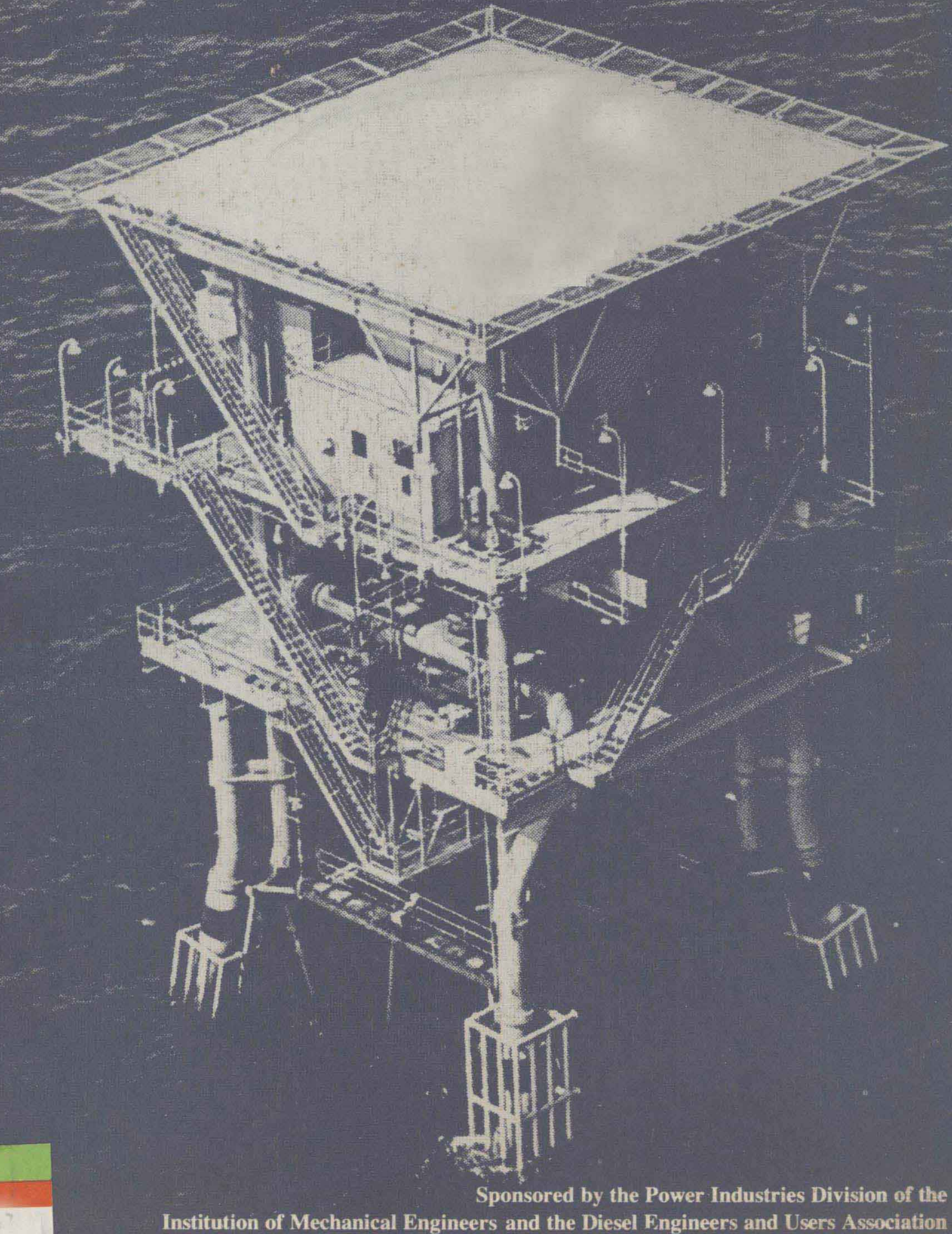
Power Plants for Offshore Platforms



Sponsored by the Power Industries Division of the
Institution of Mechanical Engineers and the Diesel Engineers and Users Association
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I Mech E 1981-11

POWER PLANTS FOR OFFSHORE PLATFORMS

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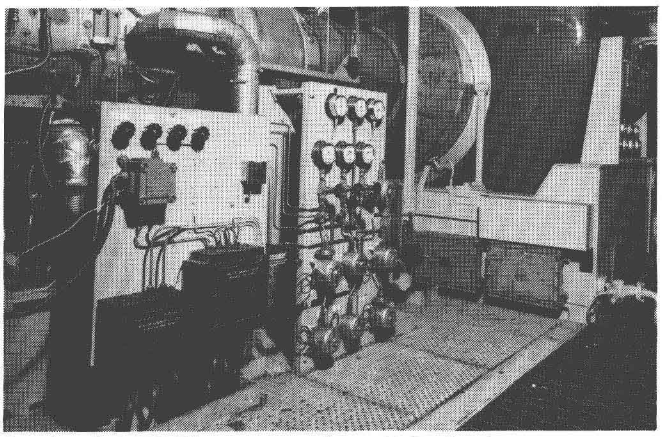
GEC Gas Turbines Limited

Over 490 machines in service or on order have firmly established the reliability and efficiency of GEC Gas Turbines power plant.

