ROLLS-ROYCE of AUSTRALIA PTY. LIMITED

MARINE GAS TURBINES

for

COMMERCIAL SHIP PROPULSION

AG BUTTOLPH

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Introduction

Rolls-Royce (1971) Limited have a large part of existing world experience with marine gas turbines.

At present this share is restricted to:

1. Hovercraft:

   The compactness and low weight of aircraft-derivative gas turbines are major advantages in such craft, by comparison with reciprocating engines in the larger sizes.

2. Hydrofoils:

   The same applies.

3. Naval Combat Vessels:

   In addition to low prime mover weight and size, the aircraft-derivative gas turbine offers major reduction in manning requirements by comparison with diesel or steam turbine propulsion machinery. The flexibility of operation, with rapid power availability from cold, is very valuable in combat and other emergencies.

In these three types of application the fuel needs of the simple-cycle non-regenerative gas turbine, which are relatively costly when considered against those of a diesel engine or steam turbine, are off-set well by the advantages of the gas turbine.

In Commercial marine work diesel engines and steam turbines have wide acceptance and low fuel costs. Both will burn low-grade fuels and the diesel engine in particular has a low heat rate.

The gas turbine has this opposition to meet, and unless some feature can be provided to improve its fuel needs it is likely to be restricted commercially to those marine applications where its inherent advantages have peculiar merit.

This is the basis of current Rolls-Royce philosophy and activity in the commercial marine gas turbine world, which this "mini brochure" seeks to explain with the aim of inviting further discussion from potential customers.

Why Gas Turbines?

Marine gas turbines developed from aircraft power plant - -

Are reliable

- Aircraft safety requirements, rigorously stated by government controlling bodies, join with commercial demands to develop aircraft jets this way.

- commonly these same units when offered for marine use have a complementary application in land-based industry, where the cost of breakdowns is harmful even if a factory or pipeline can't crash.

Are long-lived

- industrial versions of aircraft jets run long periods between overhauls in petrochemical plant and on gas transmission pipelines.
- Rolls-Royce have 10 years experience of pipeline work and have developed units to the stage where they can average 24,000 hours to reconditioning. Individual units have run in excess of 30,000 hours to reconditioning with no intervening hot section inspection.

Need little routine maintenance

- beyond a simple daily inspection and compressor cleaning to remove airborne deposits which can corrode parts and reduce performance, basic routine maintenance is largely confined to periodic filter checks.

The complexity of boilers and boiler feed systems is avoided.

Have low operating manpower needs

- propulsion system control is simple and can be handled directly from the bridge if required.

Give high ship availability

- in addition to low routine maintenance needs which reduce working time in port - at times a major factor in ship economics - a complete gas generator can be removed in a matter of a few hours and a reconditioned one substituted. "New generation" units are of modular construction, permitting change of major assemblies without gas generator removal.

Are flexible in operation

- gas turbines generally are relatively quick starting and authorities have pointed to the enhanced ship security which this can give in emergencies, as well as the reduced demands on crew preparations.

  Aircraft-derivative units are particularly quick-starting and responsive to changing power needs.

Are relatively small and light in weight

- while installation needs, eg. intake air and exhaust trunking must be carefully studied these two qualities give increased flexibility in machinery disposition, particularly where turbo-electric drive may be employed.

Why not Gas Turbines?

Gas turbines are more demanding in fuel than either diesel engines or steam turbines - -

- ability to burn low-grade fuels is worse.

However, residual and crude oils have no inherent user advantages beyond pricing.

This pricing situation is changing rapidly, and crude oils are valuable for many other commodities.

There are some distinct technical disadvantages in the use of residual and crude oils in diesel and steam power plants.

Although experience of fuel treatment for gas turbines, to remove undesirable properties from heavy fuels, is increasing there are arguments in favour of distillate fuels which are worth consideration. These centre around ease of handling and improved machinery maintenance prospects. Gas turbines can very readily burn gaseous fuels, for example regasified LPG or LNG, and by contrast with reciprocating engines do not require any de-rating in such use.

