EXPERIENCE WITH
SPECIAL APPLICATIONS

by

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1 Splitter Gears for Power Distribution

2 Large Gear Boxes with Thrust Collars

3 Parallel Shaft Gears with Extreme Power, Speed and Pitch Line Velocity

4 Epicyclic Gears

Experience with Special Applications

The MAAG Gear Wheel Company has, compared with other gear manufacturers, a relatively large engineering department with a staff of close to 50 design engineers and draftsmen. This allows us not only to supply prompt and thorough contract information but also to design special gear boxes that have to be engineered from scratch and, hence, require much more engineering hours than gears of the standard range. A good part of this engineering effort is invested in naval gear projects, where low weight, vibration and noise is of extreme importance. However, the field of turbo gearing has, also, often applications where a special gear can result in big advantages with respect to weight/space savings or for extreme powers or speeds. Some of such applications shall be explained in this part of the symposium.

1 Splitter Gears for Power Distribution

Many installations require that a single driver is used to operate several machines such as L/P and H/P compressors, a compressor and a generator, etc. If these machines are installed in line they may require several gear boxes and the total length of the installation becomes quite considerable. If there is not enough length available in the installation, an alternate solution can be offered by a splitter gear box where the driven machines can be mounted parallel to each other.

MAAG already delivered a dozen of the following splitter gears in the early 50's (Fig.1):

Gear type : G-295/5
Driver (gas turbine)= 12'500 kW/at 3836 rpm
Driven machines:
- Generator = 8500 kW at 3000 rpm
- Blower = 3500 kW at 6686 rpm
- Compressor = 3100 kW at 10'174 rpm

A few years ago we supplied three of the following gears:

Type GX-101/4 multiple shaft gearbox between gas turbine and 2 compressors (Fig. 2).

Power of gas turbine 3600 kW at 7500 rpm
Power of high pressure compressor 1980 kW at 21'538 rpm
Power of low pressure compressor 1616 kW at 15'849 rpm
$v_{pitch\ line}$ = 131 m/sec (26'000FPM)

These gears are used on an offshore platform in Dubai. The two compressors, both having their own thrust bearing, are connected to the gear box by means of special diaphragm couplings that only allow a very limited axial float, not even sufficient to absorb the thermal growth of the gear and compressor rotors. By using a thrust collar design to eliminate the helix thrust of the single helical gears and by allowing the set of gear rotors to float axially (Fig. 3) this problem could be resolved. The gear is also used to drive a lube oil pump and a control oil pump, off of one of the idler shafts.

Another, somewhat similar installation is shown on the next picture (see Fig. 4). It consists of a system driven by a gas turbine and a steam turbine used to drive 5 different compressors. This gear system, built by another gear company in 1968 with a pitch line velocity of 147 m/sec (29 000 FPM) and using thrust collar design, had frequent failures caused by scoring and tooth breakage. The initial design did not include modified leads.

In a study which we conducted, we calculated the tooth deformation incurred in operation (caused by heat as well as torsional and bending deflection) and came up with figures of up to 0.028 mm. With a new gear set, including proper tooth corrections to offset the deformations in the gear mesh, the problems were resolved and the 2 gearboxes have now been running for more than 4 years to the users full satisfaction.

2 Large Gear Boxes with Thrust Collars

With respect to the reliability of our thrust collar design, we wish to use the example of the following installation (see Fig. 5) that is running in an oxygen plant near Chicago.

Gear type	: GX-90
Center distance	= 906 mm
Power	= 30'000 kW
Speeds	= 1200/4437 rpm
Helix thrust	= 6650 kg

The function of the thrust collar is shown in Fig. 6.

3 Parallel Shaft Gears with Extreme Power, Speed and Pitch Line Velocity

Already in 1963 MAAG supplied a gear box for the following extreme power application (Fig. 7):

Gear type	: G-175
Center distance	= 1750 mm
Power	= 62'500 kW
Speeds	= 2988/1000 rpm (Steam Turbine/Generator)
Pitch line velocity	= 137 m/sec (27'000 FPM)

A total of 8 of such or similar gears have been delivered in the meantime.

In the recent years we built several gears with a similar power rating but quite higher speeds (see Fig. 8):

Gear type	: G-72s
Center distance	= 720 mm
Power	= 60'000 kw
Speeds	= 6349/3600 rpm (Gas Turbine/Generator)
Pitch line velocity	= 173 m/sec (34'000 FPM)

These gear boxes are equipped with a lube oil pump supplying 3180 l/min (840 US GPM) at a pressure of 7 bar. Whereas the bull gear has its own thrust bearing to axially locate this rotor, which is rigidly connected to the generator, the pinion is not equipped with a thrust bearing. It is also connected to the turbine rotor by means of a rigid coupling (quill shaft), i.e. the helix thrust is absorbed in the gas turbine.
By close coordination between the engineering departments of the

turbine builder and MAAG, the helix angle was selected in a way that the helix thrust acts against the thrust of the gas turbine, thus considerably reducing the active load in the gas turbine thrust bearing (Fig.9).

Another application with extreme power, tooth/bearing loads, pitch line and bearing velocities, as well as rotor speeds will very soon be installed on the North Slope of Alaska:

Gear type	: GB-50
Center distance	= 500 mm
Power	= 47'500 HP
Speeds	= 4'670/10'720 rpm
Pitch line velocity	= 170 m/sec (33'500 FPM)

Units with similar load characteristics have previously been installed at other locations in Alaska, as well as in the desert of Algeria. The pinion journal bearings of these installations are of the MAAG tilting pad design, in order to absorb the considerable heat generated in these bearings as well as to cope with the resulting high bearing velocities.

Another application with extreme power is required for steam turbine/reciprocating compressor trains. Already in 1950 MAAG delivered the following unit with a quill shaft built into the hollow low speed rotor:

Gear type	: G-70/95 (two stages)
Center distance	= 700 plus 950 mm
Power	= 6000 HP
Speeds	= 3600/230 rpm

The largest of such units is the following gear which was supplied in 1969:

Gear type	: G-65/120 (two stages)
Center distance	= 650 plus 1200 mm
Power	= 6400 kW
Speeds	= 4261/230 rpm

Recently we built two other impressive gears which were tested in Zurich at full load and full speed (see Fig.10):

Gear type	: G-55/83 (two stages)
Center distance	= 500 plus 830 mm
Power	= 4796 kW
Speeds	= 7469/333 rpm

With reference to extreme rotor speeds, the following unit can be referred to:

Gear type	: G-19/15 (2 stages)
Center distance	= 190 plus 150 mm
Power	= 220 HP
Speeds	= 2'700/60'036 rpm
Pitch line velocity (2nd stage)	= 152 m/sec (30'000 FPM)

This gear box is used for testing of fuel pumps for aircraft engines.

