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CURRENT DIESEL ENGINES IN JAPAN

by

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INTRODUCTION

Diesel engines have been greatly improved since the 1960s, giving greater fuel economy as compared to other prime movers.

During this period, we experienced two oil-crises which resulted in drastic increases in the price of fuel; most ship owners in the world have been seriously concerned about this rise in fuel costs.

In response to the request to reduce operating costs most diesel manufacturers in Japan have given top priority to the development of extremely economical engines or systems including less fuel consumption, savings in man power, and lower maintenance costs.

Major efforts, in the meantime, have been concentrated on:

- the improvement of the engine itself and also waste heat recovery systems including exhaust gases and cooling-water,

- the development of unmanned control equipment or systems for engines or power plants,

- the improvement of engine or system durability.

For ships, on the other hand, the new developments in ship building technology, including ship design itself, and propulsion systems combined with propellers and rudders, have been successful.

This paper is written primarily as a summary of the technical development in high powered diesels.

The future scope of engines can be seen in the last page.

CURRENT DIESELS:

In any particular engine, the calculation of output can be done using the following formula:

$$PS = \pi D^2/4 \times Pme \times S \times Z \times N/60 \times 1/i \times 1/75$$

$$= K \times Pme \times Cm$$

$$= K \times Pr$$

where, PS = output
D = diameter of cylinder, (cm)
S = stroke, (m)
Z = number of cylinder
N = revolution, R.P.M.
i = cycle index, 2 for 4 cycle engine
1 for 2 cycle engine
Pme = brake mean effect. press. in Kg/cm^2
Cm = piston speed, SN/30 (m/s)
Pr = power factor, (Pme x Cm)

Finally, the output of the engine is proportional to brake mean effective pressure Pme, and piston speed Cm.

Fig. 1, Tables 1 and 2 shows the increase of Pme, Cm and also the power factor of current diesels - low speed, medium speed, and high speed engines manufactured in Japan. In the case of medium speed engines, for instance, the output of current diesels is over 6.6 times higher than that of ones manufactured 40 years ago.

Fig. 2 shows the phased increase of brake mean effective pressure of current diesels.