- specific fuel consumption of a simple-cycle gas turbine is higher.

This factor can be met basically in two ways:

1. By the use of regenerative cycle power units employing exhaust waste heat to pre-heat combustion air. This gives very useful gains in efficiency.

   However, exhaust heat recuperators are bulky and heavy, representing extra problems in location and in providing mounts to withstand the weight and thermal expansion problems. They represent an added maintenance factor which may be troublesome if adequate design provision is not made for subsequent access.

2. By employing advances in technology gained from aircraft turbine work to give higher efficiency in a simple cycle unit.

Demands of aircraft design and the consequent massive research and development work put into aircraft propulsion systems have led to a new generation of gas turbines which are highly efficient both aero and thermo-dynamically, without added complexity and with long life due to improved materials and careful internal cooling.

This is the basis of the Rolls-Royce approach to viable commercial marine gas turbine propulsion systems.

It carries the backing advantage of massive build-up of experience with the associated aero-engine types and their continuing intensive service development. Funding of work to this extent could not be justified for exclusively marine power plant.

Current Rolls-Royce Marine Gas Turbine experience and Product Range

1. <u>The Olympus marine engine currently has 'B' and 'C' ratings.</u>

It is supplied as a complete module (the TM3) comprising an Olympus 'B' or 'C' rated gas generator gas-coupled to a free power turbine unit on a sturdy mounting frame suitable for direct installation in a ships' Hull. A power turbine exhaust volute suitable for coupling to the ship's uptake system is included together with an acoustic gas generator enclosure and air intake plenum. The whole is stressed to Naval shock resistance requirements.

Figures (1) and (2) show the TM3 module with basic details of size, weight and performance.

The marine Olympus so far has been, or is being, supplied for eleven of the world's Navies including those of Britain; France, the Netherlands; Brazil and Iran. The TM3B has already received Lloyd's Register approval for merchant ship propulsion. Further experience of the gas generator stems from extensive use in R.A.F V-bombers, and the Industrial Olympus is finding increasingly wide acceptance throughout the world for electrical power generation.

2. <u>The Tyne Marine engine</u> is in service in hydrofoils and as the cruise unit for conventional hull-borne warships. It is also suitable for such projects as hovercraft and fast patrol boats and may find applications in specialised craft of other types since it is light, powerful and has moderate fuel consumption.

As the Tyne 621 and RM2 it is supplied in light-weight form with or without primary reduction gearbox, while the RM1 has a more substantial mounting structure stressed for naval shock resistance and includes a more massive power turbine and exhaust volute assembly, with acoustic hood for the gas generator and an air intake plenum chamber.

Navies using the Tyne include those of the U.S.A; Argentina; Holland and Britain.

Figures 3, 4 and 5 show versions of the Tyne with brief details of performance and other features.

The Tyne is well-known as a turbo-prop aero-engine with a history of profit-making for its customers, having operating hours extending well into eight figures.

3. <u>The Marine Proteus</u> is the world's most successful and experienced marine gas turbine. In over fifteen years it has found wide acceptance and repeated orders as a main propulsion unit for fast light combat ships, hovercraft, hydrofoils and a frigate.

More than 240 of this light, compact, and reliable engine have been sold.

Figures 6 and 7 depict the Proteus and give outline details.

The Proteus originates from the turboprop powerplant of the Bristol Britannia aircraft, which first entered service with BOAC and continues to give useful freighting service.

4. <u>The Gnome Marine engine</u> finds considerable use in hovercraft work as a small, light and well-developed power unit. It is derived from a power unit with much experience in helicopter work throughout the world.

Details are shown in figures 8 and 9.

"New Generation" marine turbine prospects

The units under this heading are not yet available for marine use, although they exist as aircraft powerplant with considerable experience.

Rolls-Royce are however studying them with the aim of offering them as fully-developed units, capable of showing full economic viability in commercial marine propulsion work and embodying many features gained from experience with our existing marine product range.

