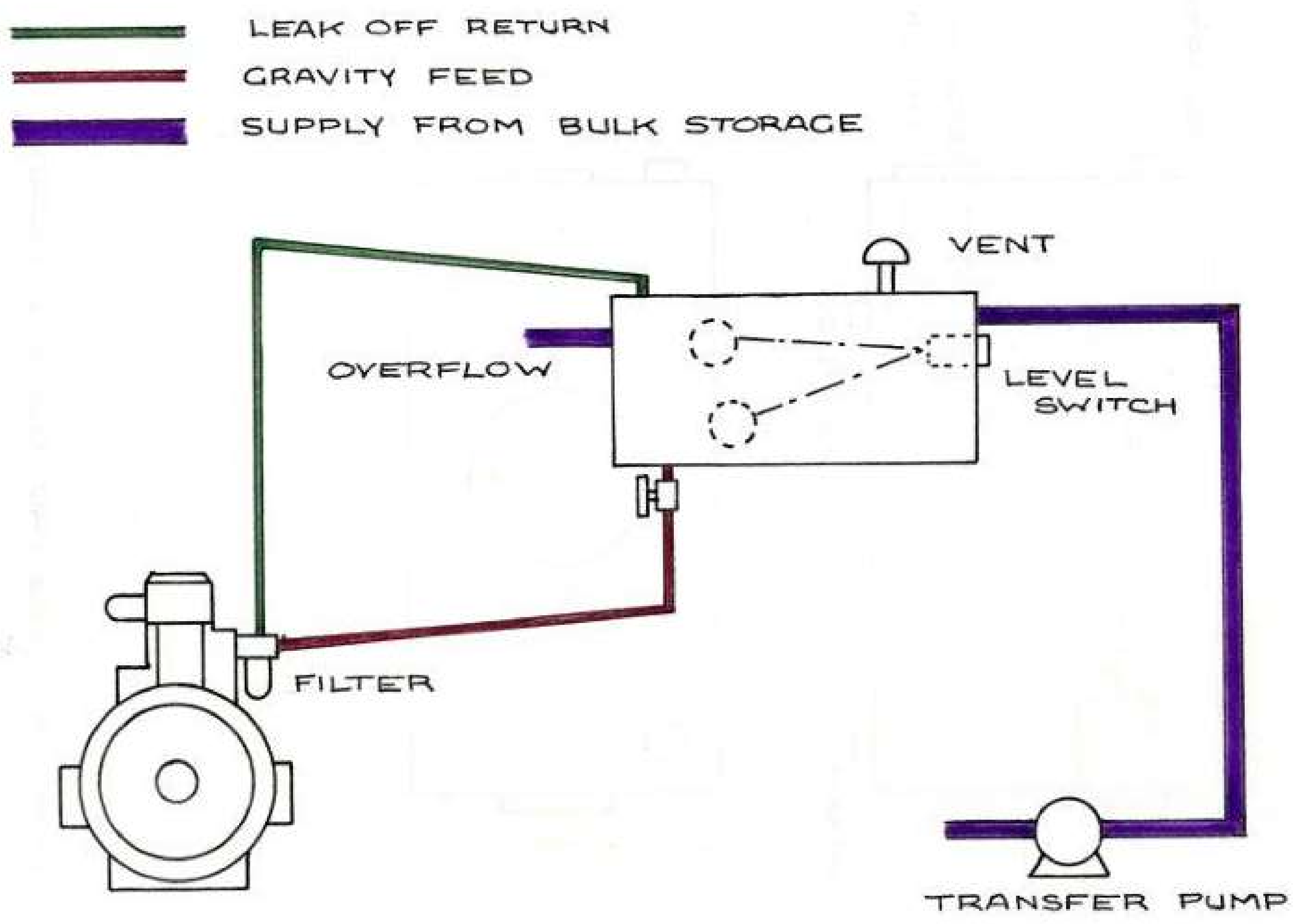
Underground storage tanks afford a certain degree of protection to their contents, in tropical conditions the fuel is protected from high temperatures that accelerate age oxidation and in extreme cold it is protected from waxing. Transfer pumps are required to transfer the fuel to the engine day tanks but the need for a pump on the refuelling tanker is eliminated.

It is good practice to provide bulkheads in the main storage tank to maintain the independent requirement of each engine. Should a serious leak develop in one supply the fuel could drain away leaving the remaining engine or engines unaffected.

The illustration shows a typical system in which an underground storage tank supplies two daily service tanks via automatic float controlled transfer pumps. Service tanks are normally designed to contain sufficient fuel for a 24 hours period. The following facilities are provided on the service tank:- A float level switch to control the pump; a contents gauge with contacts for low-level alarm; an inlet from the fuel pump and outlets for overflow return to the storage tank and supply to the engine filter; a union to accept leak-off



GRAVITY FEED DAY SERVICE TANK



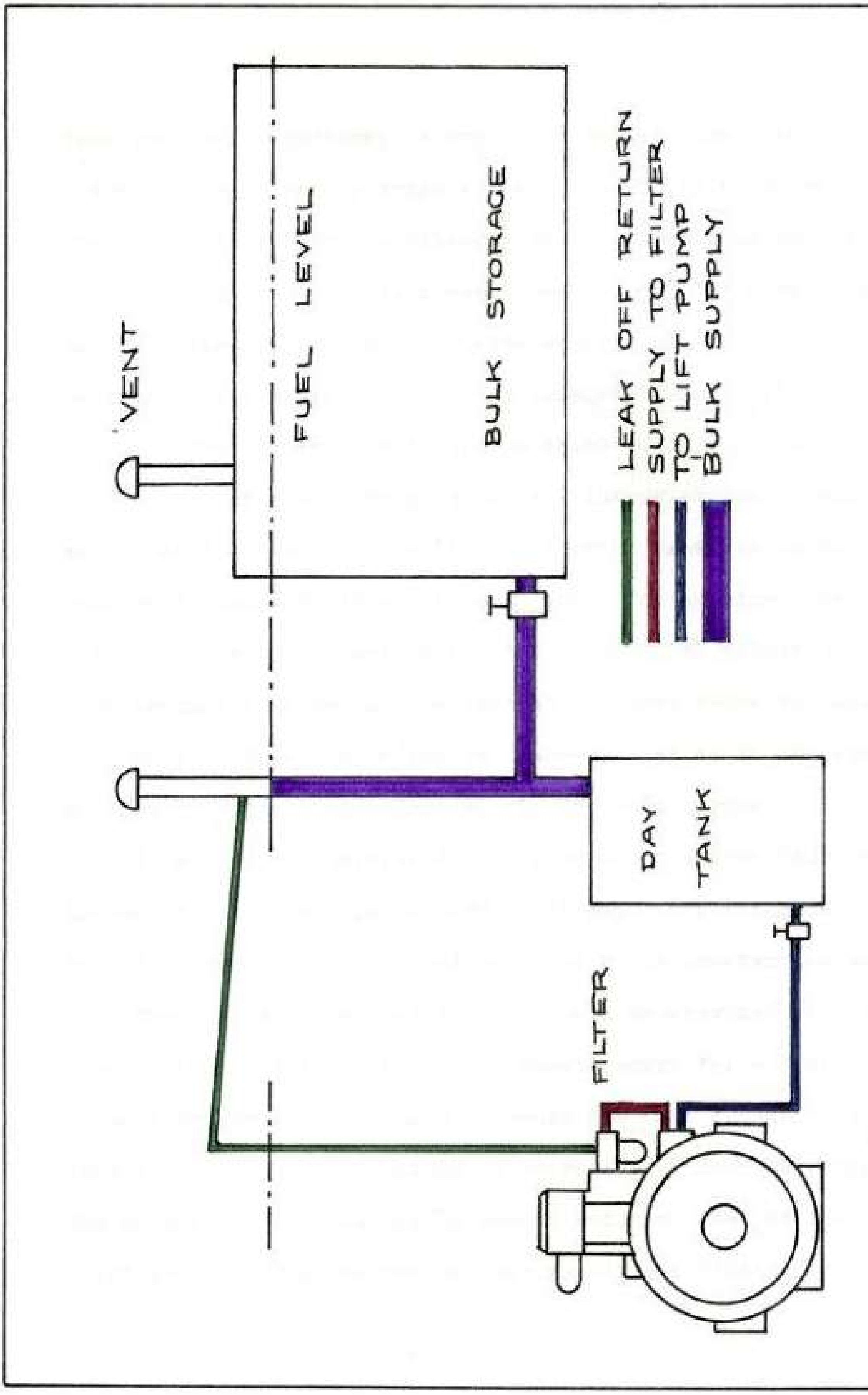
GRAVITY FEED FUEL SYSTEM WITH BULK TRANSFER BY ELECTRIC PUMP.

from the fuel injectors; a drain tap and a large inspection cover. A good quality brass stopcock should be provided in the supply to the engine filter. The overflow pipe should be of sufficient capacity to prevent build-up if the pump level switch fails to operate. At least one filter should be fitted between bulk storage tank and the transfer pump inlet.

An alternative to this system which employs a gravity feed supported bulk storage tank is illustrated and it will be seen that the level of fuel in the service tank rising vent pipe will equal the level in bulk tank. The combined fuel leak-off from the injectors and the engine fuel filter bleed pipe terminate in the rising vent at a height above the maximum fuel level. This system may be compartmented as in the previous example to allow independent supply for each engine.

