

4 Electricity Production

Introduction

Next to power for propulsion, electricity production is the largest fuel consumer on board. The electricity is produced by using one or more of the following types of machinery, either running alone or in parallel:

- Auxiliary diesel generating sets
- Main engine driven generators
- Steam driven turbogenerators
- Emergency diesel generating sets.

The machinery installed should be selected based on an economical evaluation of first cost, operating costs, and the demand of man-hours for maintenance.

In the following, technical information is given regarding main engine driven generators (PTO) and the auxiliary diesel generating sets produced by MAN B&W.

Power Take Off (PTO)

With a generator coupled to a Power Take Off (PTO) from the main engine, the electricity can be produced based on the main engine's low SFOC and use of heavy fuel oil. Several standardised PTO systems are available, see Fig. 4.01 and the designations on Fig. 4.02:

PTO/RCF

(Power Take Off/Renk Constant Frequency):

Generator giving constant frequency, based on mechanical-hydraulical speed control.

PTO/CFE

(Power Take Off/Constant Frequency Electrical):

Generator giving constant frequency, based on electrical frequency control.

PTO/GCR

(Power Take Off/Gear Constant Ratio):

Generator coupled to a constant ratio step-up gear, used only for engines running at constant speed.


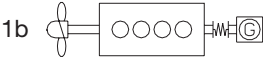

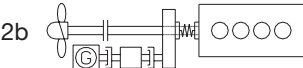

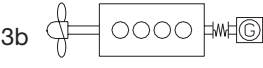

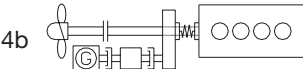

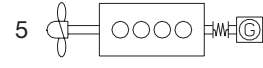
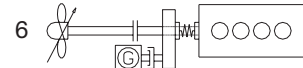
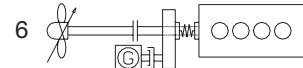
Within each PTO system, several designs are available, depending on the positioning of the gear:

BW II:

A free-standing gear mounted on the tank top and connected to the fore end of the diesel engine, with a vertical or horizontal generator.

BW IV:

A free-standing step-up gear connected to the intermediate shaft, with a horizontal generator.

	Alternative generator positioning	Design	Seating	Total efficiency
PTO/RCF	1a  1b 	BW II/RCF	On tanktop	88-92
	2a  2b 	BW IV/RCF	On tanktop	88-92
PTO/CFE	3a  3b 	BW II/CFE	On tanktop	81-85
	4a  4b 	BW IV/CFE	On tanktop	81-84
PTO/GCR	 5 	BW II/GCR	On tanktop (Horizontal generator)	92
	 6 	BW IV/GCR	On tanktop	92

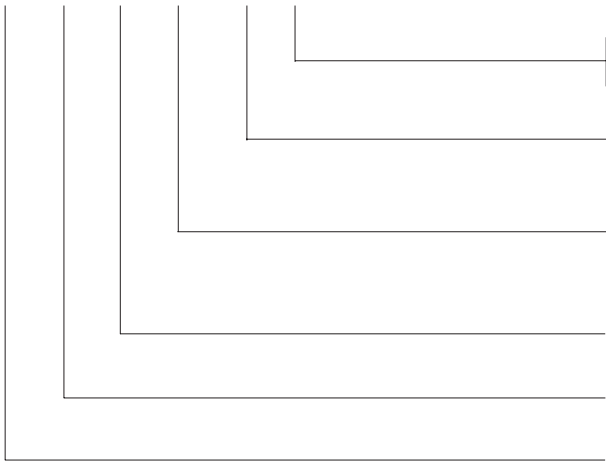
BW II/RCF (1) and BW II/GCR (5) are our standard solutions, all others are available on request

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Fig. 4.01: Types of PTO

Power take off:

BW II S35/GCR 500-60



PTO

- 50: 50 Hz
- 60: 60 Hz
- KW on terminals generator
- RCF: Renk Constant Frequency unit
- GCR: Step-up gear with constant ratio
- CFE: Step-up gear with frequency control
- Engine type on witch it is applied
- Positioning of PTO: See Fig. 4.01
- Make: MAN B&W

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Fig. 4.02: Designation of PTO

PTO/RCF

Free standing generator, BW II/RCF
(Fig. 4.01, alternative 1)

The PTO/RCF generator systems have been developed in close cooperation with the German gear manufacturer Renk. A complete package solution is offered, comprising a flexible coupling, a step-up gear, an epicyclic, variable-ratio gear with built-in clutch, hydraulic pump and motor, and a standard generator, see Fig. 4.03.