We welcome enquiries from interested shipping authorities on this basis of forward planning.

1. The RB211 fan jet powers the Lockheed Tri-Star which is entering airline service in increasing numbers.

   One of the new breed of very powerful, very quiet, very efficient aero-engines for mass transportation work, it can be adapted by fan and fan turbine removal to provide an industrial and marine power unit in the 26-32000 BHP range with fuel consumptions near to diesel levels. The industrial gas generator version enters North American gas-pumping service this year (1974) and is expected to show considerable operating cost savings by comparison with gas turbines already in wide use, which naturally will increase as fuel becomes more valuable.

   Studies are in progress to examine the merits of the RB211 as a commercial marine propulsion unit in such applications as LNG carriers and fast container ships, for which we expect to use a free power turbine unit and other engine module features drawing extensively on our TM3 Olympus experience.

   Since the RB211 is only in its early stages of continuous aero service development, the industrial and marine units have considerable potential for many years to come.

   Outline details of the marine RB211 are shown in figures 10 and 11.

2. The Marine Spey engine originates from the Spey jet engine which has been ordered by over fifty-eight airlines, one hundred and three corporate operators and six government agencies for civil use. Military versions are used by the RN; R.A.F; S.A.A.F; and U.SN - in the latter's LTV Corsair II, the Spey development known as the TF41 is becoming one of the most successful American jet fighter engines ever.

A marine Spey version is under contract study for the British Ministry of Defence as a future warship engine, and would provide a high-efficiency commercial propulsion unit giving between 12 and 17000 BHP. The Spey also has considerable interest as a gas-pumping industrial power unit to supplement and perhaps eventually supersede our extremely successful Industrial Avon gas generator, and will enter service in this application in 1975.

Some details of the Marine Spey are given with figure 12.

Gas Turbine Installation Requirements

Gas turbines are different from diesel and steam power units in several respects and need different treatment in installation and operating features to give satisfactory performance.

Rolls-Royce, from extensive marine experience to date, have gained considerable knowledge of these features.

A few follow in outline only, but can of course be discussed in much greater detail with prospective customers.

(a) Downtakes for gas turbine inlet air

Horsepower for horsepower a gas turbine uses two to three times the mass air flow of a marine diesel engine, and competent design of intake trunking is essential to give correct operation. Airborne salt is conducive to unacceptable engine corrosion, particularly of the turbine blading, and provision must be made by adequate air filters and sound positioning of the actual intakes to limit salt and water ingestion to acceptable levels without excessive pressure losses, while the actual entry to the compressor must be designed for acceptable velocity distribution of the ingoing air.

(b) Uptakes for exhaust gases

A high flow of hot exhaust gases must be accommodated without excessive pressure losses by a corrosion-resistant system which may be required to give some silencing, and whose outlet must be positioned to prevent gas recirculation into the engine intakes.

(c) Fuel Handling:

Gas turbines dislike fuels with such features as high vanadium content, salts of alkali metals and water. These can produce serious corrosion effects, particularly in the turbine. In addition to being critical of basic fuel supply specification and quality, adequate provision must be made in ships' fuel forwarding systems for filtration and removal of salt and water.

It is possible to run on heavier fuels, particularly where these are of unusual quality (for example low-vanadium Bass Strait crude and residual fuel)but there are penalties involved in such features as the need for heating and inhibitor treatments, logistic problems, and increased maintenance needs which must all be cost-evaluated for a specific operation.

(d) Installation Space:

While the gas turbine is in itself a relatively low-volume prime mover, proper satisfaction of all operational needs dictates that adequate room must be given for access, intake and exhaust trunking, and other features.

A satisfactory ship installation must be produced in full collaboration between the engine manufacturer and the ship designer.

(e) Transmission:

The high output shaft speed of any gas turbine dictates use of reduction gearing to the propeller shaft. Alternatively, advantage may be found in a turbo-electric drive system and this can offer much in convenient placing of the turbo-alternator package. There is considerable land-based experience of packaged modular gas turbo-alternator sets and their control; aero-derivative units are particularly light and lend themselves to high or forward mounting in a ship.