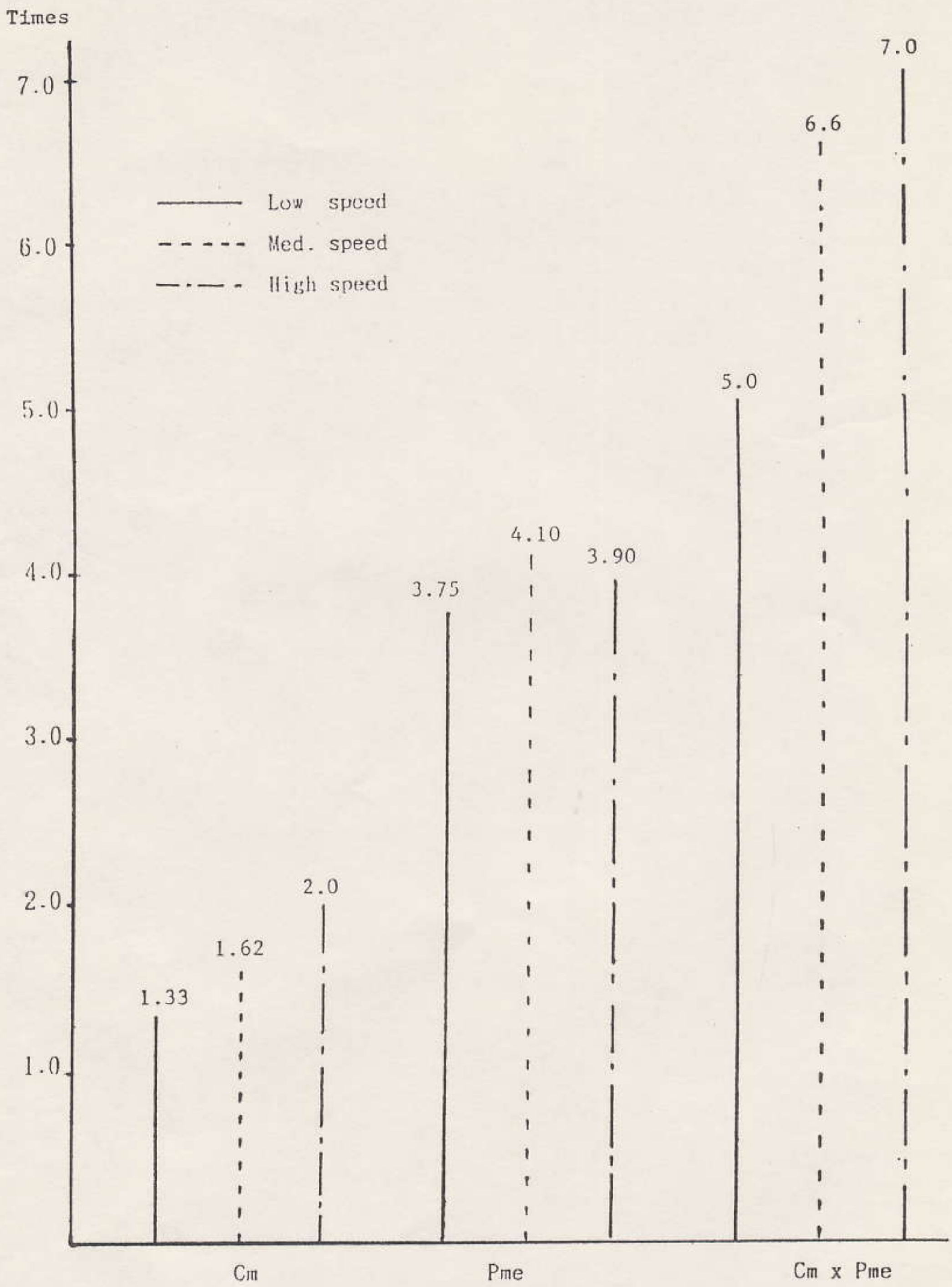


Fig. 1 The change of piston speed (Cm), brake mean effective pressure (Pme), viz power rate (since 1950)

Table 1. Pme, Cm and Power-factor of current diesel engines (for ex.)

Kind of engine	Pme (Kg/Cm^2)	Cm (m/s)	Pme x Cm
Low speed engine	18.8 ~ 19.5	6.7 ~ 7.0	130 ~ 132
Med. speed engine	20.0 ~ 22.5	9.3 ~	171 ~ 181
High speed engine	18.8 ~ 21.8	11.1 ~ 10.6	209 ~ 230

Table 2. Pme, Cm and Power-factor of former diesel engines (for ex.)

Kind of engine	Pme (Kg/Cm^2)	Cm (m/s)	Pme x Cm
Low speed engine	5.0 ~ 5.5	5.0 ~ 5.4	25.0 ~ 28.8
Med. speed engine	5.1 ~ 5.6	5.5 ~	28.0 ~ 30.8
High speed engine	5.1 ~ 5.7	6.6 ~ 8.0	37.4 ~ 41.0