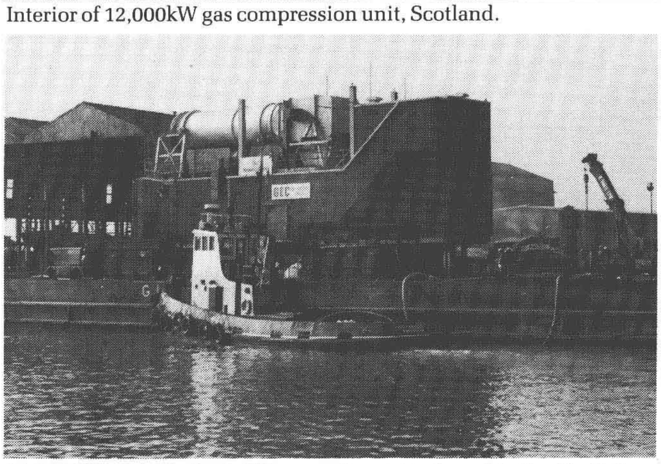
Proven in extremes of climate and duty, the range includes aero derived units from 10 to 80 MW, heavy duty machines from 6 to 80 MW simple cycle and up to 115 MW combined cycle with modules up to 350 MW using multiple gas turbines. Also available are single lift power modules specifically for between decks or top deck mounting on offshore production platforms and 10 to 22 MW mobile power stations. Whether you want to generate electricity, power a pipeline, gather gas, re-inject, or just provide standby power, GEC Gas Turbines can supply the equipment you need when you need it.

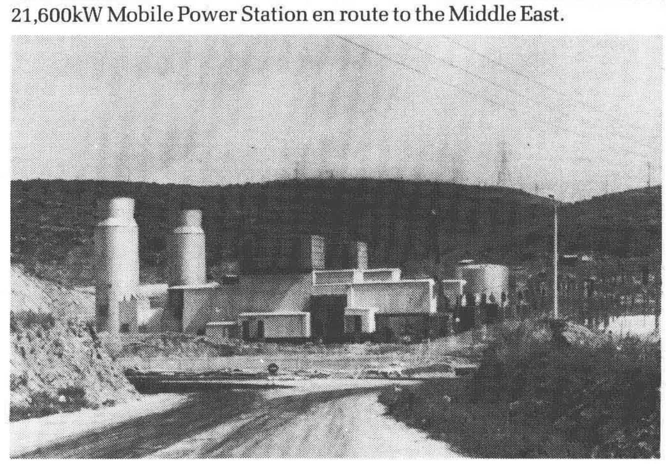
	Power-MW (ISO)	Speed-Rev/min
EM85	6.6	5100-6300
EAS- 1 Range	12.1-17.0	6500
ESP-1	12.0-13.2	6700
ERB-124	21.1-22.6	6500
EO-1/DEO-1 Range	21.6-54.8	3000/3600
EO-2/DEO-2 Range	29.4-82.0	3000/3600
ELM-125 Range	20.3-21.6	3000/3600, 6500
ELM-150/DELM-150	32.1-72.5	3000/3600, 4300
EM610	63.1-81.7	3000
EM610, Combined Cycle Range	118-355	3000

Base ratings at power turbine coupling, peak and EM610 ratings at generator terminals.


Interior of 12,000kW gas compression unit, Scotland.

21,600kW Mobile Power Station en route to the Middle East.


15,000kW top deck single lift generating set in transit to the North Sea.


Two 57,000kW generating sets supplied to Greece.