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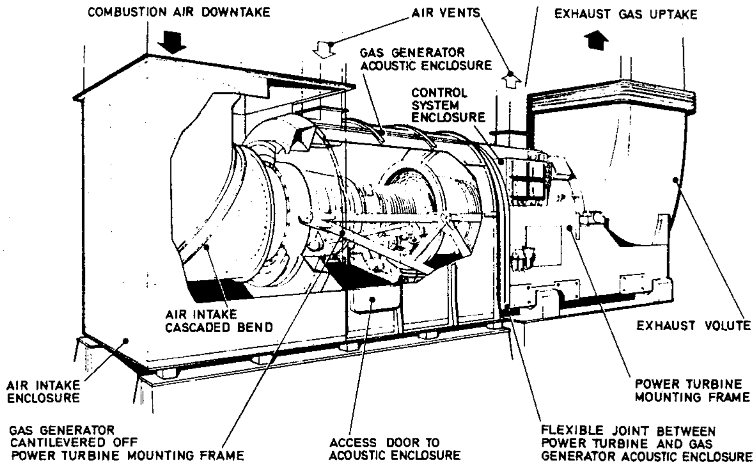


TM3B MARINE OLYMPUS PROPULSION MODULE

Fig.1

MARINE OLYMPUS

Olympus TM 3 propulsion module dimensions:

Length	29.5 ft	9, 0 m
Width	8.5 ft	2, 6 m
Height	10.5 ft	3, 2 m
Weight	62000 lb	28000 kg

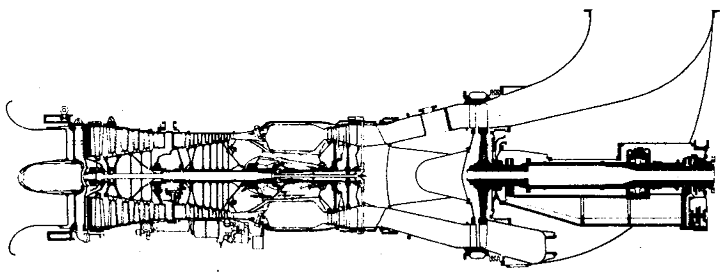


Fig.2

Olympus TM 3 gas turbine dimensions:

Length	22. 34 ft	6, 81 m
Width	8. 00 ft	2, 44 m
Height	9, 90 ft	3, 02 m
Weight	47000 lb	21320 kg

Performance:

	Maximum Military Power	
	BHP	SFC lb/bhph
TM 3B Rating ISA Conditions	28000	0.478
TM 3C Rating - at 85°F	28000	0.492

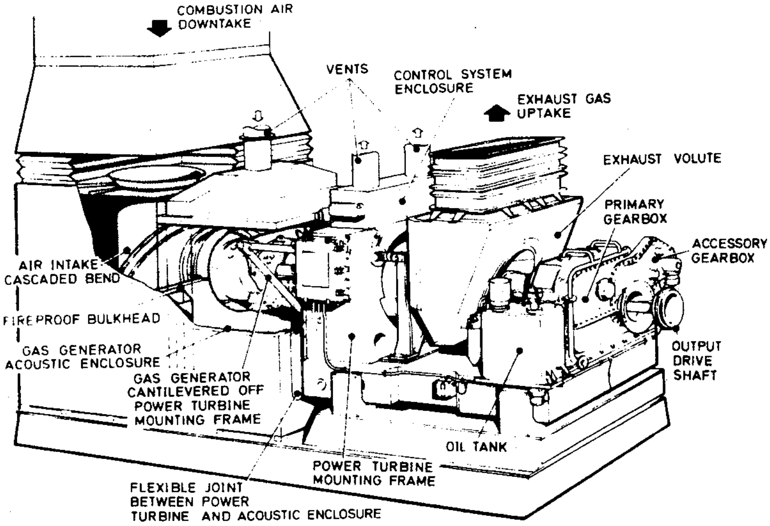
(The TM3C is Flat-rated to 85°F or 26.7°C)

Lower ratings of the same units are available for commercial use.