It should be remembered that a chemical action takes place between fuel oil and galvanised fittings, all fittings and tanks therefore should be either plain steel or of non-ferrous metal.

The bulk storage tank itself should be provided with an inspection cover large enough to permit entry for cleaning. The inspection cover may be used to house the main rising vent pipe (ard fly trap) and a suitable waterproof plug for a dipstick. The bottom of the tank should have a sediment bowl at its lowest point where foreign matter may accumulate for drawing off. The



CRAVITY FEED FUEL SUPPLY SYSTEM.

sediment bowl, or trap, should not be located directly below the filler hole where the incoming flush of fuel will stir up and spread the sediment.

Cooling Systems. If it has been decided that the cooling medium for the engine will be water there are several variations and systems that may be employed. Assuming that the engine mounted radiator type has been eliminated for reasons already put forward, we can consider the alternatives of air-blast cooler or heat exchanger.

An air-blast cooler is literally a remotely mounted radiator but with the provision of an electric motor driven fan to provide the air flow through the cooling tubes. The unit is commonly fitted into an outside wall of the engine room with the fan arranged to draw air from the engine room itself - suitable louvres and vents being located to supply sufficient air. Such air inlets should be adequately fitted with filters to prevent dust from being drawn into the engine room, they should also be sufficient to ensure that the engine is never starved of air.

The unit would be connected to the engine in the same way as a conventional radiator via steel pipes and rubber flexible connections.

As an additional refinement the header tank may be connected

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to an overhead gravity feed make-up tank to make good water losses. This system has the advantage that the unit is not affected by engine vibration and in no way does it impede accessibility. It may be mounted completely outside the engine room and will work efficiently even when located a considerable distance away. Care should always be exercised when designing the system to ensure that a slope of about one eighth of an inch to the foot is maintained up and towards the header tank to prevent air locks.

Cooling by heat exchanger is not likely to be considered except for the higher horse power ranges and where an adequate supply of raw water is available. It allows for a closed circuit cooling system and has the advantage that little or no scaling will occur in the water jacket of the engine. Circulation both through the heat exchanger and engine cooling system is by pump and valves controlled by thermostats.

If air cooled engines are to be used very careful attention should be paid to the engine manufacturer's recommendations in regard to size of ducting and restrictions in length.

Approximately one third of the fuel burnt in an air cooled diesel engine is converted into heat that must be ducted away and it is imperative that none of the heated air is allowed to recirculate through the cooling system. It follows, therefore, that the cooling and combustion air inlet temperatures should be as near to ambient temperatures as possible. In order to achieve this, cooling air inlets must be provided in the engine room in at least the following places:- One inlet near the bottom of the engine room to provide airflow past the sump; one inlet close to the air filter to provide a good supply of combustion air and one or two inlets above the engine and close to the ceiling to prevent a build-up of hot air at the top of the engine room. The engine room should be designed bearing in mind that the whole of the space is subject to air currents with no still areas where temperatures could gradually build up.

Steel outlet ducting should be connected to the engine by flexible adapters which permit the engine to move without restriction on its mountings.

Where the outlet ducting terminates outside the building a cowl should be fitted. The discharge face of the cowl should be vertical and fitted with louvres or a grill - the cross sectional area of which, should be 25% greater than the area of ducting.

Additional Equipment and Fittings. Many additional components or fittings will be required on an engine that is to operate from an automatic control circuit for extended and unattended periods of time. Some means will have to be provided to start and stop the engine, special sensing devices will be required to initiate alarm sequences for shutdown and many devices fitted to carry out the function of an operator.

Automatic Run Solenoids. There are two basic types of solenoids in use for controlling engine running and stopping, both being operated electrically from the control panel. A 'Run' (or fail safe) solenoid is arranged to draw the fuel pump rack of the diesel engine into the starting position at the same time as the engine is cranked for starting. It will remain in position until its circuit is de-energised thus allowing the rack to return to its 'off' or stopping position to shut down the engine. If an electrical fault occurs, or the run solenoid itself develops a fault, the engine will shut down under the influence of its fuel pump rack return spring. A run solenoid may comprise two separate coils, an operating coil and a hold-on coil, as far less current is required to hold the armature in the raised position. The operating coil would be arranged to de-energise after initial operation by a trip contact actuated by the armature.

A 'stop' selonoid is fitted in such a way that it draws the fuel pump rack to the 'off' position when energised. When de-energised, the rack would rest in the start position thus allowing the engine to start and run under the influence of cranking only. Energisation of the solenoid would be for a short timed period of sufficient duration to permit the engine to run down and come to rest. In the event of a fault developing in the control circuit or solenoid no shut down would take place.

Centrifugal Switches. A centrifugal switch, which may be either gear or belt driven from an auxiliary pulley, normally has two micro switches which can be independantly adjusted. The low speed switch is set to operate as the engine runs up to speed and is normally connected to a slave relay in the control panel that disconnects the starter motor circuit. The high speed switch is normally set about 2½% above nominal engine speed and serves to initiate an overspeed shutdown alarm circuit.

A more sophisticated type of centrifugal switch may have an additional contact set to operate at 2½% below nominal speed to initiate an under speed alarm circuit. Most modern control panels however, have an electronic sensing unit to detect over and under frequency which may be used in combination with - or in addition to - the centrifugal switch.

Battery Charge Dynamo or Alternator. It is not usual to equip the type of engine to which we are referring with rotating battery charge equipment. Instead, the control panel normally houses a static battery charger.

Engine Starting Facilities. Almost all diesel engines for microwave work employ axial type starter motors, on the larger engines two may be fitted - one on either side of the flywheel, and in this case both would operate together.

An axial starter motor has two actions, the first - because of the high inertia of the flywheel - is to move the pinion forward into engagement with the starter ring before full torque is applied. A small initial current is passed through auxiliary field windings to impart a slow turning motion to the armature, the same action moves the armature shaft and starting pinion forward towards the flywheel. At the end of its travel, and when the pinion is fully engaged, a trip mechanism allows the main contactor to make and apply full current to the field windings and maximum torque is applied to crank the engine. The main contactor cannot make unless the armature has travelled to its full engagement thus preventing the brass teeth of the pinion from spinning and damaging themselves against the starter ring. This type of starter has an overload clutch which protects the pinion teeth under excessive load.

Cold Starting Aids. One of the greater virtues of the diesel engine is its ability to start from cold and assume full load conditions within a matter of seconds. Not withstanding this, there is no doubt that some means of assisting the process is beneficial.

Water jacket immersion heaters and thermostats may be fitted in the engine cooling system to ensure that the cooling water is maintained above embient temperature. Similar heaters may also be fitted in the oil sump of air cooled engines but these should operate at a low surface temperature to avoid carbonising the oil. (Where such devices are fitted, adequate indication should be posted to ensure that they are isolated by maintenance personnel before oil and water are drained from the engines).

Under really adverse conditions of cold, it is possible to introduce a finely atomised spray of highly volatile spirit into the induction manifold to assist with the first few firing strokes of the engine. Such sprays may be from an aerosol-can actuated by an electric solenoid in conjunction with the start circuit. Such a device should only be used under well controlled conditions, for the introduction of too much spirit into the engine could give rise to excessive loadings with possible disastrous results.

Having accepted that the diesel will assume full load conditions within a few seconds of starting from rest, it becomes very apparent that the lubricating oil pump should be highly efficient in order that all moving parts are adequately lubricated. In order to achieve this, an auxiliary oil priming pump driven by an electric motor may be included in the lubricating system. The pump would be timed to start and pressurise the engine lubricating system for a given period - perhaps twice every twenty-four hours - thus ensuring that the oilways and bearings were maintained charged with oil. The actual duration and intervals would depend upon the conditions. Manual facilities for running the pump would be fitted in order that priming could be effected before test running the engine.

Anti-Vibration Mounts. Where heavy reciprocating engines are installed, vibrations may be transmitted which might have an unpleasant influence on adjacent equipment. Various types of anti-vibration devices can be installed to minimise these effects. Rubber or spring type mountings may be used to support the engine and generator assembly. The mountings may be adjustable by means of a screw and locknut and have additional snubbing and damping devices to take up the extra movement of starting and stopping when deflection is at its highest. Scientific selection of the correct type of mountings will dispense with the necessity for a heavy cement foundation block and make possible the installation of equipment on quite light structures such as suspended reinforced floors.

In cases where the need to eliminate vibration is essential, an isolated cement foundation block may be installed in addition to anti-vibration mounts. Such a block, which should be equal in size to the manufacturer's recommendation for an unmounted engine, would be separated from the floor structure by a wall or lining of thick sheet cork. The gap between the block and the floor should be filled with sealing compound to prevent oil and fuel from seeping into the lining. If necessary, the complete engine room floor may be isolated in this way, always providing, of course, that it is not required to run underground pipes or conduits to the plant.

Engine Air Cleaners. Under reasonable operating conditions air cleaners could be an ordinary oil bath industrial pattern. For conditions where the atmosphere is likely to be contaminated with dust or polluted in any way, a 3 stage heavy duty oil bath air cleaner should be fitted.

Oil and Fuel Filters. Oil filters should be full flow type for maximum efficiency. Fuel filters should be of the dual type with provision for changeover without affecting normal service. An additional filter should be provided between the bulk storage tank and transfer pump with a combined water separator and sedimentation trap.