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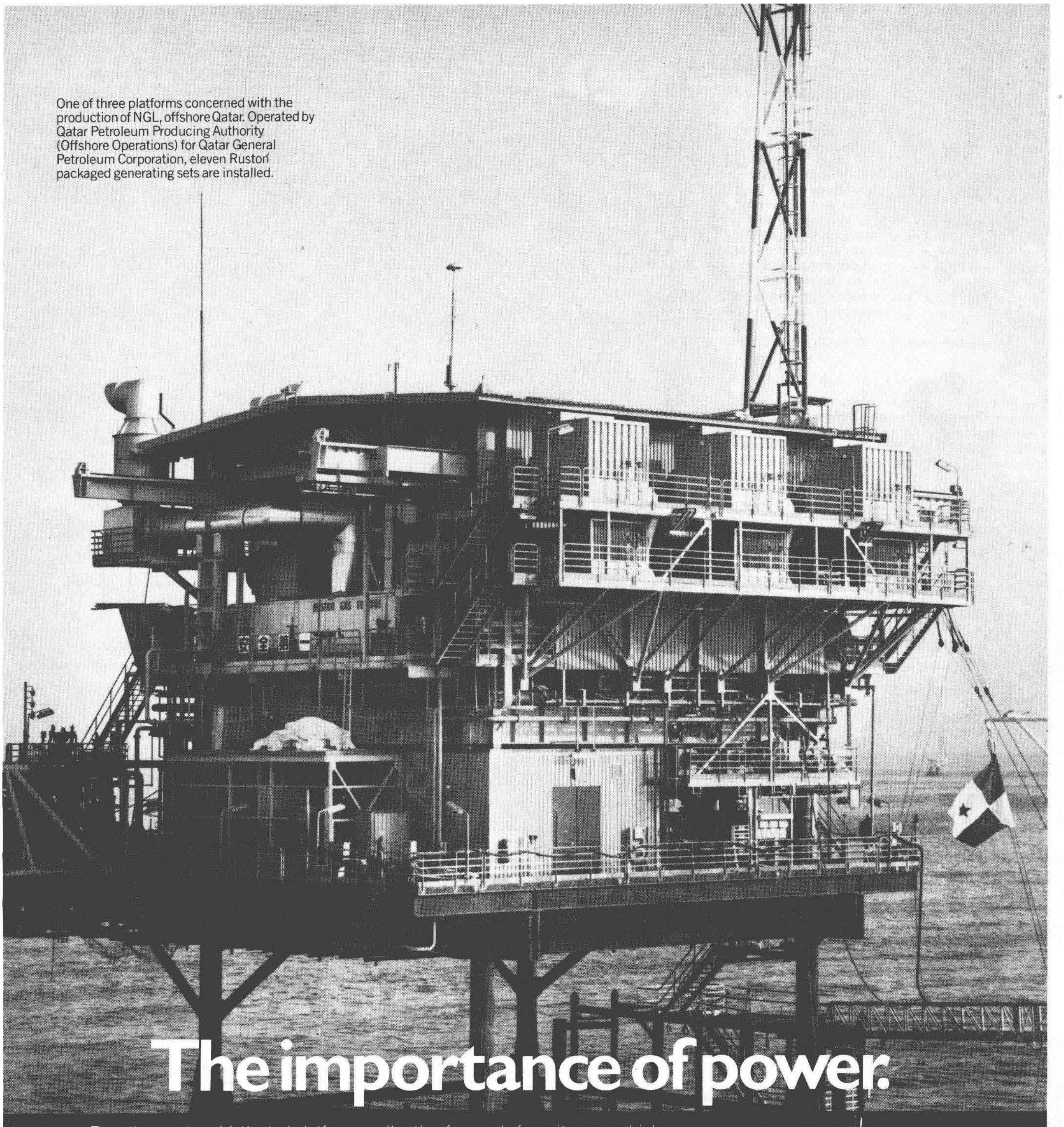
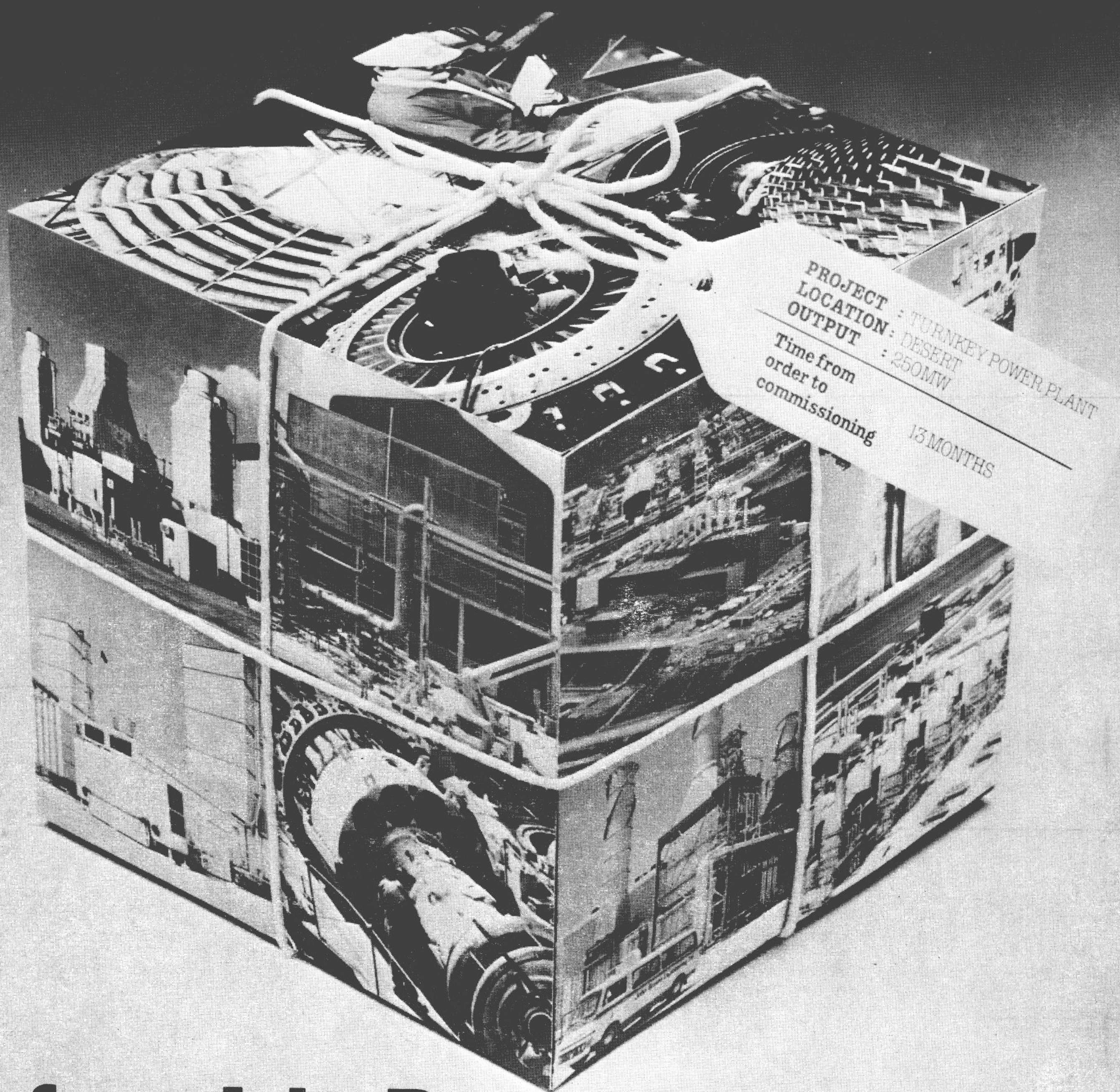


One of three platforms concerned with the production of NGL, offshore Qatar. Operated by Qatar Petroleum Producing Authority (Offshore Operations) for Qatar General Petroleum Corporation, eleven Ruston packaged generating sets are installed.