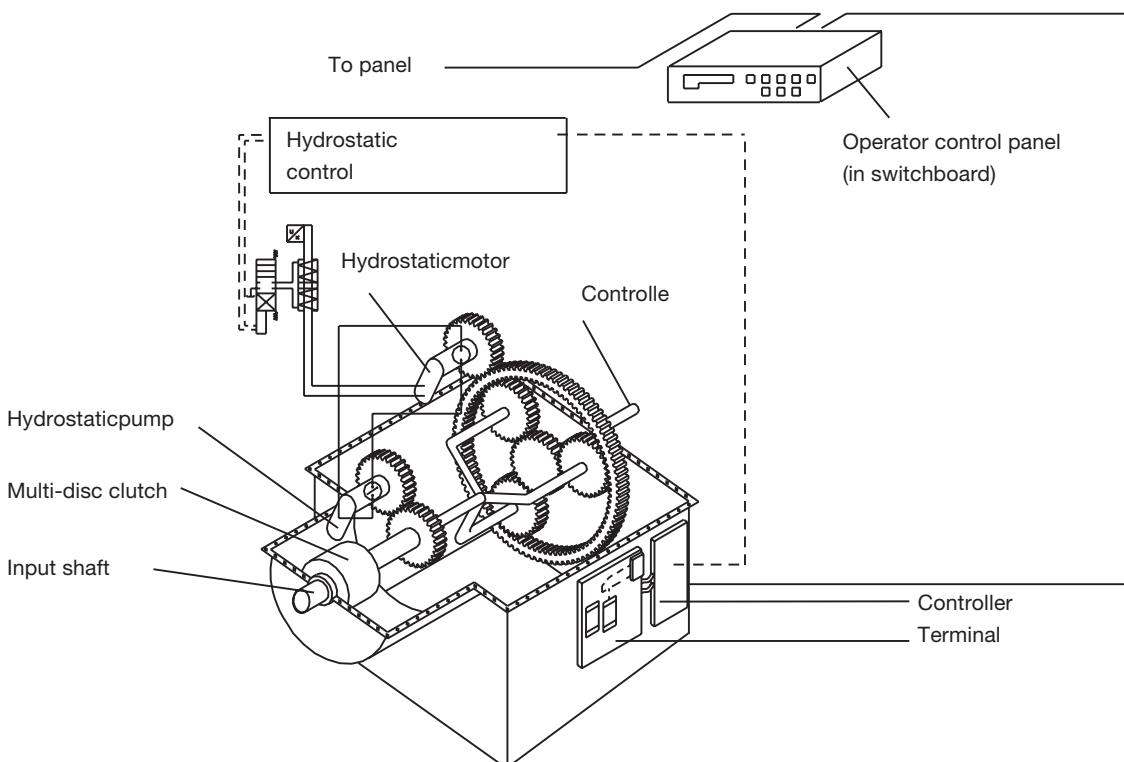
For marine engines with controllable pitch propellers running at constant engine speed, the hydraulic system can be dispensed with, i.e. a PTO/GCR design is normally used, see Fig. 4.01, alternative 5.

Fig. 4.03 shows the principles of the PTO/RCF arrangement.

A complete package solution is offered, comprising a flexible coupling, a step-up gear, an epicyclic, variable-ratio gear with built-in clutch, hydraulic pump and motor, and a standard generator.

The BW II/RCF unit is an epicyclic gear with a hydrostatic superposition drive. The hydrostatic input drives the annulus of the epicyclic gear in either direction of rotation, hence continuously varying the gearing ratio to keep the generator speed constant throughout an engine speed variation of 30%. In the standard layout, this is between 100% and 70% of the engine speed at specified MCR, but it can be placed in a lower range if required.

The input power to the gear is divided into two paths – one mechanical and the other hydrostatic – and the epicyclic differential combines the power of the two paths and transmits the combined power to the output shaft, connected to the generator. The gear is equipped with a hydrostatic motor driven by a pump, and controlled by an electronic control unit.



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Fig. 4.03: Power Take Off with Renk constant frequency gear: BW II/RCF, option: 4 85 203

This keeps the generator speed constant during single running as well as when running in parallel with other generators.

The multi-disc clutch, integrated into the gear input shaft, permits the engaging and disengaging of the epicyclic gear, and thus the generator, from the main engine during operation.

An electronic control system with a Renk controller ensures that the control signals to the main electrical switchboard are identical to those for the normal auxiliary generator sets. This applies to ships with automatic synchronising and load sharing, as well as to ships with manual switchboard operation.

Internal control circuits and interlocking functions between the epicyclic gear and the electronic control box provide automatic control of the functions necessary for the satisfactory operation and protection of the BW III/RCF unit. If any monitored value exceeds the normal operation limits, a warning or an alarm is given depending upon the origin, severity and the extent of deviation from the permissible values. The cause of a warning or an alarm is shown on a digital display.

Extent of delivery for BW II/RCF units

Standard sizes of the crankshaft gears and the RCF units are designed for 700 and 1200 kW, while the generator sizes of make A. van Kaick are:

Type	440 V	60 Hz	380 V	50 Hz
DSG	1800 kVA	r/min kW	1500 kVA	r/min kW
62 M2-4	707	566	627	501
62 L1-4	855	684	761	609
62 L2-4	1056	845	940	752
74 M1-4	1271	1017	1137	909
74 M2-4	1432	1146	1280	1024
74 L1-4	1651	1321	1468	1174

The delivery is a complete separate unit.