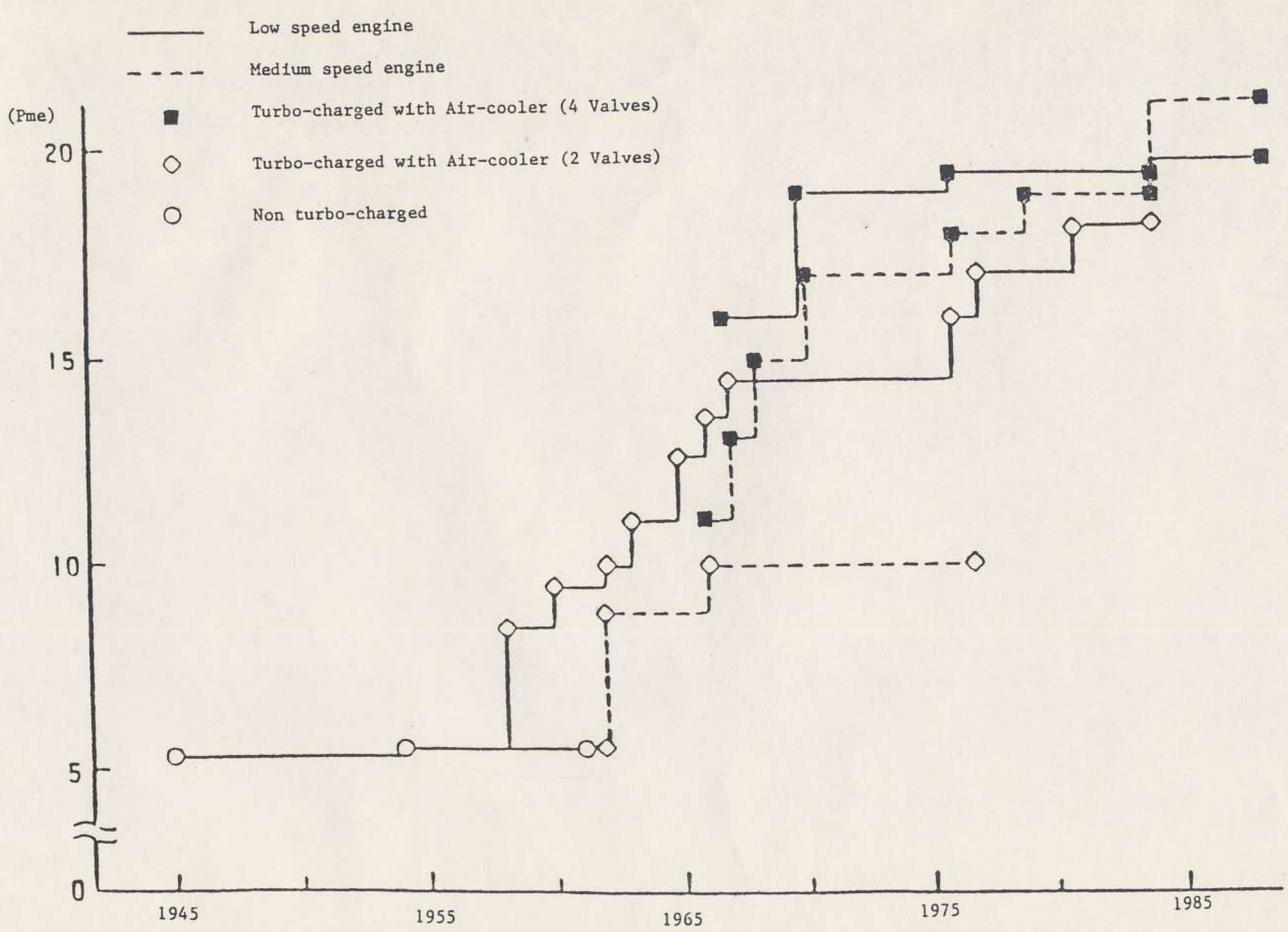


Fig. 2 The change of brake mean effective pressure (Pme)

What has most affected the improvement of current diesels especially in terms of high output, less fuel consumption, and high durability.

The following are major aspects of technical improvement.

1) The application of an "Exhaust-gas turbo-charging system" including Inter-cooling of the compressed air.

Soon after the end of World War II, in the year 1945, the application of the turbo-charging system to diesels progressed rapidly, and in the year 1953, the first practical engine, increased in power by 30%, came into service in Japan for marine use.

Further efforts were also made in studying turbo-chargers themselves, particulary, the use of new materials or parts, such as:

- high heat resistant steel for turbine blades,

- highly efficient ball bearings for rotors.

This contributed greatly to the development of highly efficient turbo-chargers.

2) Development of new bearing metals for the crank shaft, jounals and pins.

With the increase of firing pressure (maximum pressure) of the engine, a higher bearing performance was necessary, and development of "Tri-metals" - thin steel back, "Kelmet" middle and special soft alloy plated surface - contributed greatly to the development of current high powered diesels.

In addition, strict lubricating oil control systems including the application of fine filters, caused an increase in bearing performance.