POWER PLANTS FOR OFFSHORE PLATFORMS

A POWER PLANT PACKAGE



CONTENTS

C235/81

Aspects of the choice of prime movers for offshore platforms

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SYNOPSIS This paper explores areas which affect the operator and the platform designer in the selection of prime movers. It covers areas such as the electrical load curve, Electric Generation versus Direct Drive, platform location and package design.

INTRODUCTION

Keen observers of the design of oil platforms in the North Sea would have seen several changes of approach in the selection of prime movers on platforms and it is interesting to note what happened in the early days.

In the early stages, the drilling rigs and small production platforms employed the smaller gas turbines for the main generation, and the compressor and pump-drives tended to be in the few thousand horse power size. The operator's previous experience with diesel engines had encouraged him to keep to small units. The limitation on space has changed this and except for Emergency Diesel Generation, the size of prime mover required has made the gas turbine and electric motor the predominant choice.

Space on platform is now quoted at £10 000/m^2 and in some critical areas of the platform £30 000/m^2. This is not the only criterion for selecting the right equipment for the platform, but it can settle the priorities when space and weight are of such prime consideration and cost.

Also, the impact of long commissioning periods in the final stages of building the platform, has made the platform designers insist on as much 'packaged' equipment as possible, together with the maximum amount of testing being completed prior to going offshore.

Lifting equipment is much larger than ten years ago, and the lifting barges can operate under worse weather conditions than before. The result has been a definite move to fully tested packages which can be lifted on to the platform at the later stages of construction. It is worth exploring a number of the areas which affect the platform designer, in his selection of gas turbines for a particular oil platform.

Platform Energy Requirements

Basic Planning

It is important to consider the load requirements over the whole life of the field, and the fuel gas available. Once the operator has defined at what rate he will recover the oil, other power loads fall into place. Gas reinjection, water injection and oil pumping capacity represent a large portion of the electrical load and the power required for these main items usually decides the total platform load. Obviously these requirements involve the geologists who make their estimates of the size of the field - but it can be assumed that the operator would have completed these calculations prior to this assessment.

British Government regulations do not allow associated gas to be flared now, so there has to be gas reinjection if there is any spare gas after providing for the gas turbines, but a number of new fields in the North Sea only have a few years in its total life span when there is sufficient gas to power the platform. So the gas available has a big impact on the type of units selected and in particular at the beginning and the end of the life of the field.

Other fields, e.g. Statfjord in the Norwegian sector, have a high gas to oil ratio and so the gas is reinjected back into the oil field. This absorbs power and puts up the power demands on the platform, although in a way, there is less pressure on the operator to buy 'high efficiency' gas turbines, as more gas is consumed per megawatt of power generated and so need not be reinjected back into the oil field.

However, this is the area of the larger units such as the Rolls Royce RB211, the Pratt and Whitney FT4 and the GE LM2500 and LM5000, hence large high efficiency blocks are possible. The slight disadvantage is the requirement for higher fuel gas pressure. (Usually no problem in a high gas/oil ratio field).

Total Power Generation Versus Direct Drive

This question is often brought up as though there is a simple solution. There are a number of gas turbine units available around the 3000 kW power size, so a direct drive is possible for compressors etc. at this power and above. Below 3000 kW most platform designers favour multiple electric drive. Since there will be a need for electric generation anyway, there is an advantage in just increasing the size of the main power unit and having an electric motor drive where possible, where the larger units tend to be of higher efficiency; but direct drive units have their advantages, in particular for the smaller platforms and for platforms where the power requirements build up slowly over the life of the field and it is easier for the operator to install another power unit package later. When the reservoir information is limited, this gives the operator the advantage of being able to uprate his compressor and pump requirements and the field develops. Smaller units are easier to handle although multiple exhaust stacks can cause difficulties, in particular with the platform structure and the helicopter flight path.

Aero-Derivative Gas Turbine Versus Heavy Industrial Gas Turbine

A final factor is the type of gas turbine that is selected for the main generation system. The majority of the big power units for the North Sea in the 20 000 - 30 000 hp range now being selected are aero-derivatives. Not so much for their high efficiency, but for the quick turnaround that can be achieved should the gas generator require servicing. It is claimed that a new gas generator can be installed in 8 hours. Difficult to achieve as a spare gas generator does have to be available on that platform to meet this claim. Some operators who have several platforms in the North Sea only hold one spare gas generator onshore, counting on the vendor supplying an additional unit if the operator is unfortunate enough to require that second gas generator. A 24 hour changeout is more realistic if it is an unplanned shut-down.

With the right maintenance equipment available, the heavy industrial could match these times and even better them, assuming the full change-out facilities are available, but the swing to aero-derivative type offshore has been quite strong in recent years and analysis of the reasons would be helpful. The claim for higher efficiency and ease of removal of the gas generator is the normal one, although it should be noted that the efforts of the operator and the platform designer to provide a good quality fuel should not go unacknowledged. Also, the low sulphur content of North Sea crudes and hence a high quality fuel gas has been a major contribution to this decision.