If an engine speed other than the nominal is required for the main engine, this information must be supplied because it influences the ratio of the space required for the engine and generator.

In the case that a larger generator is required, please contact MAN B&W Diesel A/S

If a main engine speed other than the nominal is required as a basis for the PTO operation, this must be taken into consideration when determining the ratio of the crankshaft gear. However, this has no influence

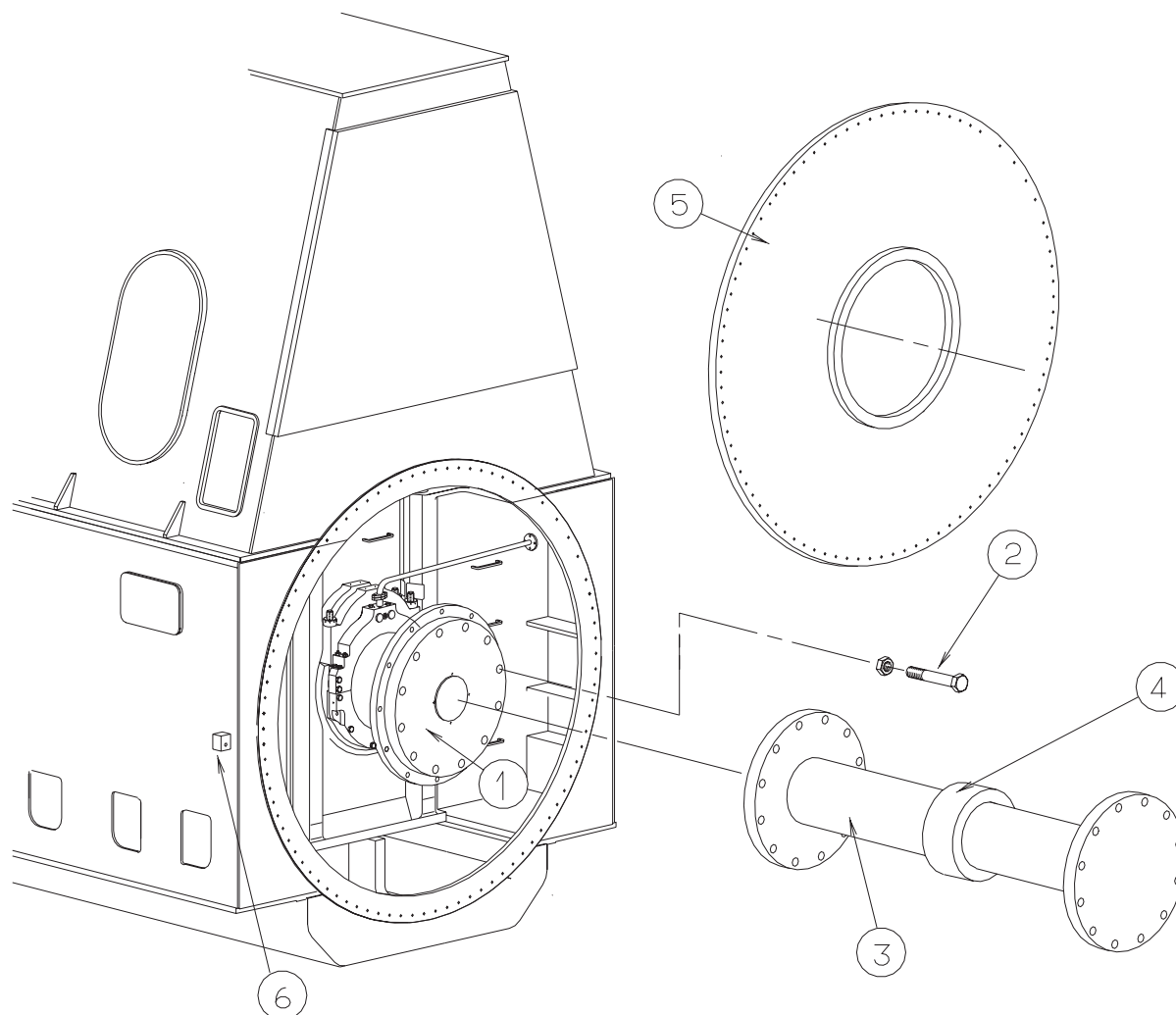
Yard deliveries are:

1. Cooling water pipes to the built-on lubricating oil cooling system, including the valves
2. Electrical power supply to the lubricating oil stand-by pump built on to the RCF unit
3. Wiring between the generator and the operator control panel in the switch-board.
4. An external permanent lubricating oil filling-up connection can be established in connection with the RCF unit. The system is shown in Fig. 4.07 "Lubricating oil system for RCF gear". The dosage tank and the pertaining piping are to be delivered by the yard. The size of the dosage tank is stated in the table for RCF gear in "Necessary capacities for PTO/RCF" (Fig. 4.06).

