Title: MARINE PROPULSION SYSTEMS

Abstract: A propulsion system for large ocean going vessels. The system includes a large turbo charged multi-cylinder two-stroke diesel engine of the crosshead type coupled to the propeller shaft as a main prime mover and one or more substantially smaller diesel engines coupled to generators as secondary prime movers. The main engine requires electric, hydraulic and pneumatic power in order to be able to startup and operate. The main engine requires heat and small hydraulic power during short stops, and hydraulic power, pneumatic and electrical power during startup. Hydraulic power is provided by one or more high-pressure pumps or pumping stations that are driven by power takeoff from the crankshaft of the large two-stroke diesel engine, by electric motors or by auxiliary diesel engines.
The present invention relates to marine propulsion systems that include a large two-stroke diesel engine of the crosshead type.

A large two-stroke diesel engine for ship propulsion is a complex machine that forms the core of the ships power and propulsion system and includes a range of auxiliary equipment.

These slow running large two-stroke crosshead diesel engines are enormous and highly effective power producing machines. The largest of these engines produce about 100,000 kW at 94 rpm, have an overall length of 33 meters and weigh close to 3500 tons.

These engines are accompanied by auxiliary diesel engines that drive electrical generators, so-called generator sets. The generator sets provide electricity and heat during engine stops and during start up.

The auxiliary equipment of the two-stroke diesel engine includes e.g. high-pressure hydraulic pumps, pneumatic pumps (compressors), lubrication oil pumps, fuel oil supply pumps, fuel oil circulation pumps, seawater pumps, jacket water pumps, central water pumps and auxiliary blowers.

Much of the listed auxiliary equipment is either electrically driven, such as the auxiliary blowers, or power is taken off from the crankshaft of the large two-stroke diesel engine by
means of a mechanical transmission (i.e. chain or gear), such as in case of the high-pressure hydraulic pumps or pumping station(s).

Electronically controlled large two-stroke diesel engines, with their hydraulically operated exhaust valves use a substantial amount of hydraulic power during engine operation (about 1.5 to 2% of the crankshaft power).

Hydraulic pressure is required in minor amounts during engine start up. Therefore, an electrically powered smaller hydraulic pump or pumping station provides hydraulic power during engine start up. Since the engines are started up by pressurizing the cylinders with compressed air, at least a part of the pneumatic pumps is electrically driven. The electric energy for electric motors that drive these hydraulic and pneumatic pumps is provided by the generator sets. The generator sets also keep the large two-stroke diesel engine warm during engine stops and provide the electric energy for circulating the heavy fuel oil in the fuel conduits and reservoirs. The generator sets also provide the heat and electric power that is used onboard the vessel by various consumers such as cooling systems for the cargo, electricity for lighting and powering electric equipment when the main engine is stopped.

Mechanical power takeoff from the crankshaft of the large two-stroke diesel engine for driving auxiliary equipment is attractive from a fuel efficiency point of view, since the energy at the crankshaft of the large two-stroke diesel engine is produced with a high efficiency. However, mechanical power takeoff from the crankshaft can only be used at locations allow
a simple and direct connection between the auxiliary equipment and the crankshaft, and is not very useful for auxiliary equipment that consumes a relatively small amount of energy. For example, the auxiliary blowers that assist in providing scavenging air during low load running (below 40-50% of the maximum rating) of the large two-stroke diesel engine are typically powered by an electric motor since their location would require a complex mechanical transmission to connect to the crankshaft. The amount of power consumed by the auxiliary blower is quite substantial, typically in the range of 1.8 to 2.3% of the maximum rating of the large two-stroke diesel engine. Another disadvantage of power takeoff from the crankshaft can be the need for high gearing ratios to increase the low crankshaft speed (max 100-200 rpm) to a substantially higher speed required by most of the auxiliary equipment. These high gearing ratios cause more complex and thus expensive transmissions between the crankshaft and the power consumer.

Electric motors have been used where the flexibility of location and the relative ease of creating the connection between the power source and the electric motor driving the auxiliary equipment has been decisive, such as for the auxiliary blower(s). The largest of the two-stroke diesel engines are enormous and a single engine may be capable of producing more than 100.000 kW. The electric motors driving auxiliary equipment consume only a fraction of the crankshaft power of the engine but are in absolute terms large electric motors. For example a MAN B&W Diesel 12K98MC-C with maximum rating of 68.520 kW deploys four electric motors of 155 kW each to drive four auxiliary blowers.
Such large electric motors with a power are relatively expensive equipment. Their high price is caused by the low production volumes and the cooling problems associated with large electric motors. Electric motors very compact and closed constructions and are inherently difficult to cool. Above a certain engine size it is not possible to suffice with air cooling. Therefore, most of the electric motors used for powering auxiliary equipment of large two-stroke diesel engines are oil cooled. Further, insurance companies require that electric motors above 500 kW are certified, which leads to a significant rise in their market price.