Total weight is a big factor, and one which cannot be ignored. In the 25 MW range probably an 80 ton advantage to the aero-derivative is a big enough difference to be taken into account.

If the fields had resulted in a fuel with a high sulphur content, then the dangers of corrosion damage would have been too high a risk to take and the industrial machines would have been selected. This raises another interesting point. The next generation of platforms may not be fixed in the sea bed. For example, the Tethered Leg Platform being engineered for Conoco by Brown & Root is a floating platform and although it is planned for operating in 200 metres of water in the North Sea, it could be used in up to 650 metres of water, and could be installed in a number of areas of the world.

So in the future, operators may look to machines which can tolerate a wide range of fuels. Vendors who insist on their customers burning high quality fuels before issuing their warranties may discover that platform designer will not be so accommodating in the future. The designer may insist on machines that can accept a wide range of fuel qualities both on calorific values and levels of impurities. This would turn the balance towards the heavy industrial gas turbine or else the operator would have to consider installing more sophisticated fuel treatment systems on the platform.

Platform Location

As stated earlier, an important factor which a platform operator must bear in mind is the shear volume of ducting involved. The exhaust ducting, rather than the inlet ducting has a greater impact, as the position of the exhaust plume can affect the helicopter landing area - the helideck. Time and time again, the problems of the exhaust stack becomes a major headache in the planning of the layout of the platform, which usually ends as a balance of the 'least worst' combination of the approach paths to the helideck for the helicopters, and the exhaust plume in the prevailing winds. It is important to carry out detailed wind tunnel tests in order to select the right configuration.

In the past, there have been vertical exhausts, horizontal exhausts, even those facing slightly down and under the platform, but the configuration that most people accept is the vertical one, usually about 20 metres above the weather deck. The impact of noise on the men in the accommodation modules cannot be ignored, and government regulations may cause operators to re-think their attitudes to noise attenuation. Retrofitting noise attenuation is very expensive and not always effective. Top deck mounting of the gas turbine is a disadvantage for noise attenuation as the gas turbines tend to be alongside the accommodation modules except that the highly directional high frequencies from the compressor stages are 'aimed' out to sea, away from the platform

Load Curves - See Figure 1.

This does not represent any particular field but quite a few have this kind of profile and it can be used to show how the platform designer decides on the power system.

Drilling

By tradition, the electrical load for drilling is usually supplied by several diesel units, is independent of the main platform power and is usually 60 Hz. This is changing as the operator realises the advantage of inter-ties. For example, some new fields are now going to a totally 50 Hz system including the drilling equipment. Some electrical engineers still object to the sharp d.c. spikes that can be imposed on the main load by drilling equipment, so there are still good reasons for keeping them separate.

Commissioning

The early stages of the production Phase I only require a few megawatts - often 10% of the main load. If this load occurs before gas is available, then there is a need for diesel fuel. This causes some difficulties as the diesel fuel has to be brought out by supply boats. This suggests either a multi-diesel generation system or a small gas turbine or running the main power system at low load. A large number of diesel units would take up valuable space. The drilling diesels could be over-sized and could provide the power, but this is the critical time for drilling and it is important to keep the drilling schedule going. Usually it is small gas turbines versus the big units on part-load. This example illustrates the impact of 'efficiency' on this choice.

Example

One year operation at 30% thermal efficiency at fuel cost of $50/barrel for 3 MW of power (small machine) = $2.57 million. One year at 15% thermal efficiency 3 MW (large machine) = $5.14 million. Gives a fuel cost difference = $2.57 million.

This ignores the storage costs which have to be built into the platform at the construction stage. This cost saving would pay for the cost of the small 3 MW unit.

Full-Load Production

This is the phase of power requirements that receives the most attention and often the cause of a great deal of argument. One of the biggest areas of concern that the power system designer faces is the over-sizing of individual pieces of equipment, and the temptation to go up a frame size with the electric motor.

Conservative assumptions are made on the sections of the equipment which are operating at the same time; a contingency is added to the total, and the total load is way in excess of the actual operating load. It is little wonder that certain vendors can claim long life for their generating equipment. Some units are very lightly loaded !

The relationship between the total load and the number of units required is often a reflection of an operator's caution and the attitude towards 100% spare capacity has changed. Many platforms now go to 50% spare capacity of main power, i.e. 3 units of 50% capacity, but the pressure on the constructor and operator has increased over the years. It is realised now that if the type of electrical load is looked at in detail, a change of emphasis will even lower the total installed capacity that is necessary. It is possible to have less than 50% spare capacity and still be able to predict high availabilities.

For example, water injection does not have to be continuous, and some operators are saying that provided the pumps are not stopped for more than several weeks at a time, and the total water injected for the year is still maintained, then there is no major change in the recovery characteristics of the oil field.

Technical references such as Heard and Lang's paper (Reference 1) on the concept of availability for evaluation have developed useful probability formulae which can be used for comparing the size of the units, their availability factors, and their planned and unplanned maintenance times.

For example, calculations can be made assuming a specific number of units will shut down over the life of the platform. The fraction of time can be calculated by defining the total number of combinations of K units which shut down in a total of N units, and also by calculating the probable time periods for possible combinations of K units being shut down. 'A' is the availability factor for a unit. This gives the fraction of time P that a specific number of units can be expected to shut down.

$$P = (N! / \{K!.(N-K)!\}) \times (\{1 - A\}^K . A^{(N-K)}) \quad (1)$$

When the units are identical in size and assumed availability, which they are, when the design for a new platform is being studied, then the total average annual power is equal to the average unit availability.