The necessary preparations to be made on the engine are specified in Figs. 4.05a and 4.05b.

Additional capacities required for BW III/RCF

The capacities stated in the "List of capacities" for the main engine in question are to be increased by the additional capacities for the crankshaft gear and the RCF gear stated in Fig. 4.06.



- Pos. 1: Flange on crankshaft
Pos. 2: Studs and nuts, dowel pipe and screws
Pos. 3: Intermediate shaft between the crankshaft and flexible coupling for PTO
Pos. 4: Oil sealing for intermediate shaft
Pos. 5: End cover in 2/2 with scraper ring housing

Fig. 4.05a: Engine preparations for PTO

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Crankshaft gear lubricated from the main engine lubricating oil system

The figures are to be added to the main engine capacity list:

Nominal output of generator	kW	700	1200
Lubricating oil flow	m ³ /h	4.1	4.1
Heat dissipation	kW	12.1	20.8

RCF gear with separate lubricating oil system:

Nominal output of generator	kW	700	1200
Cooling water quantity	m ³ /h	14.1	22.1
Heat dissipation	kW	55	92
El. power for oil pump	kW	11.0	15.0
Dosage tank capacity	m ³	0.40	0.51
El. power for Renk-controller	24V DC \pm 10%, 8 amp		

From main engine:

Design lub. oil pressure: 2.25 bar

Lub. oil pressure at crankshaft gear: min. 1 bar

Lub. oil working temperature: 50 °C

Lub. oil type: SAE 30

Cooling water inlet temperature: 36 °C

Pressure drop across cooler: approximately 0.5 bar

Fill pipe for lub. oil system store tank (~ø32)

Drain pipe to lub. oil system drain tank (~ø40)

Electric cable between Renk terminal at gearbox and operator control panel in switchboard: Cable type FMGCG 19 x 2 x 0.5

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Fig. 4.05: Necessary capacities for PTO/RCF, BW II/RCF system

PTO BW IV/GCR Power Take Off/Gear Constant Ratio

The shaft generator system, type PTO BW IV/GCR, installed in the shaft line (Fig. 4.01 alternative 6) can generate power on board ships equipped with a controllable pitch propeller running at constant speed.

The PTO-system can be delivered as a tunnel gear with hollow flexible coupling or, alternatively, as a generator step-up gear with flexible coupling integrated in the shaft line.

The main engine needs no special preparation for mounting these types of PTO systems as they are connected to the intermediate shaft.

The PTO-system installed in the shaft line can also be installed on ships equipped with a fixed pitch propeller or controllable pitch propeller running in combinator mode. This will, however, also require an additional Renk Constant Frequency gear (Fig. 4.01 alternative 2) or additional electrical equipment

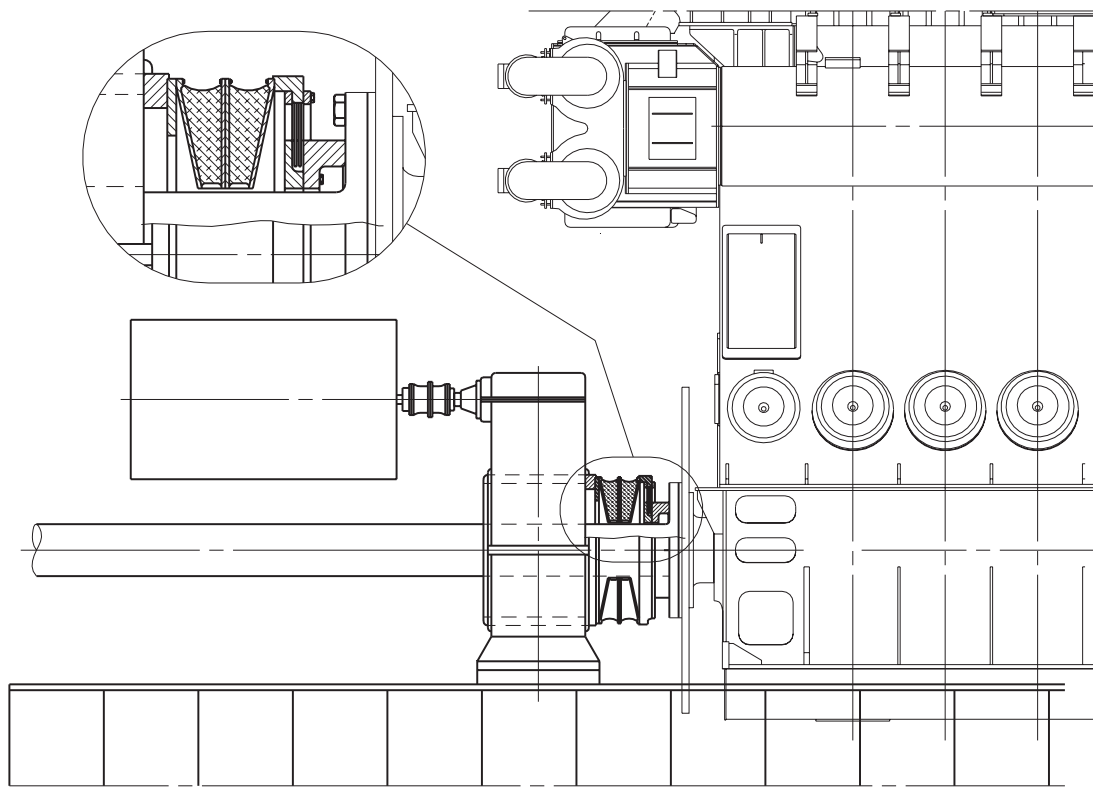
for maintaining the constant frequency of the generated electric power.