Oil Coolers. If oil coolers are required, they are normally fitted by the engine manufacturer as an integral part of his equipment. If any doubt should exist, however, the manufacturer will readily supply details and recommendations.

Engine Protection Devices. Although various types of self-actuating devices are available to shut down the engine in event of trouble developing we are less concerned with these in regard to microwave equipment. We will turn our attention then to what are more easily defined as sensing units, which transmit a fault signal to the main control panel. From this signal a sequence of events is initiated which will shut down the faulty set and start up it's standby, isolate the faulty set from duty and give local and remote indication of the condition. Local indication of the fault may be by both visual and audible alarm.

Low Oil Pressure. This is normally a bellows or diaphragm assembly which is pressurised by the engine lubrication system. When oil pressure is normal it acts on the bellows or diaphragm and extends it to operate a contact. The contact is connected to a slave relay in the control panel. If the oil pressure drops below a predetermined value the contact closes and initiates an alarm condition.

Cooling Temperature High. Cooling temperature is normally monitered by a bulb and capilliary tube unit. In the event of the engine temperature rising to an undesirable level the column of mercury expands and actuates a contact which, upon closing, will transmit the condition to a slave relay. The same system is used both for water and air cooled engines.

Radiator Fan Belt Breakage. Although not often seen, this facility has been used in the past and is worthy of mention. It consists of a small idler pulley that rides on the engine fan belt. If the fan belt breaks - or becomes too slack - the pulley moves out of position and trips a microswitch which, in turn, transmits the condition to a slave relay. This facility does have value on a radiator cooled engine as it will give warning and isolate the set before an undesirable high temperature is reached.

Engine Fail to Start. The circuit that provides a timed period for engine starting is part of the control panel equipment. The circuit however, may include a 'three attempt' start device that allows the starter motor three tries to engage with the flywheel starter ring. Manufacturers of axial starter motors do not guarantee that the starter pinion will engage first time although, in practice, they are highly efficient. In order to allow for the predicted failure to engage a small timing device is incorporated - sometimes as an integral part of the starter motor - that will permit the armature to return from the blocked position twice after the initial attempt before signalling a fail to start alarm.

Overspeed Shutdown. An interesting device to protect an engine in the presence of flammable gases has recently been developed by scientists from Esso Petroleum. Although this type of hazard is not likely to be met in the type of installation we are considering, it is worthy of note as a protection device.

If flammable gases are present in an engine room they may be ingested via the induction system into the cylinders. If this happens, the gas can act as an addition to the normal fuel supply and cause the engine to speed up with possibly disastrous consequences.

The protection device comprises a spring loaded poppet valve, fitted up-stream of the induction manifold. This valve, which can be critically adjusted to allow the engine to run at its normal governed speed, will snap shut if the speed increases beyond a predetermined point thus bringing the engine to rest by starving its air supply.

Engine Instrumentation. A minimum of instrumentation is required to indicate prevalent engine functions and should include the following:-

Tachometer and Hour Recorder. An average engine tachometer is not a very precise instrument and is often omitted on the grounds that the control panel will be fitted with a frequency meter. Despite this, it is worth fitting one for the following reasons:-

(a) It will be found to be most useful when setting up the engine after maintenance work and

(b) Most tachometers have an integral hours-run recorder. The latter will prove to be an invaluable feature and very desirable for the efficient use of a maintenance schedule.

Coolant and Oil Temperature Gauges and Oil Pressure Gauge. All three are equally important for on the spot reference and for long term record use. The values of all three should be carefully entered in the engine log book when maintenance is carried out.

Exhaust Temperature Gauges. These are less common on microwave systems but will occasionally be seen on the larger range of engines. If fitted, a careful record of their values should be kept in the engine log book.

Engine Bedplate. The engine generator assembly is mounted upon a common fabricated bedplate to create one complete unit, this would follow whether the direct coupling employed was by flexible drive coupling or by flange mounted alternator. Such bedplates should be suitably stress relieved after fabrication and all support surfaces machined true with provision for locating dowels to ensure correct alignment.

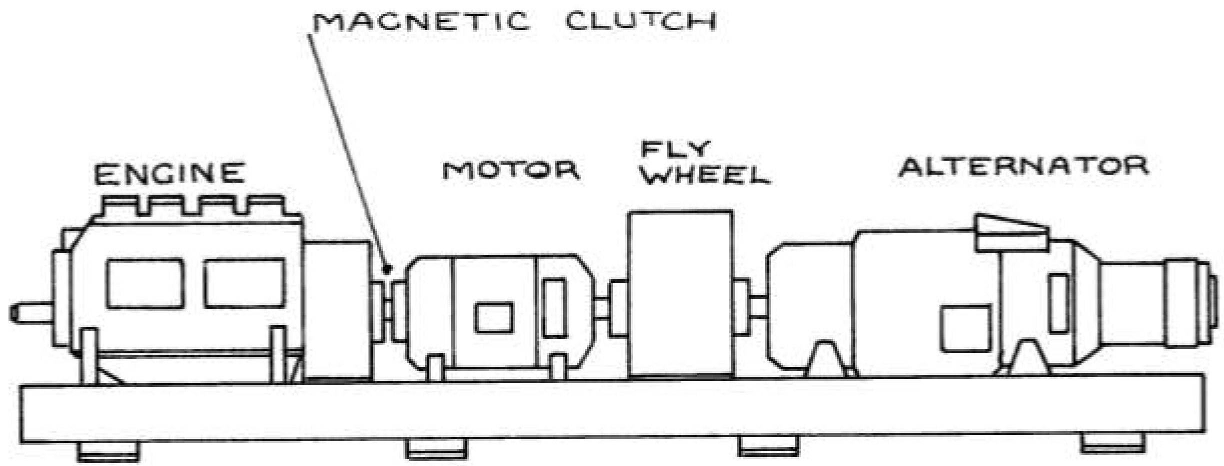
Chapter Three.

THE NOBREAK SET.

Fundamentally, a Nobreak system is one that utilises some form of stored energy that is capable of supplying the load until a reserve form of power can be brought into operation. The important proviso is that absolutely no interruption between supply and load should occur. This stored energy is, in practice, normally stored in a flywheel as kinetic energy or in a battery as chemical energy.

For the purpose of this study, we will confine our examination of Nobreak sets solely to those types that employ a diesel engine as a direct form of motive power.

<u>Three Machine Nobreak Set</u>. This system consists of a diesel engine connected through a clutch to a motor - flywheel - alternator set combination. The electric motor is driven by the public mains supply (or a diesel generator set in the case of a repeater station) which, in turn, drives a flywheel which, in turn, is coupled to an alternator. The alternator supplies the essential load at all times. If the supply to the electric motor fails, the kinetic energy stored in the flywheel drives the alternator until the diesel engine is clutched in and run up to speed. This state of



NO-BREAK SET WITH STANDBY DIESEL.

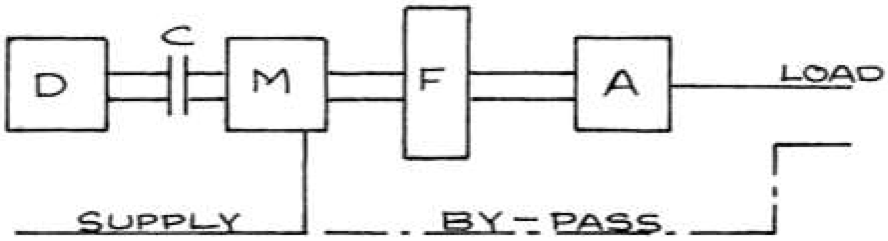
affairs would continue until the main supply restored itself within acceptable limits and resumed the drive to the motor. At this time, the diesel would de-clutch itself and return to standby duty. It will be seen that with this system, a continuous supply of un-interrupted power is available for the essential load; the supply showing no appreciable variation in voltage and only a slight frequency drop during the start cycle for the engine.

The clutch used on such a system is normally electro-magnetic and arranged to cut in when the diesel engine has attained a percentage of nominal speed.

The diesel engine itself would be built on identical lines to those described under standby to mains sets and would have similar protection devices.

Three Machine Nobreak Set with Additional Standby Diesel. This arrangement would be similar to that described above but with the addition of an extra engine connected electrically to the drive motor. This engine would start and assume the drive to the motor in the event of a fault developing in the first set or in the electro-mechanical drive.

Two Machine Nobreak Set. A two machine Nobreak set consists of a motor flywheel alternator assembly which is connected electrically to one or more standby diesel generators. The motor is driven by the public supply until, in the event of a power failure,



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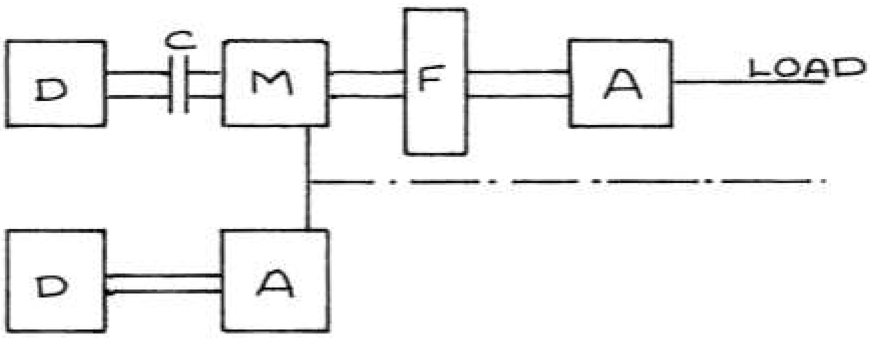

B

A. MECHANICAL NO BREAK SET

B. MECHANICAL NO BREAK SET WITH ELECTRICAL STANDBY D/A SET

KEY

D. DIESEL

C. CLUTCH

M. MOTOR

F. FLYWHEEL

A. ALTERNATOR.

the standby set/s run up to speed and assume the drive. When two or more standby engines are employed on such a system all may be started simultaneously and the first up to nominal speed and output will pick up the Nobreak set and lock out the others which will revert to standby duty.