The formulae should be applied with caution, as below a certain power level the process will not be able to operate, and the probability factors will be distorted. The formulae are useful provided the operator and the contractor has useful availability figures obtained under similar conditions offshore, but the same figure can be assumed in calculations when comparing the advantages of different size units for a particular platform load. Other probability formulae take into account planned and unplanned down time and their impact on availability, and hence the output of oil from the platform. These formulae are very sensitive to changes in availability. These figures are a direct reflection of the maintenance programme applied to the machinery.

The need for high efficiency is important, and if there is not sufficient gas in the marginal field for the gas turbines throughout the life of the field, then high efficiency machines will be even more cost effective. At the moment, there is a great deal of pressure being brought to bear on the operator by governments not to waste fuel during operation. Therefore some of the arguments in favour of selecting the machine with the highest availability tend to suffer, as the older, more reliable units have tended to be less efficient.

Run Down

The last stage of the life of the field is the hardest to predict, and yet it has to be taken into account. The latter phases of the oil extraction may alter the decision. For example, in the Statfjord field in the Norwegian sector, it is predicted that gas re-injection will have to cease after 5 to 8 years and the gas must be either flared or piped ashore as the oil field cannot tolerate reinjection any longer. This will change the operating mode both during the 'plateau' period and the run down period. The need to send the gas ashore will alter the nature of the platform's operation, and alter the load curves as well.

However, when the gas/oil ratio is falling, then the operator must try to use as much gas as possible without flaring, and consider the use of liquid fuel. This means purchasing equipment which has 'double fuelling' as one of its operating modes.

Package Design

Figure 2 shows a single lift design with the control room mounted over the alternator and fully weatherproofed for top deck mounting. This is an example of an up-to-date offshore power system, which can be full load tested and requires minimal hook-up offshore. Figure 3 is a picture of the gimbal feet, which are required for 3 point mounting.

The design of the main generation system have changed with the changes in platform design. Some say that the days of the large production platforms which are fixed to the sea bed are numbered, as operators go for large floating platforms, such as Conoco with the Tethered Leg Platform for the Hutton Field. It is, however, too early to say, as these designs do have additional problems. As there are large air intakes, which are light weight, the gas turbine can be sited on the edge of the platform, with the air intake cantilevered over the side. However, this generates a significant overturning moment on a floating platform, and is more severe than that for equipment mounted in the centre of the platform, but saves space. This puts a great deal of pressure on the platform designer to specify a 'lightweight' power package. Another factor which pushes the design into a single package is the pressure on the operator and constructor, to build the platform as quickly as possible with the minimum of offshore 'hook-up' work being required. The problems of solving commissioning problems offshore are sometimes quoted as 5 times the cost and 2-3 times on 'time delays'. Often platforms are designed so that the gas turbine packages can be lifted on to the top weather deck as a complete unit and most of the exhaust ducting being added after load out. Exhaust ducting can be a problem as the waste heat recovery systems are mounted over the gas turbine.

This design 'shift' has put more structural responsibility with the gas turbine suppliers and an involvement in the interfaces with the foundation and the overall structure design calculations which, until a few years ago, the gas turbine packagers had not been asked to do. Originally most base-plates for the prime mover have been separate from the base-plate of the driven equipment and platform designers have been expected to give them a 'fixed' under base with little or no operational misalignment - some gas turbine vendors often request 1 in 1000 alignments for their multi point mountings. This is not possible because of the massive weight penalties in providing stiff decks.

Single structures such as continuous base plates or the Warren Truss design are now specified with the 3-point mounting system isolating the package from the main platform. Compressor drives obviously have different emphases but the basic principle is the same.

Conclusions

Many vendors in the North Sea take great care to underline that their units are standard, and proven offshore. Platform designs are changing, and it is important to be aware of the increase in use of on-board monitoring systems which record various parameters in the machines and allow the operator to study vibration levels - bearing and oil temperatures, pressures and also to observe various trends. Given the right type of information from the equipment supplier, the operator can predict when a failure could occur and so take preventative action.

Other papers at this conference are expanding on this area of maintenance, but it is important to bear in mind that the operator is installing more than a piece of hardware. He wants to keep his whole platform alive and healthy, and he wants his experience and the vendor's experience to grow, hopefully not too traumatically, and the data he gains from the day-to-day running and the condition monitoring systems will enable him to plan his maintenance programmes. It is possible to predict that more and more operators will look beyond the 'standard machinery' argument and will buy machines with more sophisticated instrumentation which will give him a better 'feel' for what is happening to the machine. Vendors who offer machines which cannot adapt to these requirements may find the operator and platform designer attracted less and less to the offer of a 'standard' machine which may not be able to provide information and prediction of life of individual components within the package.

Therefore, what conclusions can be drawn from all these points. The sheer cost of building a structure for the production facilities had made the operator and platform designer still very keen to buy prime movers which are demonstrably reliable, and can fit into the smallest space with the minimum of problems at the commissioning stage. The maximum amount of testing onshore means the minimum of offshore problems. Unplanned delays at this offshore commissioning stage can be very time consuming and expensive and could cause the operator to postpone the start of the production phase.