Tunnel gear with hollow flexible coupling

This PTO-system is normally installed on ships with a minor electrical power take off load compared to the propulsion power, up to approximately 25% of the engine power.

The hollow flexible coupling is only to be dimensioned for the maximum electrical load of the power take off system and this gives an economic advantage for minor power take off loads compared to the system with an ordinary flexible coupling integrated in the shaft line.

The hollow flexible coupling consists of flexible segments and connecting pieces, which allow replacement of the coupling segments without dismounting the shaft line, see Fig. 4.06.



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Fig. 4.06: BW IV/GCR, tunnel gear

Generator step-up gear and flexible coupling integrated in the shaft line

For higher power take off loads, a generator step-up gear and flexible coupling integrated in the shaft line may be chosen due to first costs of gear and coupling.

The flexible coupling integrated in the shaft line will transfer the total engine load for both propulsion and electricity and must be dimensioned accordingly.

The flexible coupling cannot transfer the thrust from the propeller and it is, therefore, necessary to make the gear-box with an integrated thrust bearing.

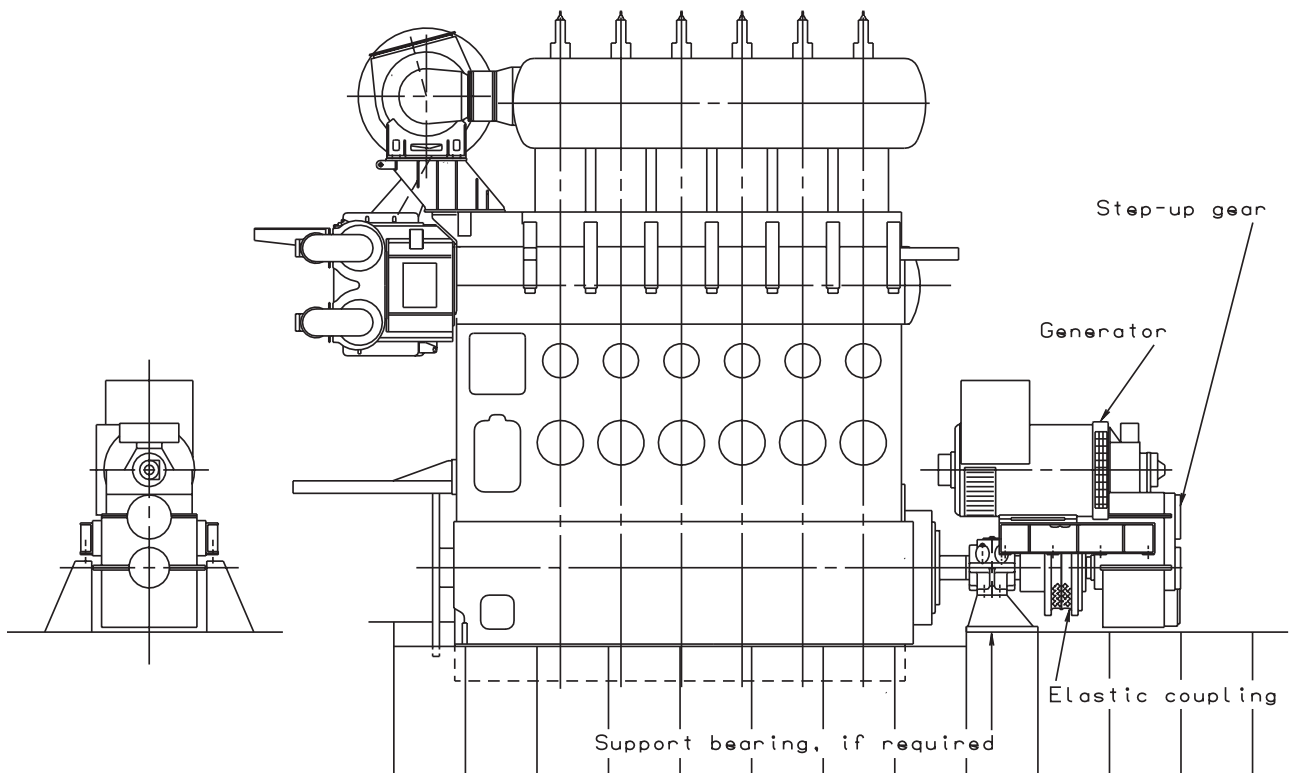
This type of PTO-system is typically installed on ships with large electrical power consumption, e.g. shuttle tankers.