3) New materials and new heat treatment technology for parts.

As the output increases, major parts of the engine have to be resistant to high mechanical stresses and the high temperatures of combustion gases.

The following are the major engine parts and the new materials of heat treatments adopted.

- Crank shaft : high quality steel with structural conformity, and the application of "RR" stamp forging.

- Cylinder-liner : antiwear special cast iron, such as high phosphorous cast iron, "tufftriding" for the inner surface of the cylinder liner to get a good running-in ability, and hybrid composites - a quite new material currently under development.

- Piston and rings : special cast iron, for example, "ductile cast iron" for pistons, the built-up piston with a steel crown and "ductile cast iron" or aluminum body, induction-hardened or laser-hardened piston ring grooves, and special cast iron for rings, including oil rings.

- Cylinder-cover : special cast iron, for example, "Vermicular cast iron".

- Valves, for Air and Ex. gases : high heat resistant special alloys with "stellite" welded seat, and the application of valve rotators for exhaust valves.

4) Improved design.

To ensure further improvement of fuel burning in the combustion chamber of the engine, the application of a longer stroke, particulary for low speed engines, is a great change in the design of high powered engines, resulting in remarkably low fuel consumption.

On the other hand, with the aid of electronics and computers, measurement and analysis of mechanical-stress of thermal-stress in major parts can be done effectively, and therefore, rigid and optimum design for parts can be assured.

The "strong-back" design applied to cylinder covers, for example, is a major change in the design of current high powered engines.

5) High pressure fuel injection.

New application of extremely precise and high pressure fuel injection pumps has made fuel atomization optimal for burning fuels in combustion chambers, and 1,500 Kg/cm^2 of fuel injection pressure, for instance, has affected reduction of fuel consumption tremendously as well as emission control.

6) Cooling systems, by water and lubricating oil.

To resist higher thermal stress on parts, in the combustion chamber, piston, liner, cylinder-cover and valves, proper cooling is very important.

Piston cooling by lubricating oil, and bore cooling by water in the upper part of the cylinder liner has been effectively adopted in modern high powered diesels.

7) Technical developments in production.

Application of exact machining technology for major parts, bed plates, crank shafts, cylinder covers, cylinder-liners, pistons, connecting-rods, and gear-traines, has had a considerable effect on the development of high powered diesels.

The installation of computerised controls for large type machinery has made major parts machining far more exact.

In addition, new heat treatment technology, including induction-hardening, laser-hardening and electro-bonding or surfacing with special alloys has been widely applied to major parts, thereby contributing greatly to the development of high powered diesels.

On the other hand, the new development of marine-gears and flexible-couplings has assured the general use of medium speed engines for marine propulsion.

8) Control systems, equipment.

With the aid of electronics, and computers, new control systems for engines and engine equipment have been widely introduced into the engine room or control room of the ship, and easy operation and high fidelity of the engine can therefore be assured.

NEW TRENDS:

1) Waste heat recovery systems.

To use energy more efficiently and reduce fuel costs, co-generation systems have become widely used for various power plants, and by the use of exhaust gas boilers together with heat exchangers, for example, over 40% energy recovery can be assured.

2) New fuels.

To save future crude oil resources, and particularly, to cope with emission control of engines, the development of new fuels has become the new technical challenge to industry.

Gas engines burning LNG or LPG have already come into practical service.

New liquid fuels, such as "Methanol", are under laboratory testing for practical use.

3) Emission control.

At present, there is serious worldwide concern about the emission control of engines, and technical development in this area is a top priority for industries involved in automobiles, generating power plants, and marine engines.

The IMO (International Maritime Organization) is now studying the standards of emission control for marine engines, and new regulations will be enforced in the very near future.

For automobiles, on the other hand, some technical developments, including the improvement of engines themselves and the use of catalysts, are in practical use at present, but are still not totally satisfactory, and further efforts for improvement will be continued.

DIESELS IN THE NEXT CENTURY

With the increase of interest in the development of more economical and reliable engines for various uses, some technical development work for the future has been started already in Japanese Diesel Industries.