MARINE TYNE RM1

Tyne RM 1 propulsion module dimensions :

Length	18 ft	5, 49 m
Height	7 ft	2, 13 m
Width	6. 67 ft	2, 02 m
Weight	31000 lb	14061 kg



MARINE TYNE PROPULSION MODULE

Fig.3

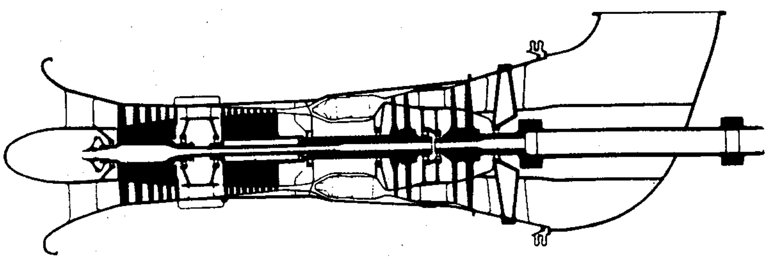


Fig.4

Tyne Gas Turbine Dimensions :

Length	14.25 ft	4, 35 m
Height	5.66 ft	1, 73 m
Width	5.4 ft	1, 62 m
Weight	19000 lb	8618 kg

Performance:

Maximum Military Power

(Continuous Crusing)

	BHP	SFC lb/bhph
RM 1A Rating	4250	0.489
RM 1C Rating	5340	0.469

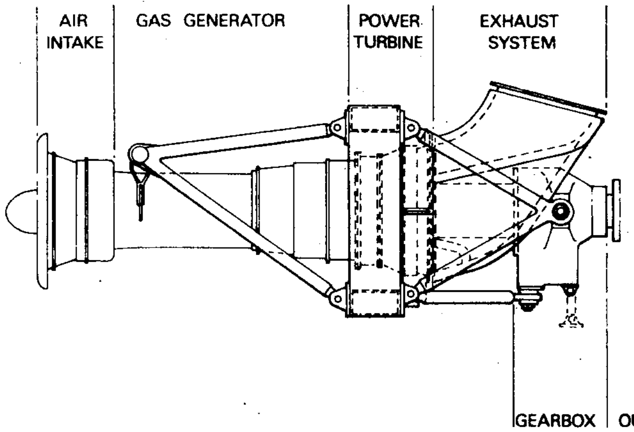


Fig.5

MARINE TYNE RM 2

Marine Tyne RM 2 gas turbine dimensions:

Length	145.5 in	369,57 cm
Height	54.5 in	138,43 cm
Width	48.0 in	121,92 cm
Weight	6000 lb	2721 kg

(Epicyclic gearbox)

The Marine Tyne RM 2 is a lightweight version of the Tyne RM 1.

A Tyne gas turbine, exhaust elbow and primary gearbox are mounted on a tubular mounting frame, forming an engine change unit. The three shaft Tyne engine consists of a two-spool gas generator and a free power turbine, driving, through the exhaust elbow, a primary gearbox which may be of parallel or epicyclic configuration. Either direction of rotation of output shaft is available.

Performance:

	Maximum Military Power	
	BHP	SFC lb/bhph
Tyne RM 2B		
Max.	4700	0.475
Max. Continuous	4000	0.497
Tyne RM 2D		
Max.	5800	0.461
Max. Continuous	5000	0.476