Power Take Off/Gear Constant Ratio, PTO BW II/GCR

The system Fig. 4.01 alternative 5 can generate electrical power on board ships equipped with a controllable pitch propeller, running at constant speed.

The PTO unit is mounted on the tank top at the fore end of the engine and, by virtue of its short and compact design, it requires a minimum of installation space, see Fig. 4.07. The PTO generator is activated at sea, taking over the electrical power production on board when the main engine speed has stabilised at a level corresponding to the generator frequency required on board.

The BW II/GCR cannot, as standard, be mechanically disconnected from the main engine, but a hydraulically activated clutch, including hydraulic pump, control valve and control panel, can be fitted as an option.



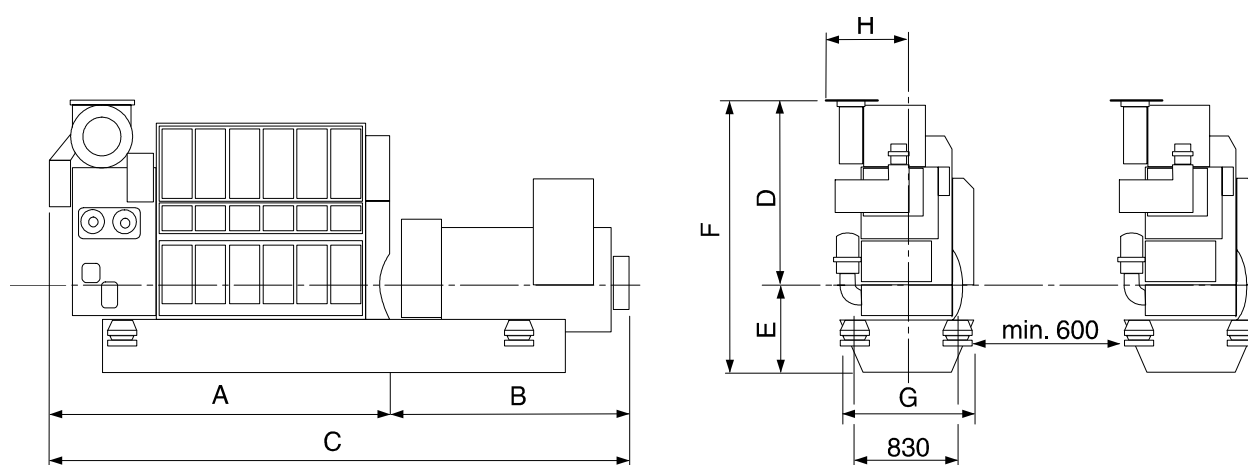
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Fig. 4.07: Power Take Off (PTO) BW II/GCR

L16/24 GenSet Data

Bore: 160 mm Stroke: 240 mm

	Power lay-out			
	1200 r/min	60 Hz	1000 r/min	50 Hz
	Eng. kW	Gen. kW	Eng. kW	Gen. kW
5L16/24	500	475	450	425
6L16/24	600	570	540	515
7L16/24	700	665	630	600
8L16/24	800	760	720	680
9L16/24	900	855	810	770



Cyl. No.	A mm	B mm	* C mm	D mm	E mm	F mm	G mm	H mm	** Dry mass Engine/frame t	*** Alternator t
5 (1200 r/min)	2745	1399	4145	1365	810	2175	1000	738	6.5	8.4
6 (1000/1200 r/min)	3020	1489	4509	1365	810	2175	1000	738	7.6	9.7
7 (1000/1200 r/min)	3295	1584	4880	1405	810	2215	1000	843	8.2	10.6
8 (1000/1200 r/min)	3570	1679	5250	1405	810	2215	1000	843	8.6	11.3
9 (1000 r/min)	3845	1679	5525	1405	810	2215	1000	843	9.4	12.1
9 (1200 r/min)	3845	1679	5525	1505	810	2315	1000	903	9.4	12.1

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- * Depends on alternator make (the above is based on Leroy Somer alternator)
- ** Engine and engine base frame
- *** Mass incl. standard alternator (based on a Leroy Somer alternator)

All dimensions and masses are approximate, and subject to changes without prior notice.