Battery Maintained Nobreak Sets. These systems employ large banks of batteries to feed the essential load via inverters. The batteries float fully charged on the mains electricity supply. In the event of a failure in the mains supply the batteries continue to feed the essential load inverters while a standby diesel engine starts up and assumes the supply to the battery charger.

Three Diesel Generator Sets arranged for Nobreak Operation on a Common Busbar. This uses the principle of maintaining generating capacity surplus to essential load requirements to the extent that one engine can shut down without endangering the supply to the total essential load. In this case, two sets would supply the busbar continuously and one set would remain at rest. The total essential load should not exceed the continuous output of one set alone, but non-essential load up to the capacity of the second set may be added if fast acting relays are provided to dump this load if the capacity of the busbar drops by one set shutting down.

Four Machine Nobreak Set with Two Diesels. This type of Nobreak equipment consists of a standard three machine Nobreak set with the addition of an extra diesel engine and clutch connected at the alternator end. In effect, the diesel engines operate as dual duty cycling sets, alternating the drive at predetermined time clock intervals.

The foregoing gives a fairly broad outline of what is available in Nobreak equipment. Variations and combinations of the various types are abundant and would require a complete work to describe in detail. Suffice it to say that each microwave system has its own peculiarities and requires its own specific design.

There is a general trend towards less power requirements as transistorisation takes place and it is likely that, in the future, the mechanical Nobreak will give way entirely to the smaller type of D.C. Static Nobreak system.

Chapter Four.

ALTERNATIVE FORMS OF POWER

Despite the supreme position that the diesel engine has attained and held for so long in the field of microwave engineering, what are its prospects for the future ? Let us first consider its advantages:-

It is relatively efficient and extremely reliable.

It is easy to maintain.

It starts well and will continue to run under adverse conditions.

It does not emit toxic fumes (as does the petrol engine) and its fuel is not a serious fire hazard.

Fuel costs are relatively cheap and long periods may be expected between major overhauls.

It can assume full load conditions from cold.

Against these advantages, we should consider the following:-

It has a poor power to weight ratio.

Its initial cost is high.

It is noisy and transmits vibration.

It requires skilled personnel to attend to maintenance and overhaul problems.

These are only general terms for it may well be argued that its advantages are not as meritorious as they appear at first sight and that its disadvantages are not as bad as they seem.

Perhaps it has held a rather unique position for its only serious contenders have been the petrol engine and the gas turbine. The petrol engine would fail miserably on its poor starting characteristics and fire risk. The gas turbine may offer some opposition in the higher horse power ranges but even at high speed on full load it has a lower efficiency than the diesel.

Perhaps it will be the evolution of the microwave system itself that will eventually render the diesel engine a less favourable proposition than alternative power sources. The greatest influence will be the actual amount of power required.

Let us examine some of these alternatives.

" The power consumption of a solid state repeater for a low capacity radio relay system is so low that it could be supplied by storage batteries charged by a small wind generator, provided that the wind characteristics of the site are satisfactory. Suitable sites, where the annual mean wind speeds exceed 8 mph will be found in almost all coastal belts and on many inland hills and ridges. Wind generators for this purpose are not commercially available at present but the author believes that reliable designs could now be developed .... "

The above quotation has been taken from an article by P. A. Sachs in Point to Point, dated February 1964.

Historically speaking, wind power has established itself well - especially in the domestic field. In the field of telecommunications a wind powered generator is reported as having successfully provided power for a 10 cm. television link - giving three troublefree years of service. The initial power demand had been calculated to be 26 Kwh/day but in the first winter the diesel standby generator immersion heaters consumed 24 Kwh/day to prevent the engine from freezing up. The system comprised two 6 Kw wind generators supplying 50 Kwh/day daily with the minor problem of overcharging being the only real trouble encountered. In a recorded one year period these sets provided 13.3 Mwh with a maximum outage time of only 24 days due to blade icing.

The capital cost of a wind generating system would be less than the cost of the smallest possible diesel set - excluding running and maintenance costs.

The advent of solid state devices has done much to lower the power requirements of repeater stations - a solid state two-way 60 channel repeater for example, would require a supply of only 5 amps. at 28 volts DC. a power of 140 watts. A similar station employing valve circuitry would demand a supply of 1 Kw. AC.

Solid state equipment then, would require far less space - conceivably in a weatherproof housing which could be mounted on the wind generator tower alongside the weatherproof battery container. The economics of such a system appear extremely attractive as the need for a building proper would be eliminated completely. Such a system would require a high degree of reliability and it should not appear unreasonable to specify maintenance visits at yearly intervals.

The principle of operation is relatively simple, it being required that the motive unit tunes itself to a random input force - the wind - by means of a hydraulic servo-mechanism and centrifugal governor. In addition, a gearbox would be required to adjust the input speed to the generator and regulator.

Commercial machines favour the medium or high velocities of wind - starting to rotate at 7 - 10 mph, reaching their rated output at 20 - 30 mph and furling their blades at 60 mph.

To satisfy the requirements of a radio relay system calling for a small trickle charge into the batteries - not maximum power - a more suitable machine would start to operate at about 4 mph and reach its peak at 15 - 20 mph.

Wind speed, taken as a mean average, does not vary to any great extent from year to year. Over a period of 31 recorded years on 31 United States Weather Stations, it was found that the long term average did not fall below 12½% of the annual mean speeds.

With the world facing a potential fuel shortage in the not too distant future, it seems likely that wind power will begin to be exploited to a much larger degree.

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A great deal of research has been carried out with fuel cells as a form of energy producer, indeed, recent excursions into space would have been seriously handicapped without them. It is interesting to note that General Electric fuel cells marked the first practical use of this new form of power aboard Gemini 5 and Gemini 7 spacecraft.

Fuel cells are silent, vibrationless and give rise to no exhaust fumes. They are extremely efficient and require no recharging as we understand it and will operate as long as the basic reactants - oxygen and hydrogen - are supplied. The hydrogen may be generated in an apparatus attached to the fuel cell itself. In an ion-exchange membrane cell the required oxygen can be derived directly from the air. Other types operate directly on low cost hydrocarbons such as propane or liquid fuels.

The fuel cell is basically an energy conversion device in which chemical energy is converted isothermally into direct current electricity. In the hydrocarbon/air fuel cell the hydrocarbon is first converted into hydrogen which is then oxidised at the anode or fuel electrode. The resulting flow of electrons, which is collected by the anode, is transferred to the external circuit, thus making up the electric current of the cell. After doing useful work in the external circuit, the electrons are consumed at the air electrode or cathode in a reaction utilising the free oxygen in the air.

The performance of a fuel cell is measured by the following: The current density at which it operates, the voltage, the Kw per pound and per cubic foot and the weight of any ancillary equipment required to operate it.

. . . .

Solar energy is another form of energy that may find a useful application in the field of microwave engineering, always providing that the cost of harnessing it can be brought into realistic proportions.

A great amount of heat and energy is given off by the sun and may be usefully trapped in what are known as Solar Collectors. These collectors are not energy systems in themselves, for they do not convert heat directly into power; but they do provide the heat that may be converted into the production of energy of some other form.

The collectors themselves are divided into two basic types - the flat plate type which is a low temperature device not too well suited for energy conversion - or the concentrator type.

The concentrator type is somewhat more elaborate for it requires special tracking equipment to follow the sun's orbit and concentrate its rays on to a given point. It is capable of producing temperatures up to 3,500 degrees centigrade, which may be used for powering steam turbines, vapour turbines or thermo-electric generators.

Chapter Five.

ENGINE ROOM DESIGN.

In order to obtain a high degree of reliability and efficient running of, the engine room and the layout of the equipment require very careful consideration. The diesel engine and associated generator and control equipment will have been designed and built to the very highest standards, despite this and the exacting inspection and testing it will have had in the factory it cannot be expected to work satisfactorily unless the same care and attention is given to its installation. There are indeed, some very abortive attempts at installation in existence and the subsequent failure of the equipment to function correctly with any degree of reliability and efficiency is more often than not attributed to the manufacturer of the equipment itself. As a result, perhaps, the manufacturer has increasingly begun to insist that his own trained personnel should be contracted to install and commission the equipment.