4 Epicyclic gears

Standard epicyclic gears are based on a design with 3 planets in order to insure equal load distribution. By means of a patented flexible pin design, MAAG has the possibility of building gears with more than 3 planets, but still insuring equal distribution of the load to be transmitted.

One of the applications is shown in Fig. 11 and 12. The gear is bolted directly onto the gas turbine casing and, hence, is an integral part of the turbine structure.

Gear type	: TPV 12/20
Power	= 4000 kW
Speeds	= 12'000/1500 or 1800 rpm

The planet carrier with planets are supported by flex pins (Fig. 13). The patent of this design belongs to a British company, but MAAG has the right to use it.

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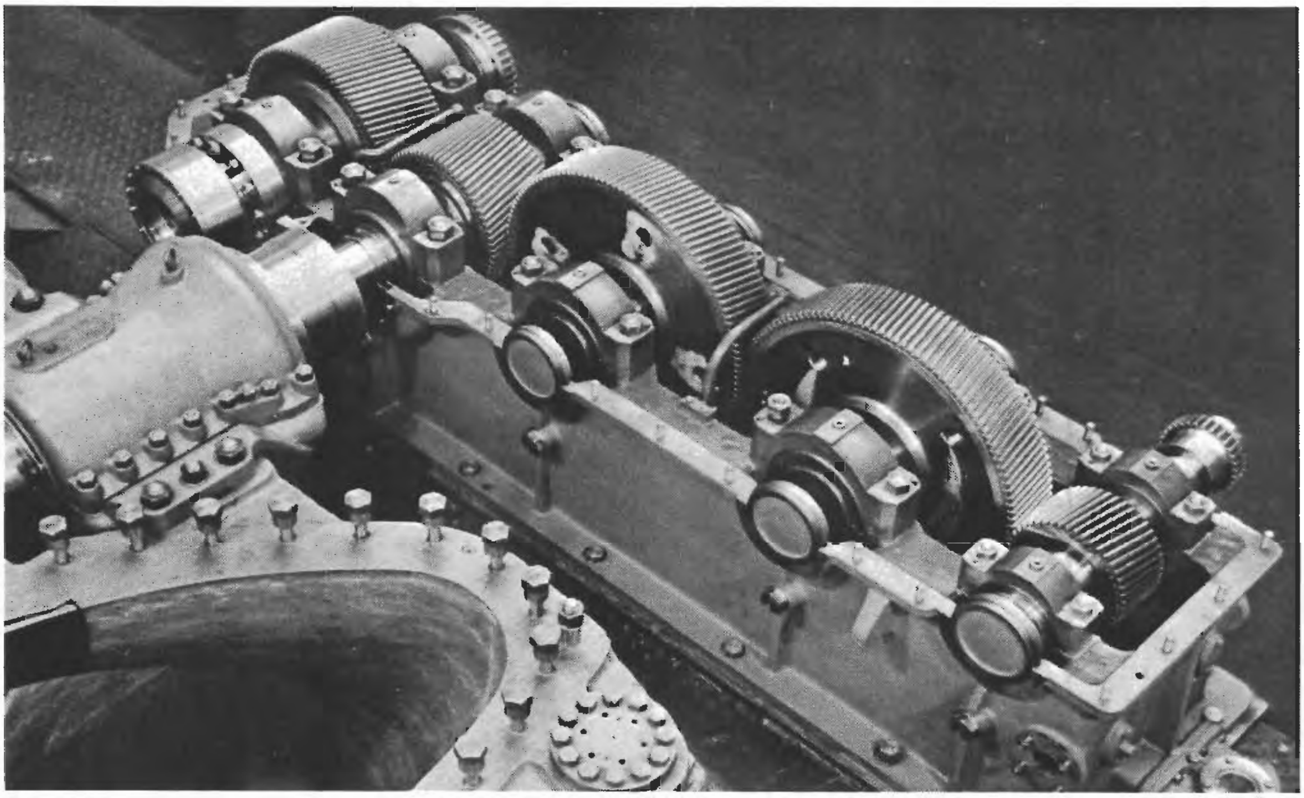

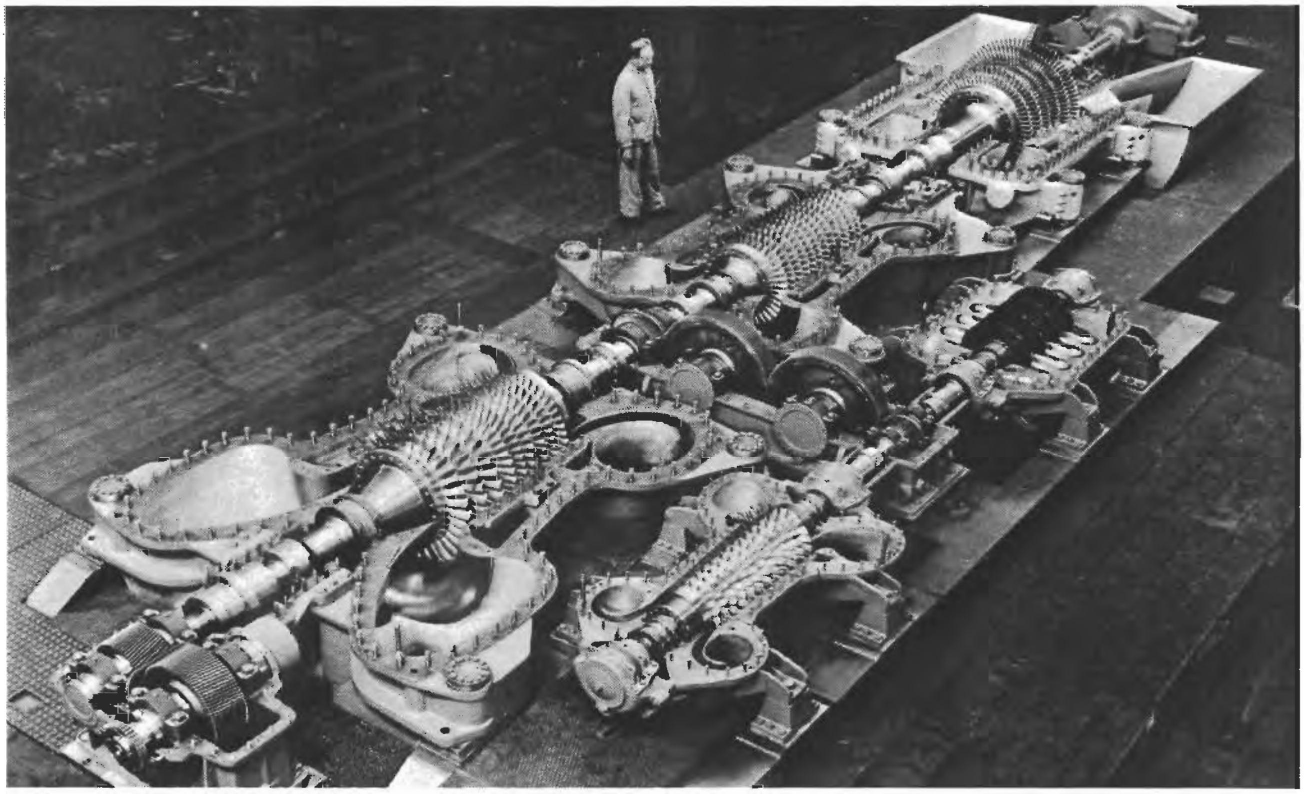

Fig. 1

Gear type : G-295/5
Driver (gas turbine) = 12'500 kW/at 3836 rpm
Driven machines:

- Generator = 8500 kW at 3000 rpm
- Blower = 3500 kW at 6686 rpm
- Compressor = 3100 kW at 10'174 rpm

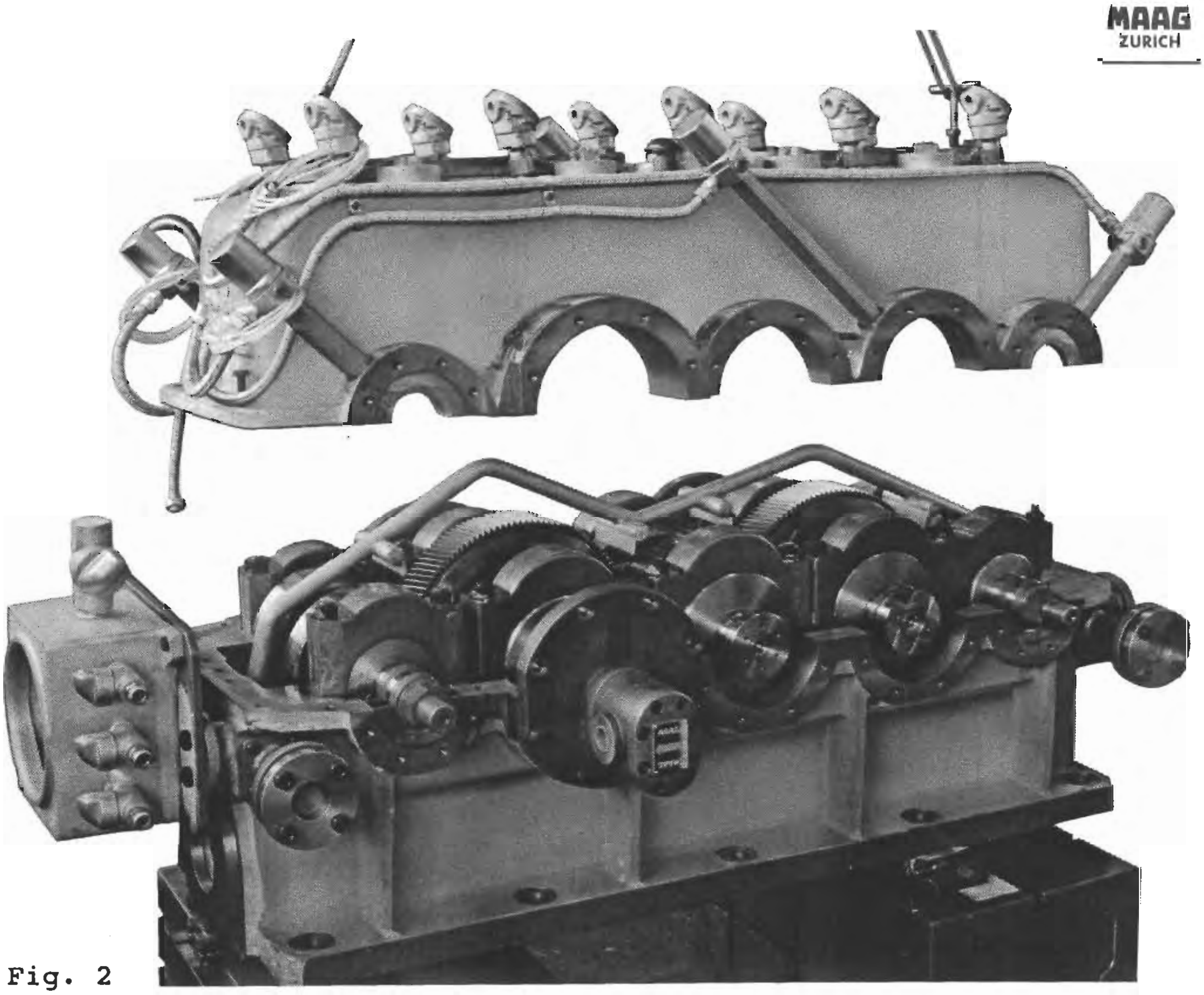

Fig. 2

Gear type GX-101/4, multiple shaft gearbox
between gas turbine and 2 compressors

Power of gas turbine : 3600 kW at 7500 rpm
Power of high pressure compressor: 1980 kW at 21'538 rpm
Power of low pressure compressor : 1616 kW at 15'849 rpm