Fig. 4.08a: Power and outline of L16/24

L16/24 GenSet Data

Max. continuous rating at	Cyl.	5	6	7	8	9
1000/1200 r/min	kW	450/500	540/600	630/700	720/800	810/900

ENGINE DRIVEN PUMPS

HT cooling water pump	(2.0/3.2 bar)	m³/h	13.1	12.7/15.2	14.5/17.4	16.3/19.5	18.1/21.6
LT cooling water pump	(1.7/3.0 bar)	m³/h	17.3	18.9/20.7	22.0/24.2	25.1/27.7	28.3/31.1
Lubricating oil	(3-4.5 bar)	m³/h	25	23/27	24/29	26/31	28/33

EXTERNAL PUMPS

Fuel oil feed pump	(4 bar)	m³/h	0.15	0.16/0.18	0.19/0.21	0.22/0.24	0.24/0.27
Fuel booster pump	(8 bar)	m³/h	0.45	0.49/0.54	0.57/0.63	0.65/0.72	0.73/0.81

COOLING CAPACITIES

Lubricating oil	kW	115	127/138	148/161	169/184	190/207
Charge air LT	kW	45	48/54	56/63	64/72	72/81
*Flow LT at 36°C inlet and 44°C outlet	m³/h	17.3	18.9/20.7	22.0/24.2	25.2/27.6	28.3/31.1
Jacket cooling	kW	109	113/130	132/152	151/174	170/195
Charge air HT	kW	104	116/125	135/146	154/167	174/188
*Flow HT at 36°C inlet and 80°C outlet	m³/h	4.2	4.5/5.0	5.2/5.8	6.0/6.7	6.7/7.5

GAS DATA

Exhaust gas flow	kg/h	3358	3627/4029	4232/4701	4837/5373	5441/6044
Exhaust gas temp.	°C	345	345	345	345	345
Max. allowable back press.	bar	0.025	0.025	0.025	0.025	0.025
Air consumption	kg/h	3258	3519/3909	4106/4561	4693/5213	5279/5864

STARTING AIR SYSTEM

Air consumption per start	Nm³	0.18	0.21	0.25	0.28	0.32
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HEAT RADIATION

Engine	kW	24	27/28	31/33	35/38	40/42
Alternator	kW	(see separate data from the alternator maker)				

The stated heat balances are based on tropical conditions, the flows are based on ISO ambient condition.

* The outlet temperature of the HT water is fixed to 80°C, and 44°C for LT water. At different inlet temperatures the flow will change accordingly.

Example: if the inlet temperature is 25°C, then the LT flow will change to $(44-36)/(44-25) \times 100 = 42\%$ of the original flow. The HT flow will change to $(80-36)/(80-25) \times 100 = 80\%$ of the original flow. If the temperature rises above 36°C, then the LT outlet will rise accordingly.

Power lay-out		MCR version	
Speed	r/min	1000	1200
Mean piston speed	m/sec.	8	9.6
Mean effective pressure	bar	22.4	20.7
Specific fuel oil consumption*	g/kWh	189	188

* According to ISO + 5% tolerance without engine driven pump.

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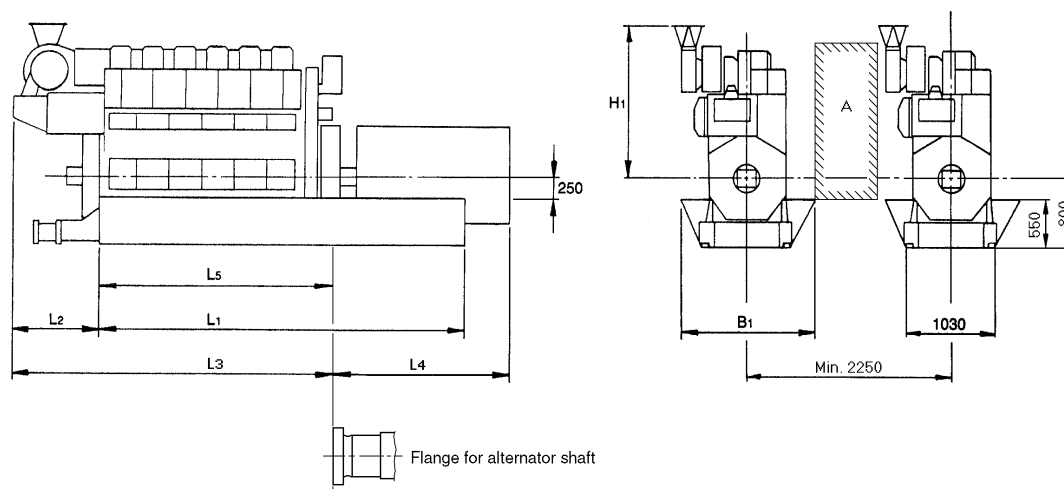
Fig. 4.08b: List of capacities for L16/24

L23/30H GenSet Data

Bore: 225 mm Stroke: 300 mm

	Power lay-out					
	720 r/min	60Hz	750 r/min	50Hz	900 r/min	60Hz
	Eng. kW	Gen. kW	Eng. kW	Gen. kW	Eng. kW	Gen. kW
5L23/30H	650	615	675	645		
6L23/30H	780	740	810	770	960	910
7L23/30H	910	865	945	900	1120	1060
8L23/30H	1040	990	1080	1025	1280	1215
SFOC*	191 g/kWh		192 g/kWh		196 g/kWh	

* According to ISO 3046/conditions without pumps.