Basic economy should never be a prime consideration when designing an engine room. The author has had the dubious pleasure of servicing a 1½ Kw generating set installed in an abandoned privy where no door existed and the roof leaked consistently; it was impossible to reach most of the servicing points and, as a result, maintenance was only carried out with the utmost difficulty. On another occasion, I was involved with a 24 hour commissioning run on a 500 Kw standby to mains set in the basement of a large London Bank. On this occasion the engine, generator and control panel had literally been 'stuffed' into a room that was hopelessly inadequate in size and location. Elaborate and complicated arrangements were called for to pipe the cooling water to an outside radiator and the exhaust system had to be seen to be believed. This was a fine example of lack of thought and foresight in the initial stages.

The moral then, to designing an engine room, is to have adequate space while making use of as small an area as possible. Fortunately, with the type of equipment we are discussing, the project engineer will more often than not be asked to design an engine room to suit the proposed equipment.

The internal dimensions of the engine room will depend upon the physical size of the equipment plus an allowance to permit (a) maintenance to be carried out effectively on each piece of equipment, and (b) any piece of equipment to be removed or replaced without interfering with normal operation.

At least two feet six inches should be allowed between each engine and the piece of equipment nearest to it - the physical size of an engine being defined as the distance between its most extreme points. Lengthways this will normally be from the guard over the crankshaft extension to the furthest point on the generator: across the engine it will probably be from the side of the air cleaner on one side to the flywheel guard on the other. The points vary according to the type of engine, of course, but the rule of extreme points should always apply. If the diesel generator set is to be located on a raised cement foundation, which is larger than the extreme measurements of the set, then these dimensions should be used instead. For example, it may be found on some engines that additional space is required during major overhaul work, e.g. if the crankshaft can only be removed lengthwise from the front of the engine, the length of the crankshaft will have to be taken into account at the design stage, and added on to the normal allowance.

If air cooled engines are being used, the air outlet ducting should be kept as short as possible to avoid having to increase its cross-sectional area. Fuel and oil tanks then, should not be placed in a position that forces the engine further than necessary from the wall through which this ducting will pass.

The day running fuel service tanks and extended running oil tanks may easily be mounted on twin racks - one adjacent to each engine - to make a neat and functional arrangement; this may have further advantages in that the fuel and oil supply lines may be run in the same trenches and aid economy both in time and labour. If the tank racks are mounted either side of the engines the width of the tanks plus the width of the engines plus the calculated allowance will give the effective width of the engine room.

The length of the engine room will be decided upon in a similar way, however, it may be considered worthwhile to allow clearance from the starting handle when it is in position rather than from the normal extreme point of the engine. Although it will hardly ever be called upon to crank the engine for starting, it is almost indispensable for maintenance work.

The control panel should be installed in such a position that all the equipment controlled by it may be easily seen by the operator - probably the effective position is with the facia at right angles to the engines. The length of the engine and control panel plus the required allowances now give the total length of the engine room. Before drawing up a plan, a careful check of the dimensions should be made to ensure that there is adequate space to manoeuvre each engine should it be required to remove one at any time for major overhaul.

The height of the engine room will depend on the height of the engine when mounted, plus a minimum allowance for gravity feed between the day service tank and the engine filter plus the height of the tank, plus a minimum of one foot clearance between the top of the tank and the ceiling. As a general guide, a minimum of two feet six inches should be allowed for the gravity feed head. A calculation based on the foregoing figures should give adequate space for the exhaust pipe vertical run and the rising hot air ducting - if it does not, then a further dimension will have to be calculated with this information in mind. In situations concerning the larger types of engines it may be necessary to make allowance for withdrawing a piston/connecting rod assembly. It might further be required to install a lifting tackle above the engine and in this case, the effective height must be considered to be at the lowest point of the lifting tackle.

The design engineer may be asked to locate a work bench and spare parts cupboard in the engine room and, if this cannot be avoided, extra space will have to be made available to accommodate them. An effort should be made to locate workspace and tools elsewhere on the grounds that an engine room is an engine room and not a workshop.

It would be impossible to design a perfect engine room layout due to the large amount of variations of types of equipment and most designs are a compromise between experience and necessity. Let us look at some problems and see why and how they may be overcome in certain ways.

Arrangements for air cooled engines have been discussed in an earlier chapter and it was seen that engine manufacturers lay down adequate details on how to provide and exhaust cooling air in order to keep the engine running at an optimum temperature. Despite this it is not unusual to encounter problems - not the least of which is to find an exhaust pipe discharging sooty smoke adjacent to a cooling air inlet grill. It requires little imagination to realise that 90% of the soot will be drawn into the engine cooling ducts and eventually block them up.

Although most designers seem to build ducts that run out horizontally some very successful vertical outlets exist. They have the advantage of eliminating bends and offering a shorter run, they also make for a much neater installation. With careful planning and workmanship the problems of rainwater seepage through the roof join should not exist at all. Perhaps most problems with ducting arise from the flexible connection between the engine and the rising section; this should always be of strong canvas held securely in position with strong metal clamping strips. At least six inches should be allowed between the two ducts to take up engine vibrations and starting and stopping movement.

The control panel is placed at right angles to the equipment to allow the operator to carry out switching procedures while being able to observe the sets without 'craning' his neck. It may be argued that it is difficult to see the panel meters while carrying out adjustments on the sets themselves; however, in reality, this will seldom be necessary for portable instruments such as tachometers and voltmeters will no doubt be used at such times. With the tendency to miniaturisation, control panels are becoming smaller and the console type is coming into being. With this innovation the operator may face both the panel facia and the engine equipment at the same time - much as a conductor faces his orchestra, from above a music stand. It is not unusual to find an additional panel for the purpose of isolating the main control panel for maintenance purposes. If this is the case, the same must hold good - that it be located intelligently and in such a position that it may easily and readily be operated.

Power cables and control wiring may be laid between equipment and control panels in a variety of different ways which include cable racking or ladders, floor trenches, metal trunking and/or conduits. Each system may be used in combination and it is worthwhile to examine the merits of each method.

Cable racking is normally run overhead and presents a neat and accessible way of running cable from one point to another. They are easy to install and maintain and may be added to at will. Continuous earth connections should be made between each section and the whole eventually connected to the common station earth. On the debit side, it will be seen that cables supported on racking are relatively unprotected from accidental damage, and, as the racks are run overhead, they may obstruct rising pipes and ducts from the engines.

Metal trunking comprises an open box section in continuous lengths with a tightly fitting lid to enclose the fourth side. Special bends, tee's, outlets and reducers are available which allow for a quick and efficient installation. The result is generally very neat and has the advantage that it may be opened up for inspection and addition very easily. Like racking, it needs to be earth connected. Although not fully self-supporting it is quite rigid and requires little extra material for wall or ceiling supports. Cables enclosed in trunking are fully protected from accidental damage.

Steel conduits are often built into the floor of an engine room to carry cables from the engines to the control panel. Such installations will probably be laid by the civil building contractor and very careful control is required to ensure that they are correctly positioned and rise at the right place and at the right angle. It does make for a neat and tidy engine room if done properly, but some very poor attempts are in existence and it should only be employed where reliable contractors and inspectors are available; the problems involved in correcting them after the floor has been laid are obvious. Rigid buried conduit systems are not easily added to, nor is it possible to inspect the cables once they are in position. On long circuituous runs extreme difficulty may be experienced in pulling the cables through. Where such conduits rise from the floor they may be easily connected to flexibles for connection to a vibrating engine. Rigid conduit systems are excellent when fitted to walls for they are neat, quickly installed and may be converted and added to if required.

As with trunking, a great selection of adapters and fittings are available. On exposed conduit runs special pulling boxes or inspection fittings are used to assist with drawing the cables.

Floor trenches or channels are frequently used to carry cables from one point to another, they are neat and practical and permit easy access. They generally take the form of a moulded cement channel the top of which is shouldered to take a chequer plate cover which fits flush with the floor level. In some cases, and where absolute protection from flooding by oil or water is essential, the shoulder may be made deep enough for the cover plate to be lightly cemented in position. In some cases, the type of load may demand that A.C and D.C cables be separated to prevent inductive currents from circulating, in such cases rigid conduits may be laid in the trench to separate the wires or, alternatively, separate trenches may be built. It is not unusual to fill floor trenches with dry sand to protect the cables from small rodents and insects.

Where floor trenches or buried conduits are used they will normally terminate in a pit beneath the control where the cables can rise to their respective termination points. The pit should be adequate in size for large diameter cables require a large bending radius. Any rigid conduits terminating in this pit should have protective nipples to prevent damage to the cable insulation, in addition, all the conduits should be connected to the station earth.

The choice of what system to employ on a given installation will not be difficult, the type of equipment and its situation will frequently determine the most suitable method to adopt. Some very good combinations may be used, rigid conduit may be run on racking for example and each method will readily convert or adapt to another.

When the diesel generator set is built all the control wiring should terminate in a common connection box on the baseplate. If possible, this box should be located at a point that allows easy connection to whichever of the above systems is used. The same should apply, of course, to fuel and oil pipe connections. These should always terminate with a flexible portion which should be long enough to reach to within at least four inches of the floor. (It should be remembered that it is far more practical and economical to carry out such work at the manufacturer's factory than at the installation site).

The use of floor trenches (covered in the same way with chequer plate), to carry oil and fuel lines from the engine to the relevent tanks is good practice also. As before, the trenches may be filled with dry sand which, in this case, serves the additional purpose of insulating the pipes against vibration. Under no circumstances should piping of this sort ever be cemented into the floor. Nor should it be laid on the floor and covered with wooden ramps which are both dangerous and unsightly.