The ADD (Advanced Diesel Engine Development Co;), for instance has designed a quite new engine, expecting 50% output increase and high durability, being maintenance free for six months.

The first test engine with three cylinders, incorporating new sophisticated technologies in materials and design, has been tested and performs well as expected.

The building of a practical engine with six cylinders is expected by the end of March 1994.

New ceramics applied to pistons, piston-rings, and cylinder-liners can be expected to improve the life of these parts.

In addition, to reduce fuel consumption by 15%, computerised high pressure oil control valve operating systems, for air, exhaust gases, and fuel injection, are in the experimental stage.

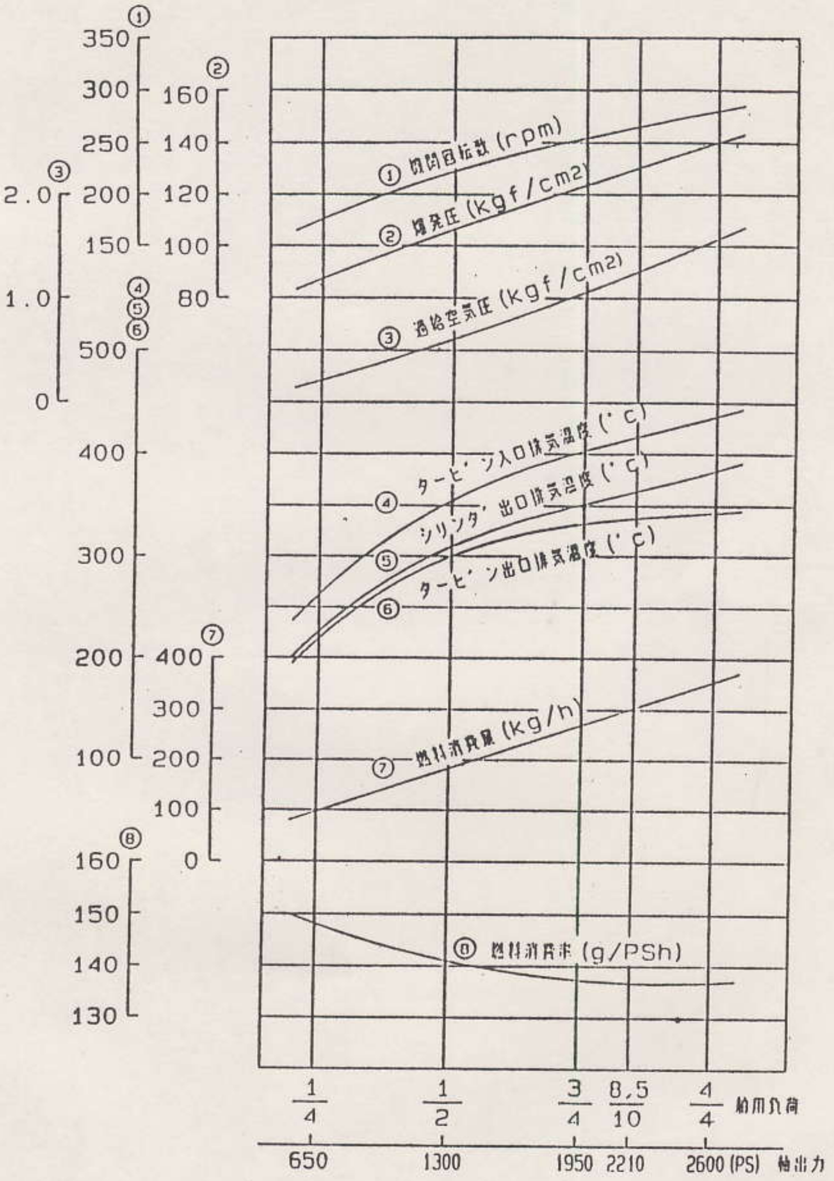
Looking at the future scope of new technology, the development of high fidelity engines such as the AI engine (Artificiality Intelligent engine), together with greater fuel economy and higher reliability, can be expected in the very near future, and toward the next century, the words "Gentle to the Earth" may have a very important position in the evaluation of engines.