Cyl. No.	L ₁ *	L ₂	L ₃	L ₄ *	L ₅ ****	B ₁ *	H ₁	Dry mass** t	Dry mass GenSet*** t
5	3925	1070	3350	2155	2340	1380	1583	12.2	16.8
5 (900 r/min)	3885	1070	3350	2135	2340	1380	1583	12.2	16.8
6	4505	1070	3720	2385	2710	1380	1583	12.9	18.7
6 (900 r/min)	4445	1070	3720	2325	2710	1380	2015	12.9	18.7
7	4745	1070	4090	2270	3080	1600	2015	14.3	19.2
7 (900 r/min)	4745	1070	4090	2270	3080	1600	2015	14.3	19.2
8	5225	1070	4460	2380	3450	1600	2015	15.8	23.7
8 (900 r/min)	5180	1070	4460	2355	3450	1600	2015	15.8	23.7

A Free passage between the engines, width 600 mm and height 2000 mm.

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* Depending on alternator

** Engine and engine base frame

*** Mass included a standard alternator, make A. van Kaick

**** Incl. flywheel

All dimensions and masses are approximately, and subject to change without notice.

Fig. 4.09a: Power and outline of L23/30H

L23/30H GenSet Data

Max. continuous rating at		Cyl.	5	6	7	8
720/750 r/min		Engine kW	650/675	780/810	910/945	1040/1080
900 r/min		Engine kW		960	1120	1280
720/750 r/min	60/50 Hz	Gen. kW	615/645	740/770	865/900	990/1025
900 r/min	60 Hz	Gen. kW		910	1060	1215
ENGINE-DRIVEN PUMPS		720, 750/900 r/min				
Fuel oil feed pump	(5.5-7.5 bar)	m ³ /h	1.0/1.3	1.0/1.3	1.0/1.3	1.0/1.3
LT cooling water pump	(1-2.5 bar)	m ³ /h	55/69	55/69	55/69	55/69
HT cooling water pump	(1-2.5 bar)	m ³ /h	36/45	36/45	36/45	36/45
Lub. oil main pump	(3-5/3.5-5 bar)	m ³ /h	16/20	16/20	20/20	20/20
SEPARATE PUMPS						
LT cooling water pump*	(1-2.5 bar)	m ³ /h	35/44	42/52	48/61	55/70
LT cooling water pump**	(1-2.5 bar)	m ³ /h	48/56	54/63	60/71	73/85
HT cooling water pump	(1-2.5 bar)	m ³ /h	20/25	24/30	28/35	32/40
Lub. oil stand-by pump	(3-5/3.5-5 bar)	m ³ /h	14/16	15/17	16/18	17/19
COOLING CAPACITIES						
LUBRICATING OIL						
Heat dissipation		kW	69/97	84/117	98/137	112/158
LT cooling water quantity*		m ³ /h	5.3/6.2	6.4/7.5	7.5/8.8	8.5/10.1
SW LT cooling water quantity**		m ³ /h	18	18	18	25
Lub. oil temp. inlet cooler		°C	67	67	67	67
LT cooling water temp. inlet cooler		°C	36	36	36	36
CHARGE AIR						
Heat dissipation		kW	251/310	299/369	348/428	395/487
LT cooling water quantity		m ³ /h	30/38	36/46	42/53	48/61
LT cooling water inlet cooler		°C	36	36	36	36
JACKET COOLING						
Heat dissipation		kW	182/198	219/239	257/281	294/323
HT cooling water quantity		m ³ /h	20/25	24/30	28/35	32/40
HT cooling water temp. inlet cooler		°C	77	77	77	77
GAS DATA						
Exhaust gas flow		kg/h	5510/6980	6620/8370	7720/9770	8820/11160
Exhaust gas temp.		°C	310/325	310/325	310/325	310/325
Max. allowable back. press.		bar	0.025	0.025	0.025	0.025
Air consumption		kg/h	5364/6732	6444/8100	7524/9432	8604/10800
STARTING AIR SYSTEM						
Air consumption per start		Nm ³	0.30	0.35	0.40	0.45
HEAT RADIATION						
Engine		kW	21/26	25/32	29/37	34/42
Generator		kW	(See separate data from generator maker)			

Please note that for the 750 r/min engine the heat dissipation, capacities of gas and engine-driven pumps are 4% higher than stated at the 720 r/min engine.

If LT cooling is sea water, the LT inlet is 32° C instead of 36°C.

These data are based on tropical conditions, except for exhaust flow and air consumption which are based on ISO conditions.

*Only valid for engines equipped with internal basic cooling water system no 1 and 2.

**Only valid for engines equipped with combined coolers, internal basic cooling water system no 3.

178 34 54-5.1

Fig. 4.09b: List of capacities for L23/30H