There is no reason why trenches should not carry pipelines below an engine if this offers the shortest and best route, the pipes may be removed if required for there will be adequate space beneath an engine supported on anti-vibration mounts. Some attempts have been made in the past to draw copper fuel line through buried conduits, this method is doomed to failure and should be avoided at all costs for the tubing work hardens badly on the first bend and takes on a decided oval shape on the second. I was once personally involved in trying to talk an authority out of adopting this method and, although he failed to be convinced on the grounds stated above, I eventually won the argument on the possibility of electrolytic action harming the pipes.

An important aspect of design that is frequently overlooked is that of putting the correct slope on pipework. Pipes have to slope for two reasons: (a) to prevent air locks from forming, and (b) to allow condensation to run off. As a general rule one inch in eight feet is adequate for all pipework. Let us examine an engine room and see why the slope is required.

Exhaust Pipe	Should slope away from the engine to allow condensate to run off.
Water header Pipes (To radiator)	Should slope up and away from the engine to assist hot water rise and to prevent air locks.
Hot Air Ducting	Should slope down and away from the engine to allow condensate to run off.
Fuel Lines	These are very important and must slope to prevent air locks. There should never be more than one high point in such a run, i.e. if the

pipe is allowed to sag badly two high points where air locks can form will be created. Wherever possible, the highest point of a fuel run should have a bleed point as at the fuel filter.

Oil Feed Pipes

Air locks may form just as easily in these as in fuel pipes, they should, therefore, have a suitable slope. Where balance pipes are used - such as to balance pressure between an engine and dry sump tank - extra care should be taken. If no balance of pressure is permitted it is possible for the tank to burst, adequate slope on the balance pipe is therefore essential.

The engine starter batteries should be located as close to the starter motor as possible to minimise voltage drop and installed in well ventilated, wooden boxes which have been protected with acid resistent paint.

No discussion of engine room design would be complete without reference to engine room lighting. At least six 100 W. tungsten lamps should be fitted in the engine room - not necessarily where they look prettiest or most symetrical - but where they will illuminate usefully all the different pieces of equipment. Strip lighting of the type that is synchronised to the supply frequency can be dangerous where rotating equipment is operating, (It can make the motion appear to be stationary if the frequencies are matched), and should not be used under any circumstances. At least four outlet sockets should be installed where an inspection lamp can be plugged in, at least two of these should be adjacent to the engines.

Above all, some form of emergency lighting should be provided. This may well take the form of a simple 24 volt D.C circuit fed from two spare batteries. The batteries, which would be maintained fully charged from a charger incorporated in the control panel, would serve the dual purpose of being available as reserve batteries in the event of one set of engine batteries failing.

Plate I.

A typical twin repeater station employing Lister F.R.2. water cooled engines. The layout of the Air-blast coolers, water make up tanks and day fuel tanks can be seen clearly. One of the automatic fuel transfer pumps can be seen to the right of bottom centre.

Engine room layout, installation and photo by the author.

Location - Quibala, Angola. Power equipment for Marconi V.H.F. system.

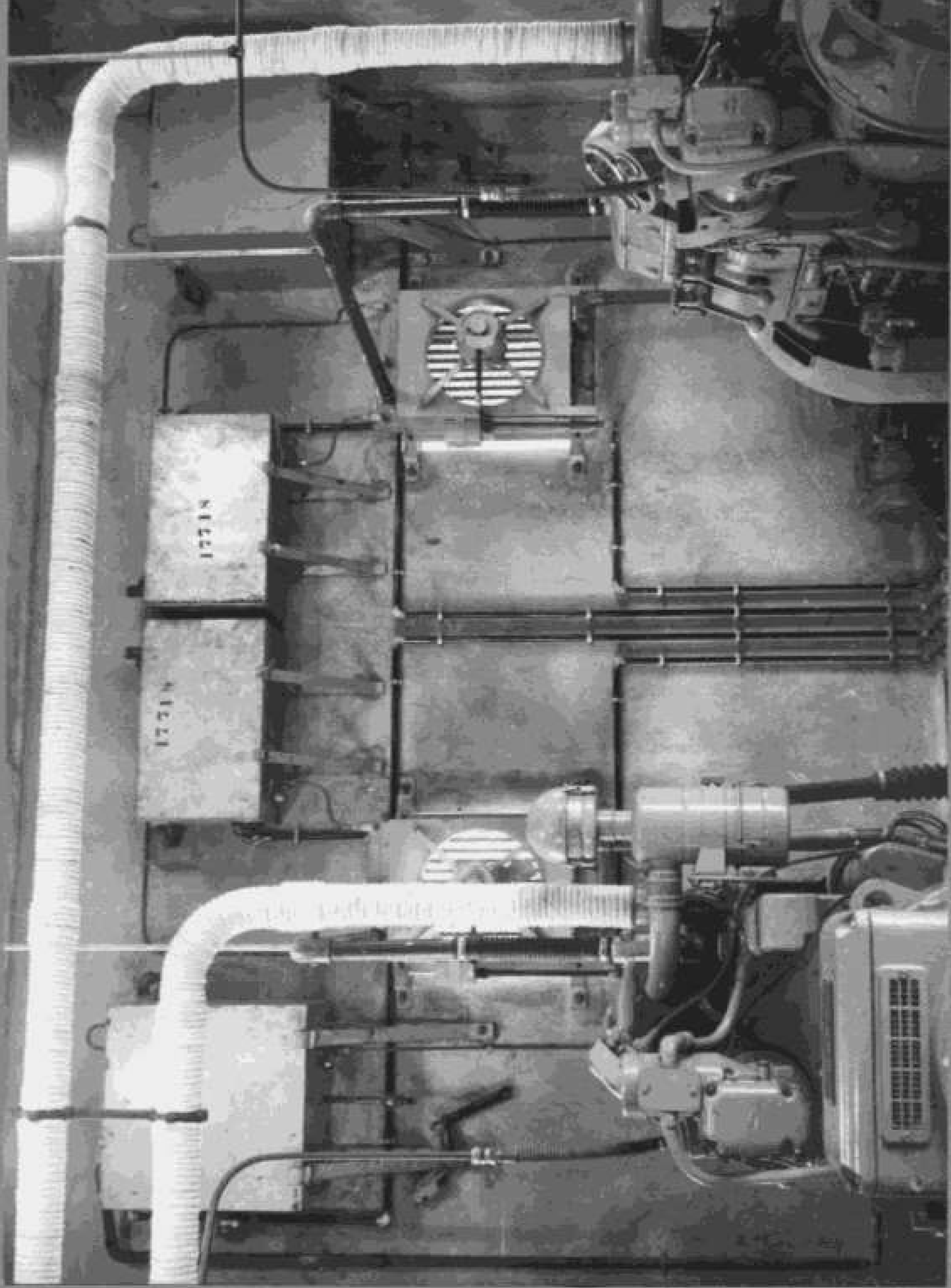
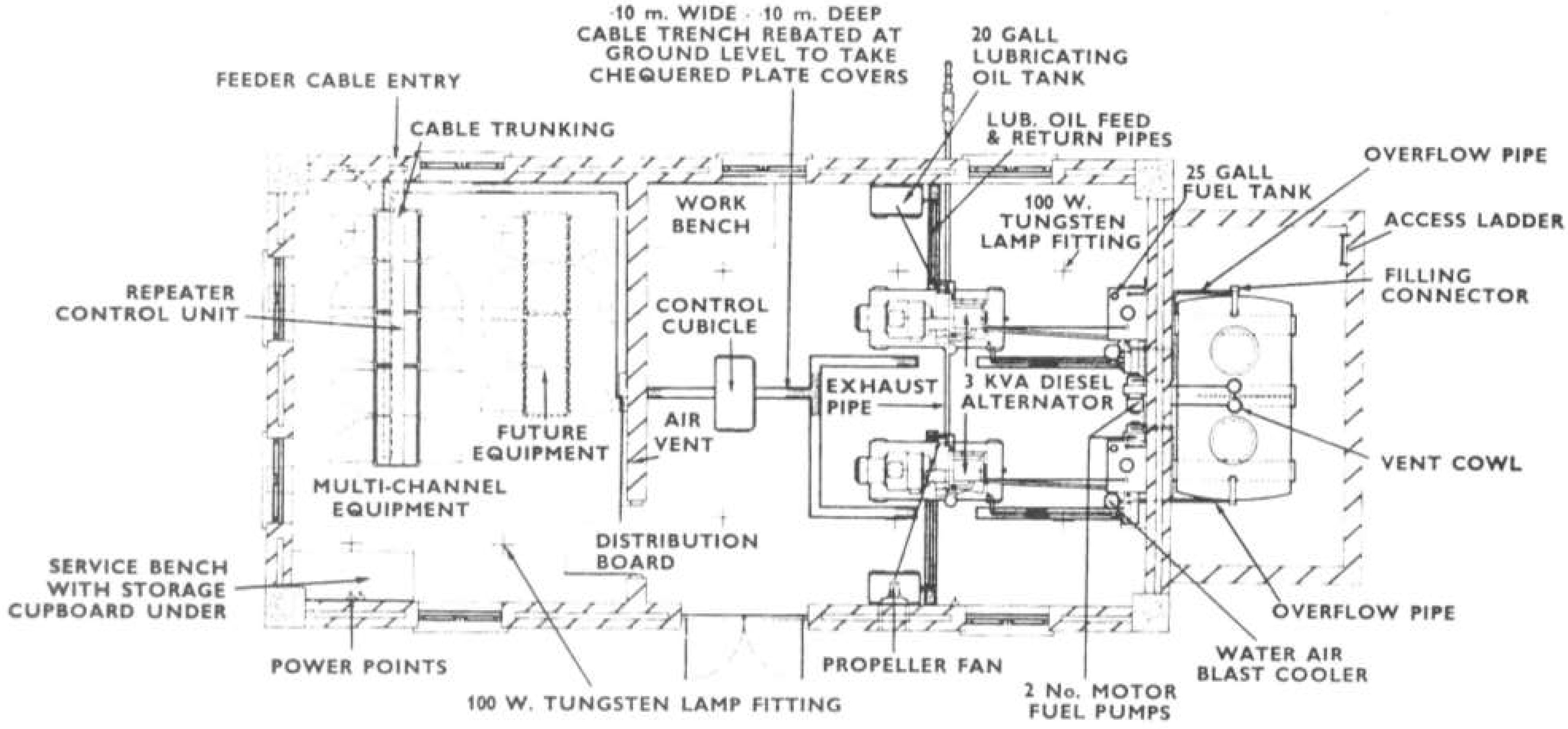


Plate 2.