A better understanding of the platform designer's problems is essential. The gas turbine manufacturers must use the information gathered from the earlier platforms in their subsequent designs, so that mistakes will be avoided. The best results can come from an 'openness' at the preliminary stages of design, and just as important, an openness at conferences such as these can achieve a great deal.

Reference

(1) Heard T.C. and Lang R.P. - The Concept of Availability for Gas Turbine Application Evaluation. ASME Publication 78-GT-140 for ASME Gas Turbine Conference London 1978.

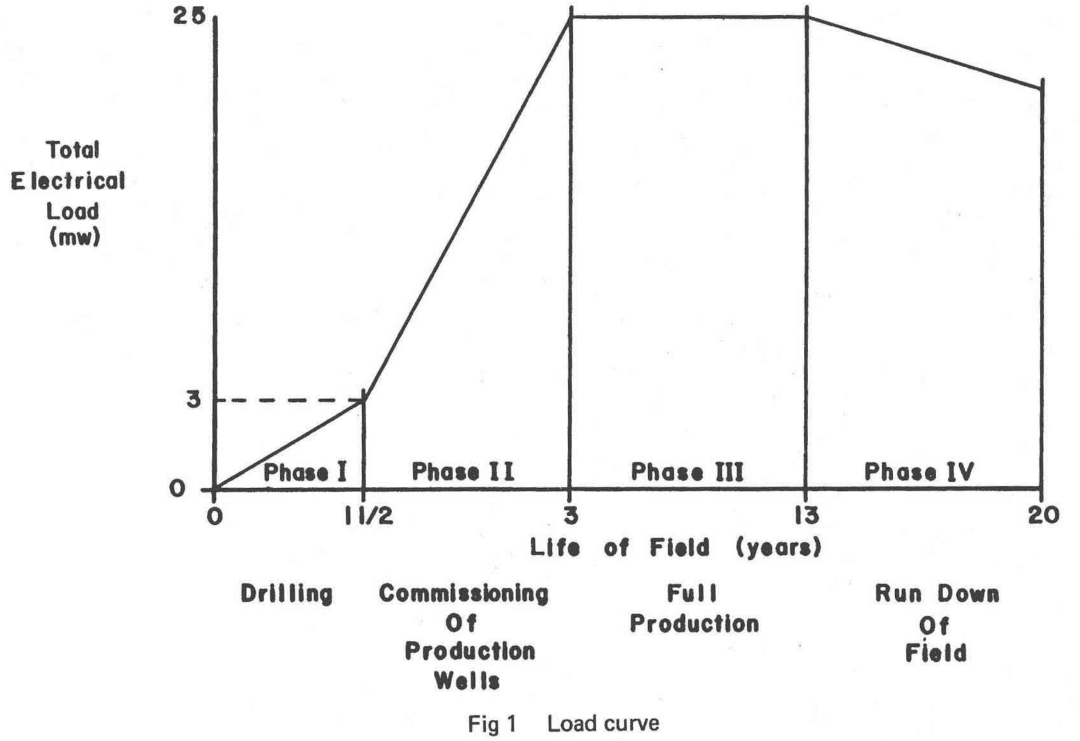

Fig 1 Load curve

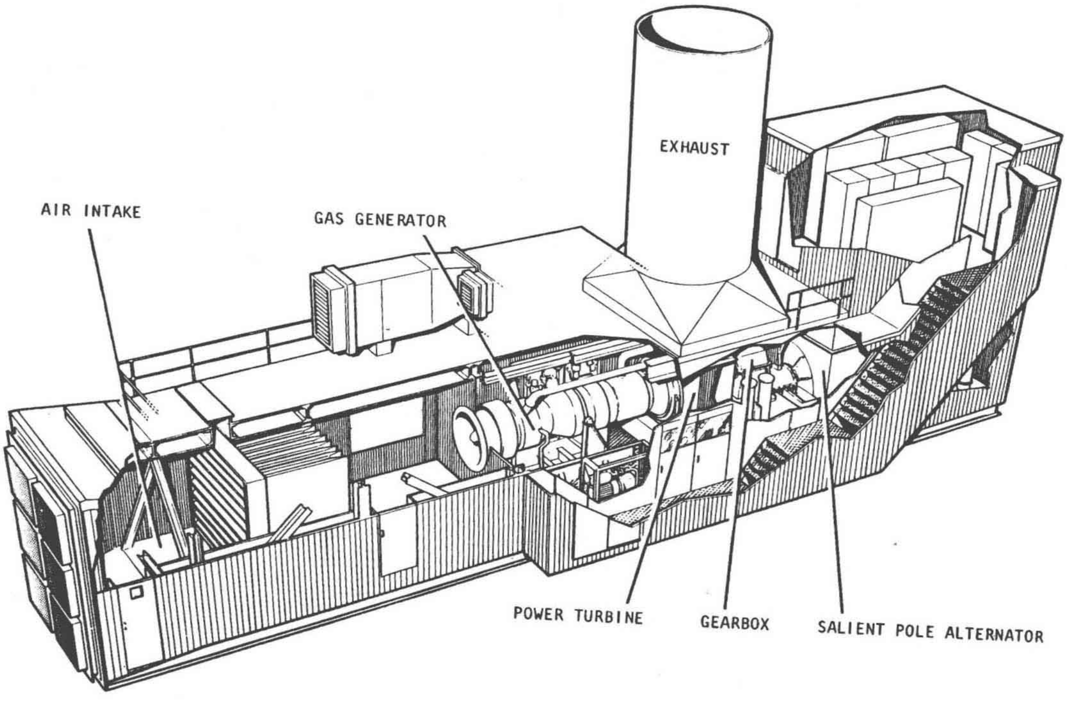

Fig 2 Single lift top deck mounted machinery module

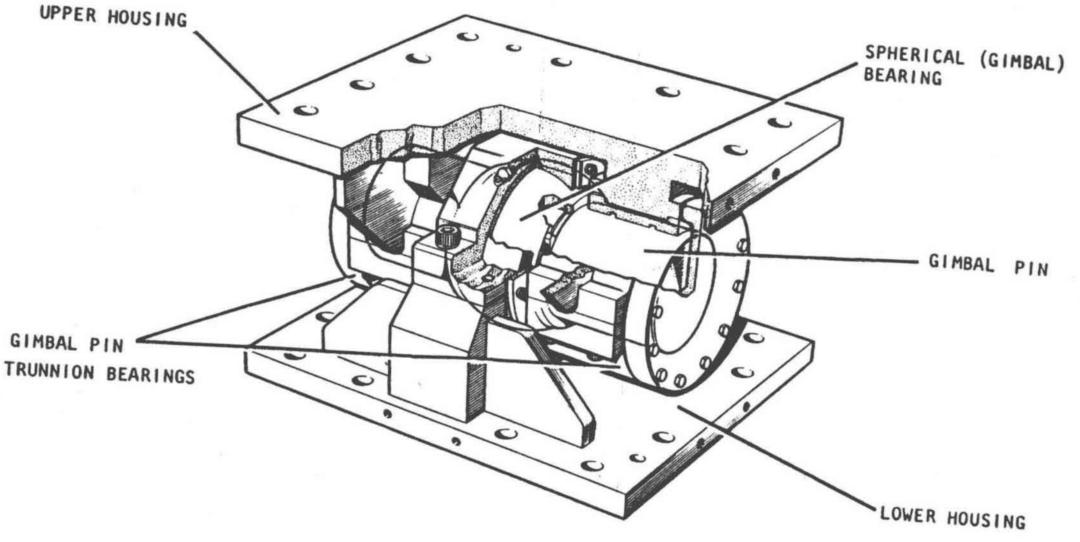

Fig 3 Gimbal feet

C236/81

The application of high power diesel engines to offshore platforms

D F TURNER
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SYNOPSIS The recent up-grading of fire-fighting/platform cooling requirements and the necessity to increase the power output of emergency generators, has increased the demand for power from the diesel prime movers.

The paper describes mounting and coupling arrangements, cooling systems and starting methods of the higher power engines.

It also shows some of the difficulties encountered in applying some of the Rules, Regulations, Requirements, Recommendations, Standards, Specifications and Guidances to such engines and shows how in many cases the spirit, if not the letter of the law can be met.

INTRODUCTION

On very early offshore platforms the power requirements were modest. "Adma Enterprise" had four 430 hp engines for drilling and three 330 hp engines for electrical generation. A total installed power of 2000 brake kW (2710 hp).

Power requirements of modern platforms are such that it is not practical to produce it from diesel engines but there are still duties for which diesel engines are well suited.

The few accidents which have occurred have resulted in the issue of regulations which require fire-fighting sets and emergency generators to have considerably greater outputs than their predecessors.

For the purpose of this paper, "High Power Diesel Engines" covers the range 750 to 3000 kW brake (say 1000 to 4000 hp) which seems to cover present-day demands.