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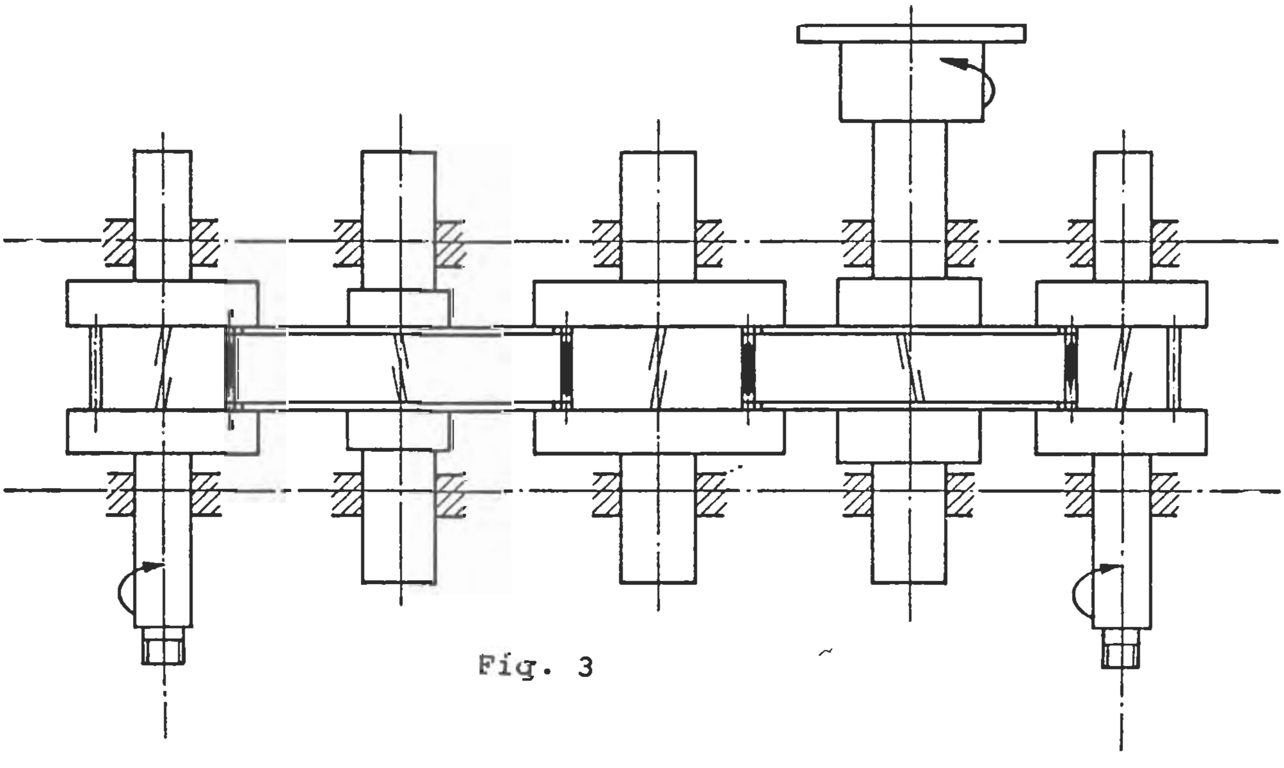
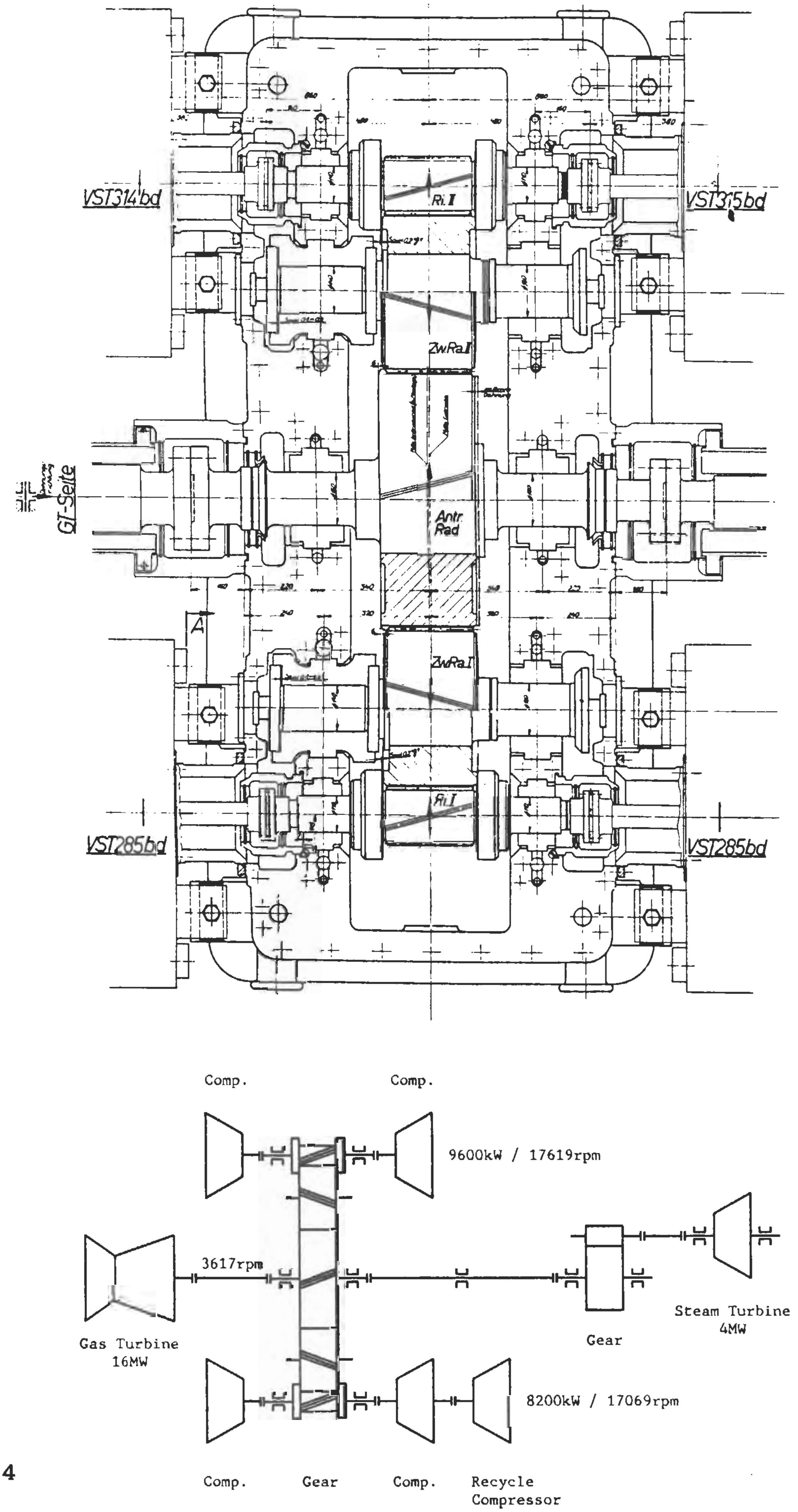


Fig. 3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Ri.I
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Comp.
Comp.
9600kW / 17619rpm
3617rpm
Gas Turbine
16MW
Gear
Steam Turbine
4MW
8200kW / 17069rpm
Comp.
Gear
Comp.
Recycle
Compressor