The engine room layout for the installation shown on plate I.

By kind permission Pelapone Engines Ltd.,
Slack lane, Derby.



Repeater station layout.

Plate 3.

A twin repeater employing Lister H.A.2. air cooled engines. The oil make up tanks with level control valves are seen against the far wall. The neat appearance of this installation is made possible by the use of underground conduits and floor ducts.

Engine room layout, installation and photo by the author.

Location - Nirgua, Venezuela. Part of a 23 station Microwave radio system by General Telephone and Electronics de Venezuela. Power equipment by Auto Diesels Ltd., Uxbridge, Middlesex.

Plate 4.

A typical triple automatic station. Of particular interest are the fully insulated engine foundation blocks. Each one is cast in a cork lined pit and ultimately sealed to prevent the ingress of oil, fuel and water.

Engine room layout, installation and photo by the author.

Location, - Altimira, Venezuela.

Plate 5.

The No-Break set and control panel at Nirgua repeater station.
The first two panels are similar and afford automatic control and protection to engines one and two respectively.
The third panel provides common control and bye-pass facilities.
The last panel provides supervision and auto control for the No-Break equipment.

Installation and photo by the author.

Location - Nirgua, Venezuela.

Plate 6.

A triple automatic control panel showing the engine protection and supervisory facilities. A novel feature of this panel is that it forms a dividing wall between the engine room and the adjoining room. The large control switches on the two end panels have locks to prevent operation by unskilled personnel.

Installation and photo by the author.

Location - Altimira, Venezuela.

Plate 6 B.

Back of board view of the Altimira triple automatic control panel with inspection doors removed.

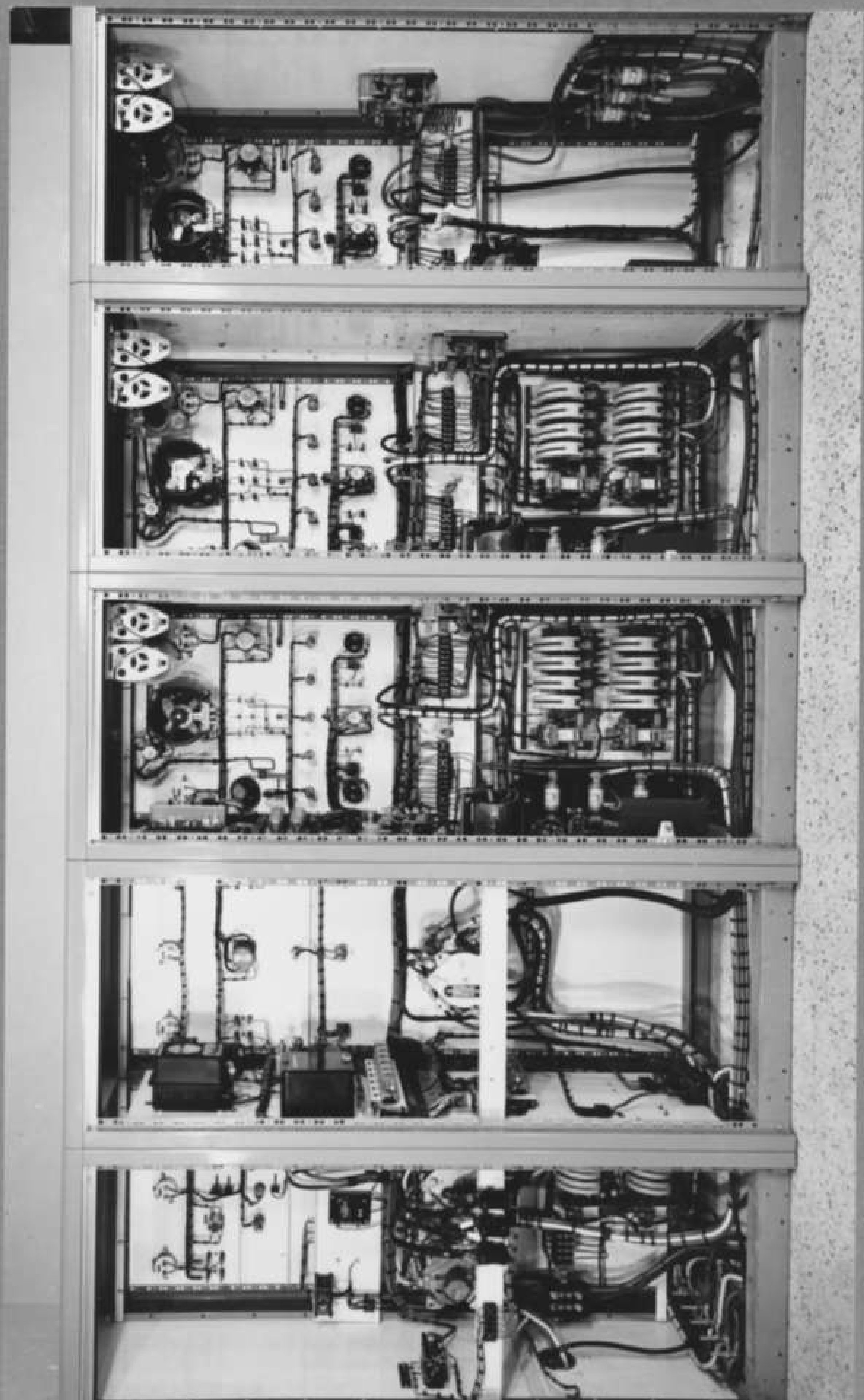


Plate 7.

A triple automatic generating station providing power for defence system communications in S. America.

Engine room layout, installation and photo by the author.

Location - Estancia, Southern Chile.

Power equipment designed and built by Dale Electric Ltd., Filey, Yorks.

Plate 8.

A 250 K.V.A. Standby to mains set on the Chilean defence system. This equipment is fully automatic and arranged to start up and assume the load in the event of an out of limit variation in the mains supply.

Engine room layout, installation and photo by the author.

Location - Estrecho, Southern Chile.

Power equipment by Dale Electric Ltd.