Platforms are costly so it is important to make the best use of all available space. The compact, light-weight, medium to high speed V-form diesel engine is ideal for platform duties.

ANTI-VIBRATION MOUNTINGS

All diesel engines vibrate and it is undesirable that these vibrations are transmitted into the structure. The V-form light-weight engine is no better and no worse than its slower-speed, heavy-weight counterpart but has an advantage in that engine vibrations are much easier to isolate. The smaller rotating parts and reciprocating masses enable the mounting system to isolate 98% of the vibration.

Figure 1 shows the layout of a lineshaft pump set. The engine drives a right-angle gearbox which is mounted on the above-base discharge of the pump. The pump and caisson tube are suspended from the underbase, so the gearbox, discharge casing and underbase are fixed (see Fig. 2). The engine is resiliently mounted, to prevent vibrations being transmitted into the underbase which is in direct contact with the platform structure.

Since the mountings allow the engine to move, the drive must be flexible enough to absorb the constantly changing alignment. One way of transmitting the power from engine to gearbox is by a Hardy-Spicer type shaft. Whilst such a drive would absorb the movement, it would also transmit torsional vibrations from the engine into the gearbox and shaft system, so a torsionally flexible coupling would be needed as well. By using a coupling which is torsionally flexible and capable of running continuously while misaligned, the overall length of the set can be kept to a minimum by dispensing with the Hardy-Spicer shaft.

It is sometimes necessary to drive the pump by some other method. Fig. 3 shows the engine driving an hydraulic pump or pumps via a speed increasing gearbox. The hydraulic pump delivers fluid under pressure to the hydraulic motor which is coupled to the pump. This drive system is more expensive than the lineshaft but is useful when it is not possible to install the pump vertically below the power unit.

Where, for some reason the high pressure pipelines cannot include flexible sections, the gearbox becomes a fixed item and the coupling between engine and gearbox has to be flexible.