Fig. 4

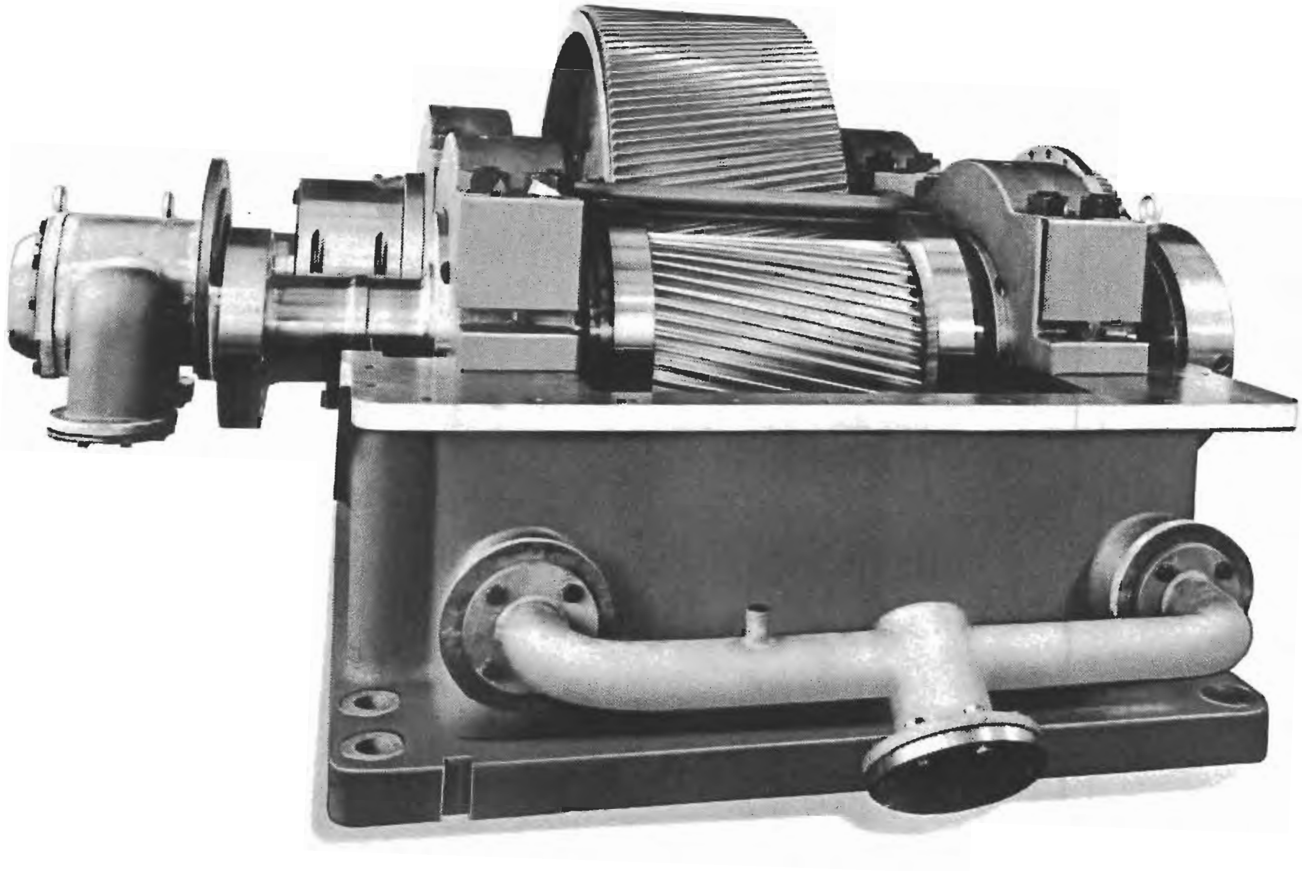


Fig. 5

Gear type	: GX-90
Center distance	= 906 mm
Power	= 30'000 kW
Speeds	= 1200/4437 rpm,
Helix thrust	= 6650 kg