There is no end to the possibilities of technological development, and new challenges for the century have already been started.

REFERENCE-1

Performance of Model 6H36L(A)

No. of cylinder	: 6		Pme	:	20.42 kg/cm²
Din of cylinder	: 360 mm.		Cm	:	6.25 m/s
Stroke	: 670 mm.		Max. press	:	140 kg/cm²
Output	: 2,600 p.s.		Fuel cons.	:	137 gr/ps/hr
Revolution	: 280 rpm				

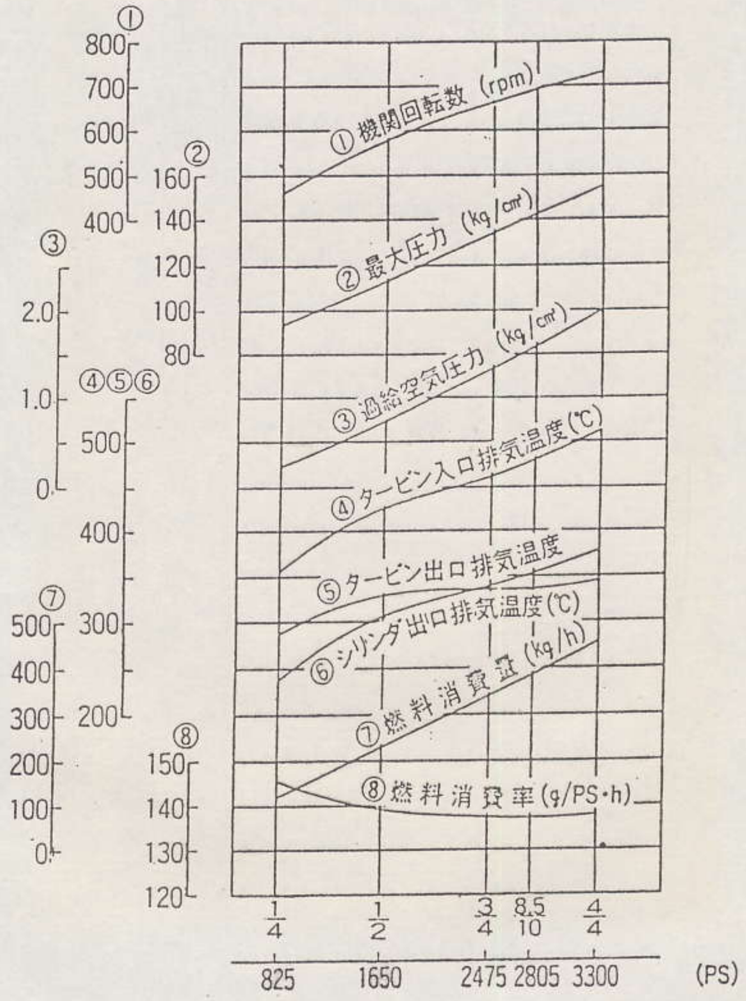


1 : R.P.M	5 : Ex. gas temp. Cover out °C
2 : Max. press kg/cm²	6 : Ex. gas temp. Turbo out °C
3 : Boost press kg/cm²	7 : Total fuel cons. kg/hr
4 : Ex. gas temp, Turbo inlet °C	8 : Fuel cons gr/ps/hr

REFERENCE-2

Performance of Model 8M x 28

No. of Cylinder		8
Dia. of Cylinder	mm	280
Stroke,	mm	380
Output,	PS	3,300
Revolution	rpm	730
Brake Mean effect. press.	Kg/Cm2	21.73
Piston speed,	m/s	9.25
Max. Press.,	Kg/Cm2	155
Fuel Consumption,	g/ps/hr	138
Weight,	ton	24



1 : R.P.M.
2 : Max Press. Kg/Cm2
3 : Boost Press. Kg/Cm2
4 : Gas Temp. Turbo inlet, ζ
5 : Gas Temp. Turbo outlet ζ
6 : Gas Temp. Cover outlet ζ
7 : Total fuel consum..Kg/hr
8 : Fuel consum. g/ps/hr