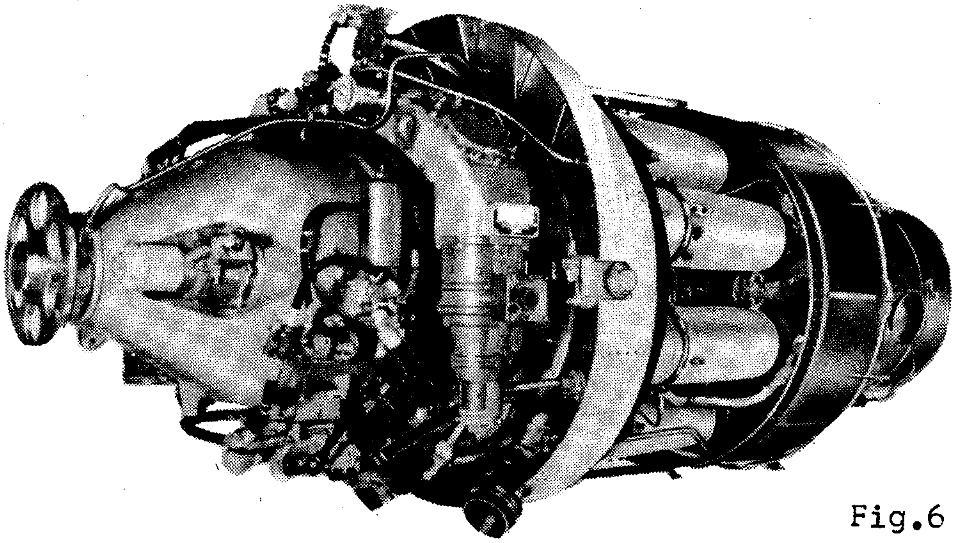


Fig.6

MARINE PROTEUS

Marine Proteus gas turbine dimensions

Length	110 in	280 cm
Diameter	42 in	106, 5 cm
Weight	3184 lb	1444 kg
	3118 lb	1414 kg

(according to gear used)

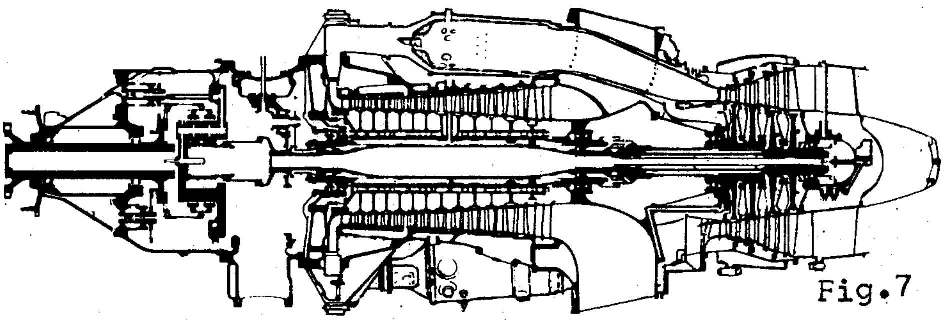


Fig.7

Reduction Gears

1.	2. 2140:1	(5240 rev/min)
2.	11. 59:1	(1000 rev/min)
3.	7. 5:1	(1500 rev/min)

Performance:

Maximum Military Power

BHP	SFC lb/bhph	Residual Exhaust Thrust
		lb
4500	0.565	423

Advantages can be taken, where practicable, of using the exhaust thrust.

A special rating for hydrofoil use offers 5000 BHP for "take-off" purposes.

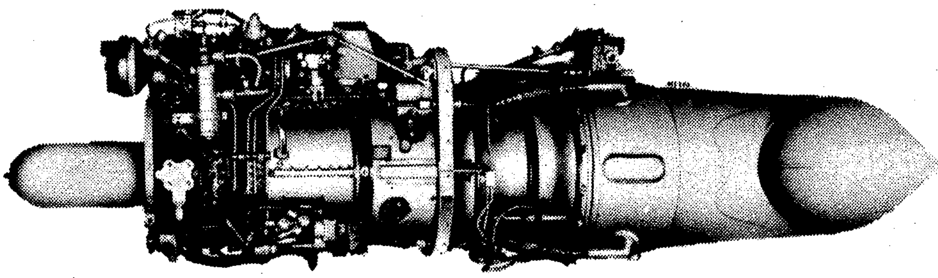


Fig.8

MARINE GNOME

Marine Gnome gas turbine dimensions:

Length	72. 8 in	184, 9 cm
Width	12. 36 in	31, 4 cm
Height	20. 4 in	51, 8 cm
Weight	353 lb	160 kg

The above dimensions are for an engine with bifurcated exhaust duct. Width across extremities of exhaust duct = 30. 3 in 77 cm

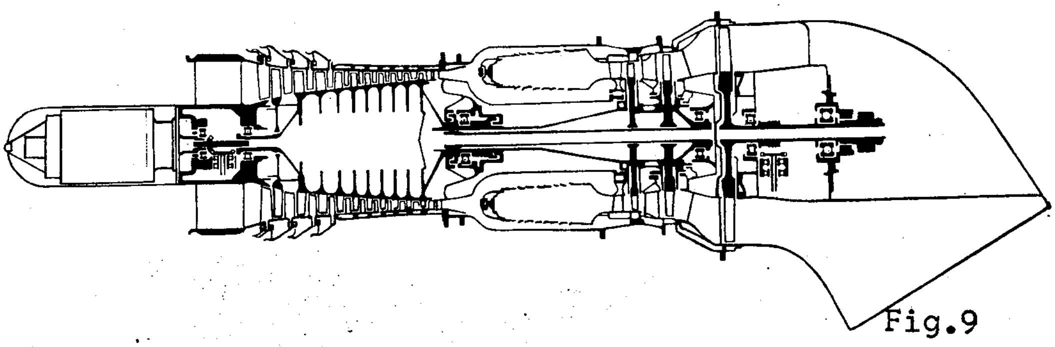


Fig.9

Performance:

	Maximum Rating	
	BHP	SFC lb/bhph
Gnome 105	1050	0.625
Gnome 1301	1400	0.62
Gnome 1201	1435	

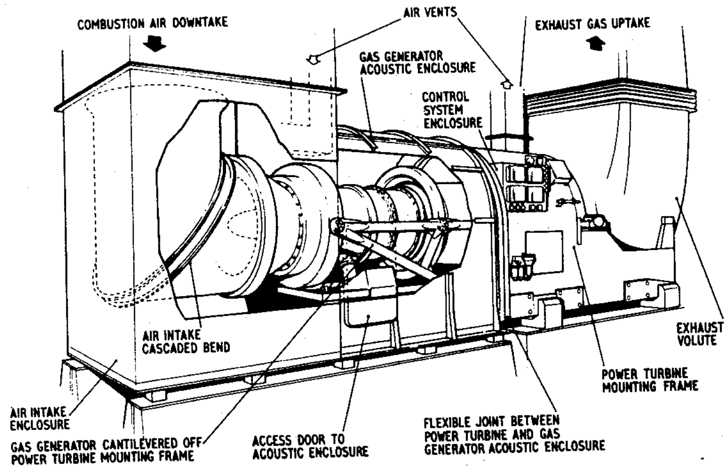


Fig.10

MARINE RB.211

RB. 211 propulsion module dimensions:

Length	26.5 ft	8, 0 m
Width	8.5 ft	2, 6 m
Height	10.0 ft	3, 0 m
Weight	62000 lb	28000 kg