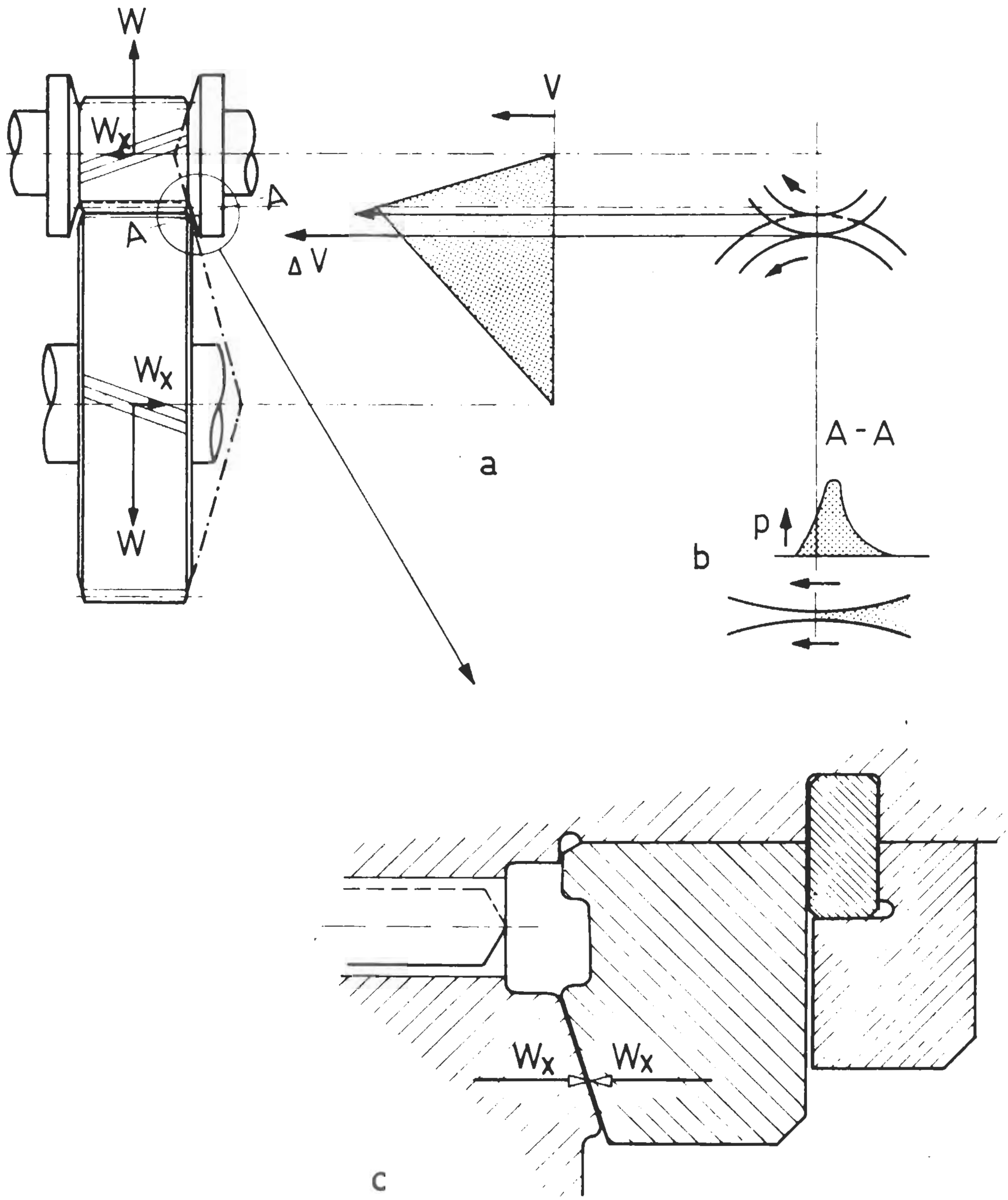


Fig. 6

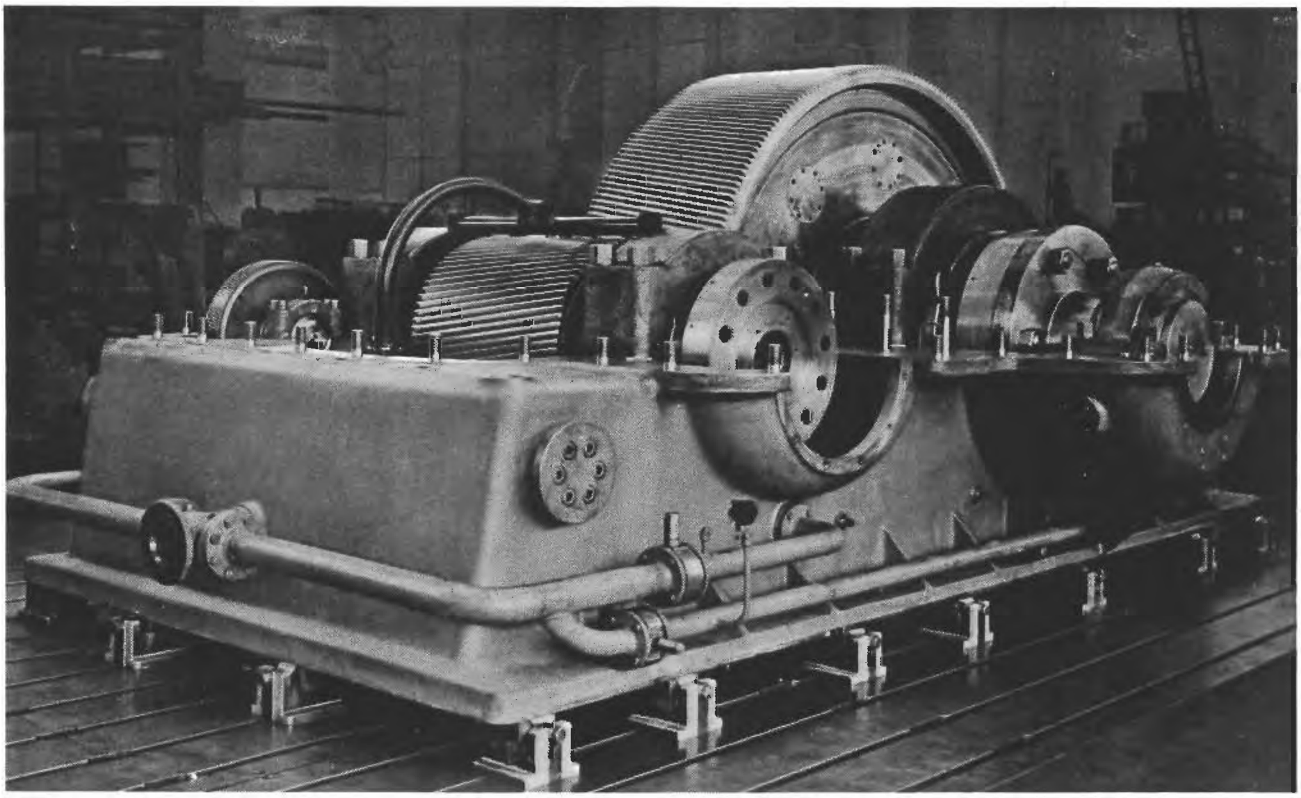


Fig. 7

Gear type	:	G-175
Center distance	=	1750 mm
Power	=	62'500 kW
Speeds	=	2988/1000 rpm, (Steam Turbine/Generator)
Pitch line velocity	=	137 m/sec (27'000 FPM)

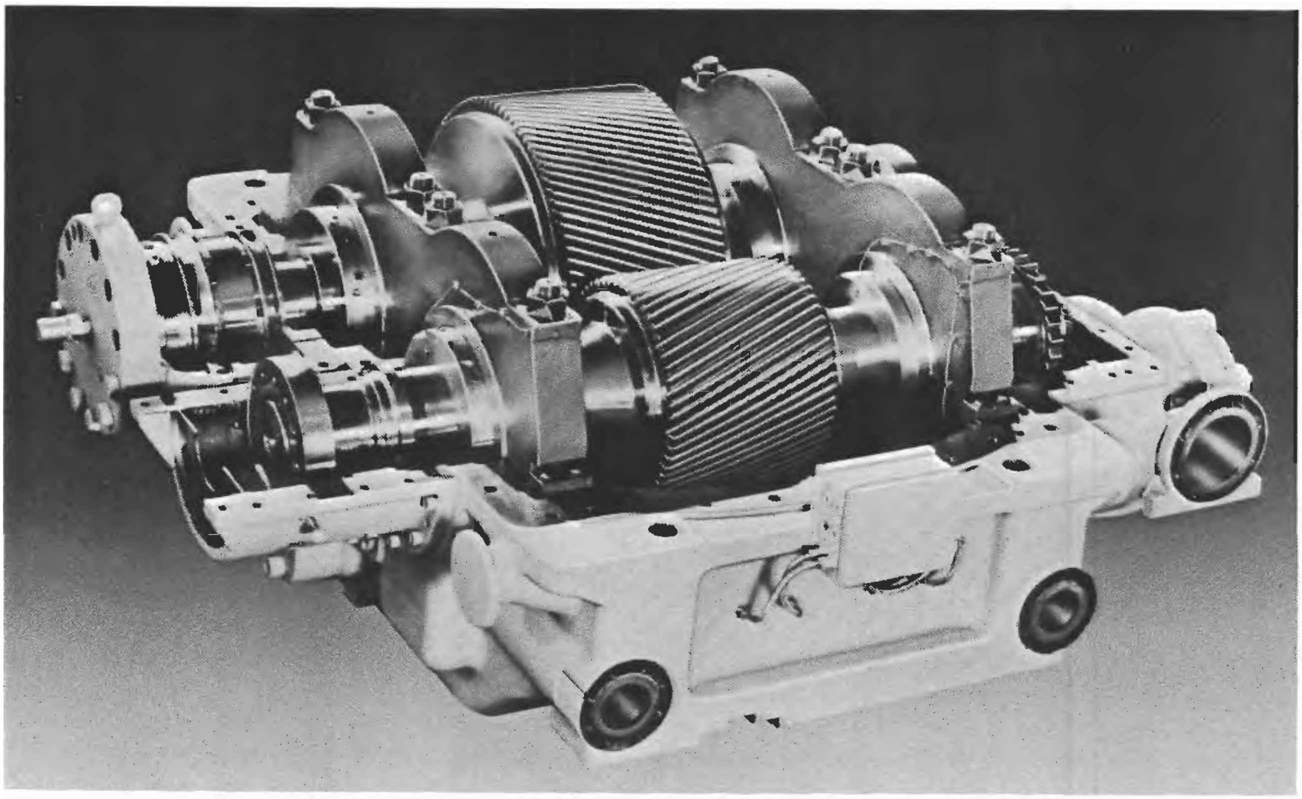


Fig. 8

Gear type : G-72s
Center distance = 720 mm
Power = 60'000 kW
Speeds = 6349/3600 rpm
(Gas Turbine/Generator)
Pitch line verlocity = 173 m/sec (34'000 FPM)