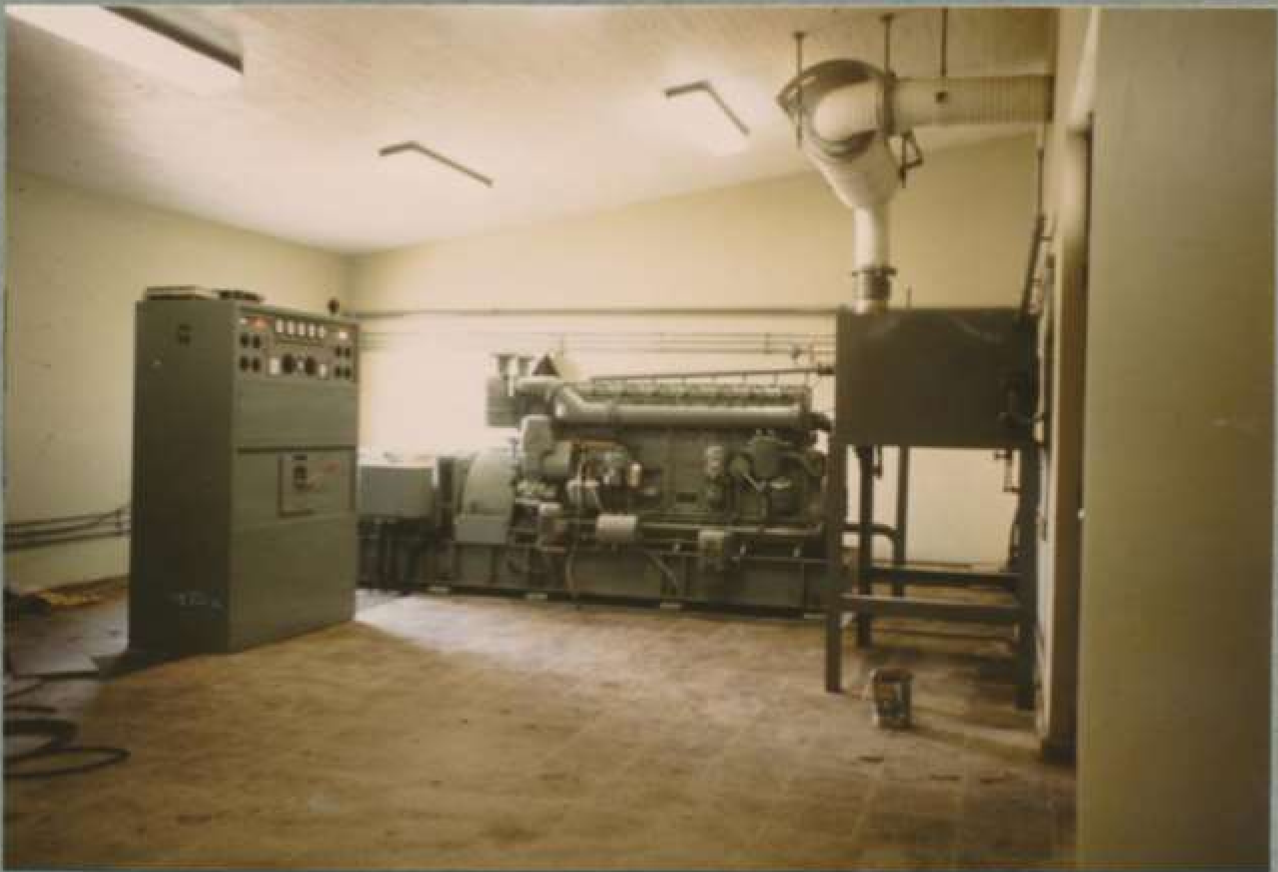


Plate 9.

A simple manual control panel of the type used to supervise and monitor an attended generating set. This is one of six built by the auther for the Newfoundland and Labrador Power Commission.

Photo, the author.

Location - Port aux Basque, Newfoundland.

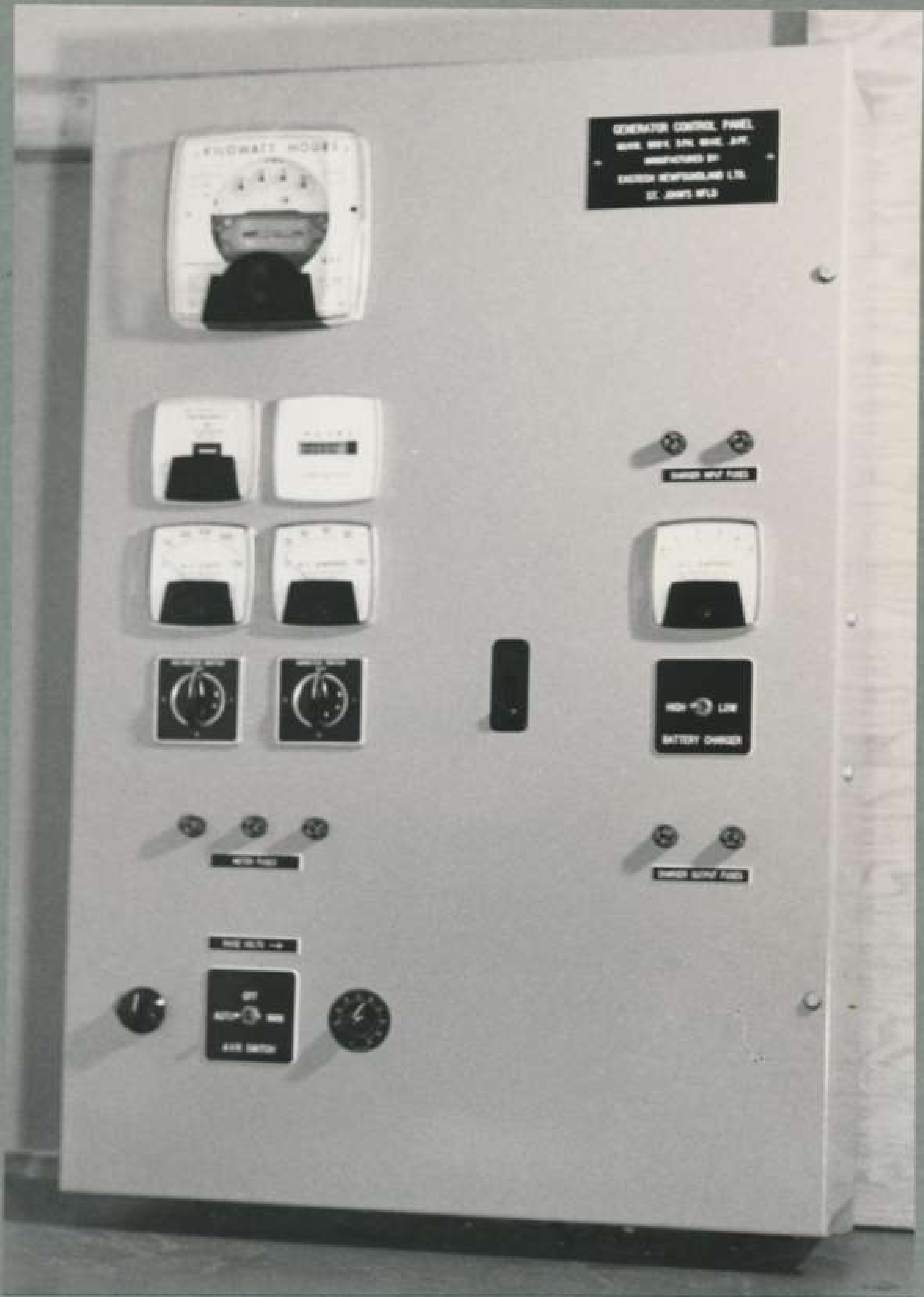

GENERATOR CONTROL PANEL
KILOWATT HOURS
HIGH LOW
BATTERY CHARGER

Plate 9.B.

Interior of the manual engine control panel shown in plate 9.

ACKNOWLEDGEMENTS

It has been my pleasure to have worked very closely with many companies and suppliers of diesel power equipment in positions ranging from installation supervisor to managing director.

I owe them all a big debt of gratitude for I gained much valuable experience and enjoyed at all times a very happy association.

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Compania Annonima National Telefonos de Venezuela.

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Newfoundland Light and Power, St. John's, Nfld.

Armadas de Chile, Santiago de Chile.

Maritime Tel. & Tel., Halifax, Nova Scotia.

United States Air Force.

Central Electricity Generating Board, U.K.

B I B L I O G R A P H Y

Lister Data Book 285

R. A. Lister & Co., Ltd., Dursley, Gloucestershire.

Audels Diesel Engine Manual

Theo. Audel & Co. New York.

Hydrocarbon-Air Fuel Cell Systems.

C. Gordon Peattie. (Texas Instruments Ltd).

Developments in Energy Conversion Devices

H. K. Bourne.

Further thoughts on Generating Small Electrical Energies

J. B. Goodacre.

The Selection of Nobreak Power Systems.

M. A. Thomas and D. E. Holland of M. A. Thomas Associates, Consulting Electrical Engineers, Vancouver, Canada.

Marconi 'Point to Point'. Feb. 1964, Vol. 8, no. 2.

Article by P. A. Sachs, M.A.

Engineering Magazine. Vol. 212 November 72.

Diesel & Gas Turbine Progress Magazine. June 1972 and August 1972.

AB Volvo Penta Output Standards. Pub. no. 1573B.

Pelapone Ltd., Technical publication 6/64/T2-12.

Marine Diesel Engines, C. C. Pounder. G. Newnes Ltd.

APPENDIX

British Standard Specification 649-1958.

B.S 649-1958 includes diesel engines for all purposes with the exception of ship propulsion.

All mechanically driven auxiliaries required for engine operation are to be included with the exception of the cooling fan in the case of liquid cooled engines.

Standard Operating Conditions:-

Mean barometric pressure: 749 mm Hg.

Air temperature: 29.4 degrees centigrade.

Humidity: 15 mm Hg.

Continuous Output, Rated Output: The net output which the engine is capable of delivering continuously at a stated crankshaft speed under the conditions stated above. The engine must be run-in and in good condition.

Intermittent Output, 1 hour Rating: The engine shall be capable of satisfactorily providing an output 10% in excess of the continuous rating at the same speed for one hour in any period of twelve hours continuous running.

For Derating, B.S. 649:1958 stipulates the following:-

For engines which are normally aspirated or fitted with mechanically driven pressure chargers, there is to be a derating of 3½% for every 1,000 ft. in altitude over sea level above 500 ft. and for engines which are exhaust turbo-charged the corresponding derating is 2½%.

For every increase in air inlet temperature of 5½ degrees C. (42 F.) above 30 degrees C. (85 F) there is to be a derating of 2% for normally aspirated engines and those fitted with mechanically driven pressure chargers; 3% for engines which are exhaust turbo-charged and not fitted with a charge air cooler. Should a charge air cooler be fitted, there should be no derating for air temperature but a derating by 3% for every increase of 5½% degrees C. (42 F.) above 24 degrees C. (75 F.) in the temperature of cooling water at the inlet of the charge air cooler. For derating concerning air humidity see relevant table which shows a highest derating of 13.4% at 100% air humidity and an air temperature of 51.5 degrees C. (125 F.)