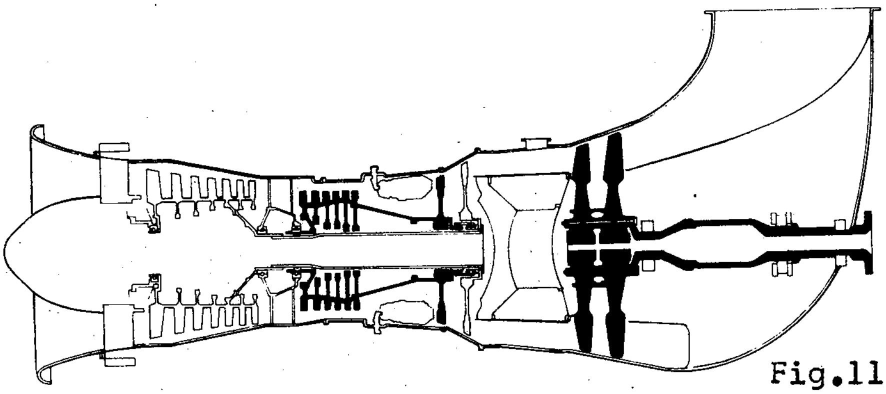


Fig.11

MARINE RB. 211

Derived from the aero engine by the removal of the fan and its turbine and the addition of a free power turbine

Performance:

At 26.7°C 80°F)

	BHP	SFC lb/bhp/hr
Military Rating	28500	0.400
Commercial-Service - Rating	22000	0.429
Commercial-Max. - Continuous Rating	24500	0.419

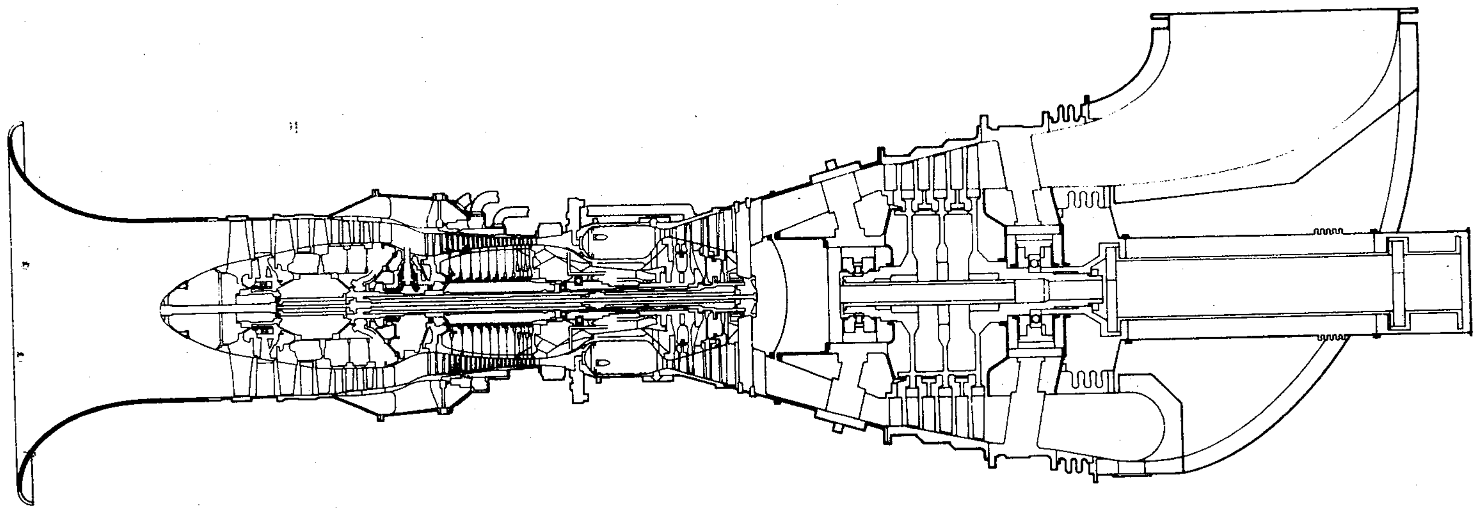


Fig.12

Marine Spey with 3 stage power turbine.

Performance:

	BHP	SFC
Max. Continuous (Flat-rated to 80°F 26.7°C)	13200	0.442 lb/bhp/hr
Service (Flat-rated to 80°F 26.7°C)	12000	0.457
Lightcraft "Sprint"	19000	0.403
Maximum	17500	0.413

Conditions Taken:

1. Powers are minimum expected. SFC's nominal
2. Fuel 10,300 CHU/lb LCV
3. Atmospheric pressure 14.7 lbf/in ^{2}abs
4. No ducting losses or power offtakes