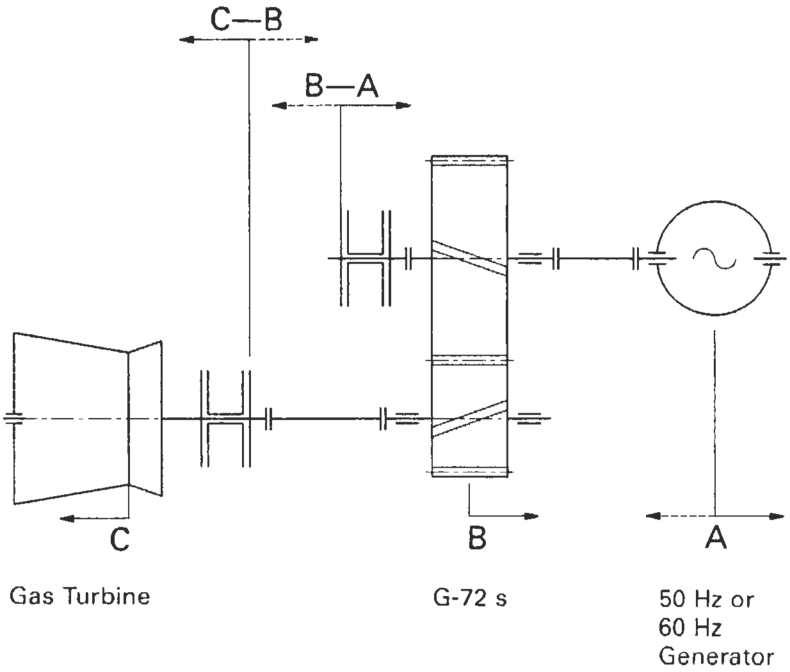


Fig. 9

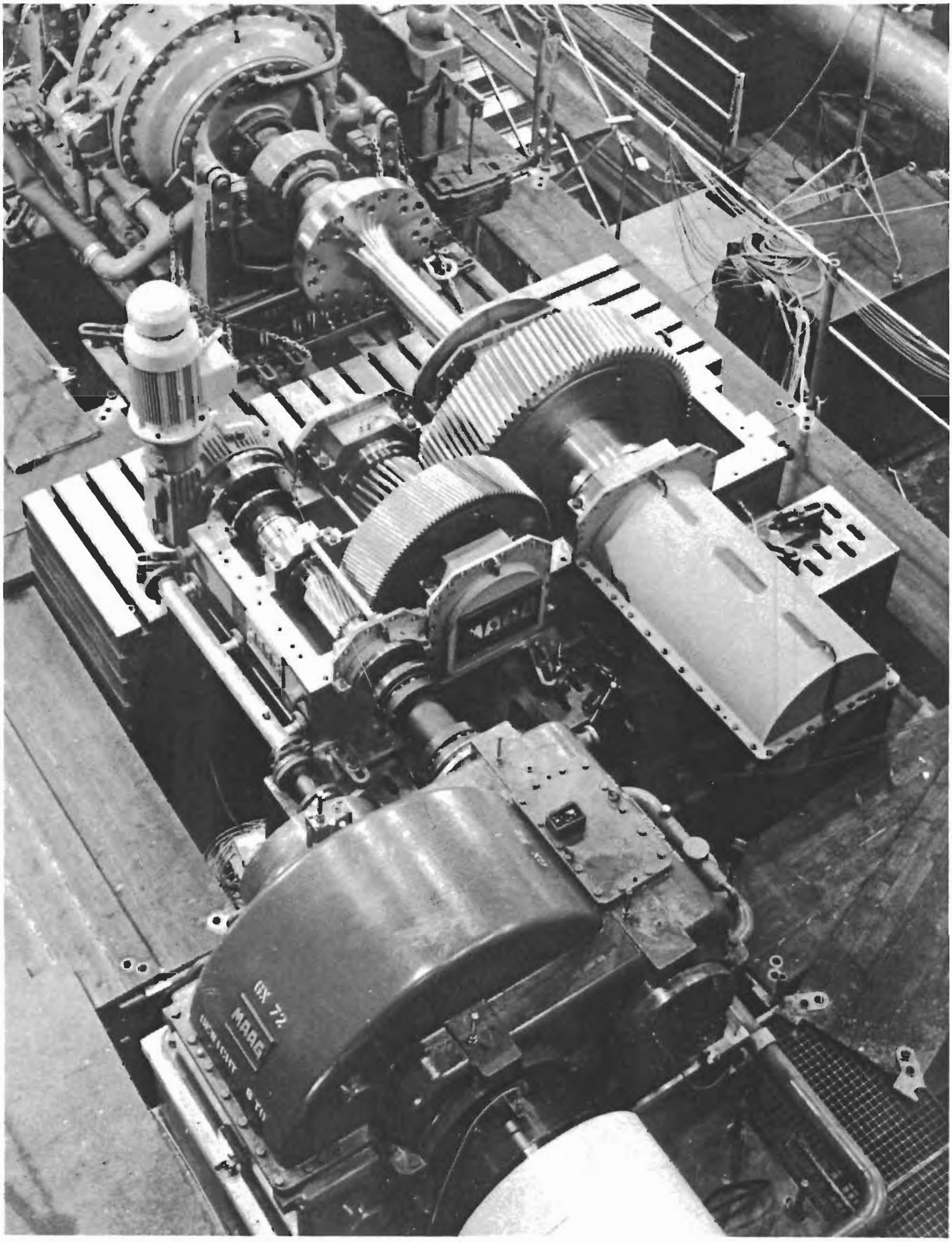


Fig. 10

Gear type	:	G-55/83 (two stages)
Center distance	=	500 plus 830 mm
Power	=	4796 kW
Speeds	=	7469/333 rpm

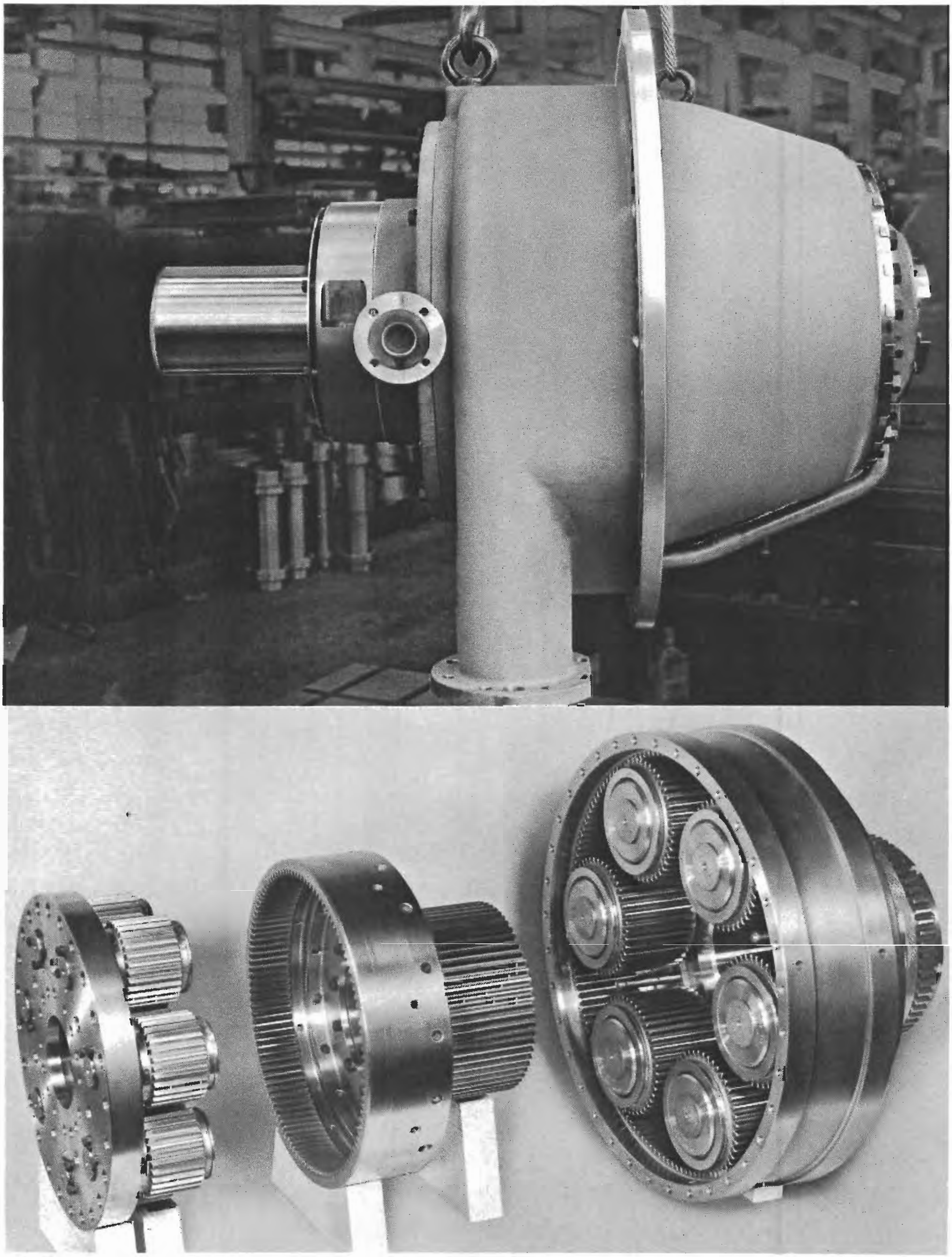
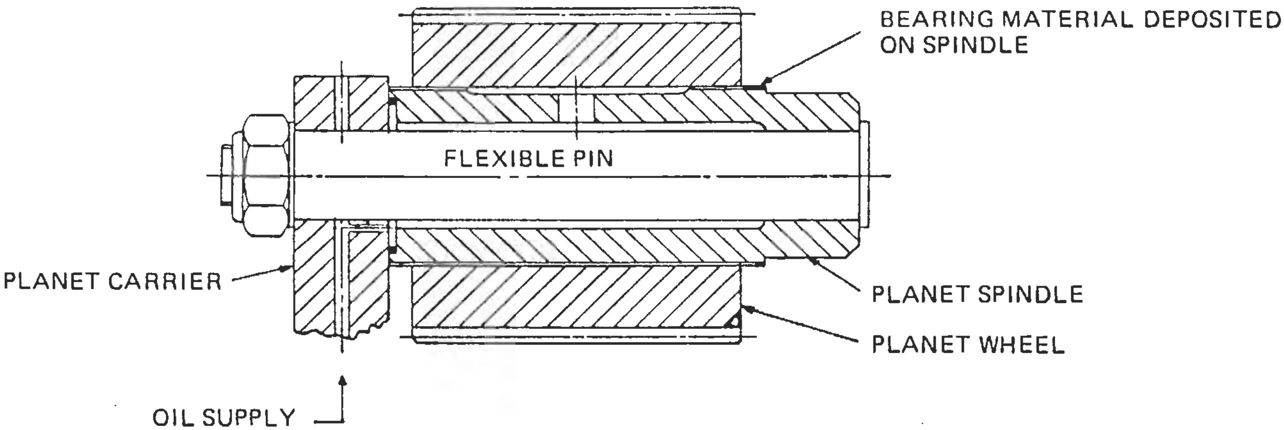
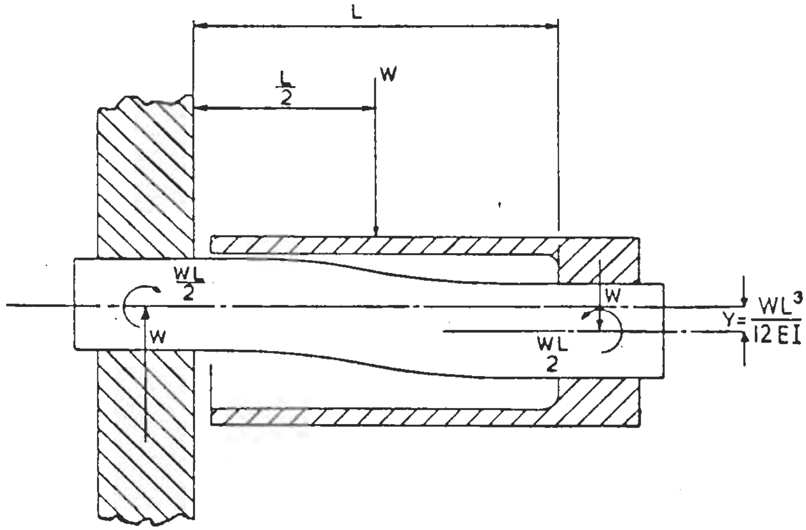


Fig. 11/12

Gear type : TPV 12/20
Power = 4'000 kW
Speeds = 12'000/1500 or 1800 rpm



(a) PLANET WHEEL ROTATES ON FLEXIBLY MOUNTED SPINDLE



(b) PLANET SPINDLE LOADED AT CENTRE

Fig. 13