Electric motors of this size are typically asynchronous motors. Thyristor-based variable frequency AC converters required for variably controlling the speed of these electric motors are extremely expensive, and therefore these motors are typically only controlled in an on/off manner. In case of the auxiliary blowers this means that the blowers have to run at full speed, even if the main engine does not require full output of the auxiliary blower. Consequently, energy is simply wasted since the electric motors are running at full power even if much less power is required to drive the auxiliary blowers. Avoiding this energy waste can up to now only be avoided by investing in the above mentioned very expensive electric equipment.

Asynchronous electric motors can only run at predetermined speeds that depend on the frequency of the deployed AC current system (50 or 60 Hz), and these rotational speeds coincide only in rare cases with the optimal rotational speed of the auxiliary blowers and thus, in practice, the auxiliary blowers often run at non-optimal speeds.
Owing to the relatively high starting current, the auxiliary-blowers start in sequence with 6-10 seconds in between.

The electric cables for connecting the electric engines the generators or control equipment are relatively massive cables, and the placement of these cables is subjected to a large amount of mainly safety related criteria, and consequently complicated to plan and expensive to carry out.

Most modern oceangoing vessels have a single engine driving a large propeller. A large oceangoing vessel that is rendered unmaneuverable by a defect main engine is a highly undesirable and unsafe situation. Therefore, large two-stroke diesel engines for marine propulsion are constructed to be extremely reliable machines. However, constructions that cannot fail at all do not exist and therefore there has recently been an increasing demand for redundancy or at least a minimum amount of take-home power in case the main engine should fail. This objective could be achieved by installing two smaller engines in parallel instead of one large engine in a vessel to provide proper redundancy. However, from a fuel efficiency and operation cost perspective it is not attractive to install two smaller engines instead of one larger engine in a vessel. Propeller efficiency is also higher for a single large propeller than for two small propellers.
DISCLOSURE OF THE INVENTION

On this background, it is an object of the present invention to provide a large two-stroke marine diesel engine in which the power supply for the auxiliary equipment is improved.

This object is achieved in accordance with claim 1 by providing a large turbo charged multi-cylinder two-stroke diesel engine of the crosshead type comprising one or more auxiliary blowers for scavenging of the cylinders at low engine loads, one or more hydraulic pumps or pumping stations for supplying the hydraulic system and/or the lubrication and/or the fuel system with pressurized fluid, and one or more electric motors that drive both the one or more auxiliary blowers and the one or more hydraulic pumps or pumping stations.

It is another object of the present invention to provide a more efficient power supply for an auxiliary blower of a large two-stroke diesel engine.

This object is achieved in accordance with claim 7 by providing a large turbo charged multi-cylinder two-stroke diesel engine of the crosshead type comprising one or more auxiliary blowers for scavenging of the cylinders at low engine loads whilst the turbocharger scavenges the cylinders at higher engine loads, a hydraulic pump or pumping station driven by electric motors and/or by power takeoff from the crankshaft, and one or more hydraulic motors driving the one or more auxiliary blowers.
It is another object of the present invention to provide an improved power supply for hydraulic valve actuators of a large two-stroke diesel engine.

This object is achieved in accordance with claim 16 by providing a propulsion system for a large ocean going vessel, comprising a large turbo charged multi-cylinder two-stroke diesel engine of the crosshead type, one or more electricity generators powered by power takeoff from the large turbo charged multi-cylinder two-stroke diesel engine and/or one or more auxiliary diesel generator sets for providing electrical power, one or more auxiliary blowers for scavenging the cylinders at low engine loads, said auxiliary blowers being driven by a hydraulic motors, one or more high-pressure pumps or high-pressure pumping stations powered by electric motors delivering high-pressure fuel oil, hydraulic valve actuators for actuating the exhaust valves, wherein either both or one of said hydraulic valve actuators and said hydraulic motors are operated with high-pressure fuel oil delivered by said one or more high-pressure pumps or high-pressure pumping stations.

It is yet another object of the present invention to provide a large two-stroke marine propulsion system with improved fail safe characteristics.

This object is achieved in accordance with claim 21 by providing a propulsion system for a large ocean going vessel comprising a large two-stroke diesel engine of the crosshead type that is connected to a propeller via a drive shaft, one or more generator sets including a prime mover and a generators for producing electricity independently from the operational state.
of said large two-stroke diesel engine, a high-pressure hydraulic pumping station or pump driven by one or more electric motors, and a hydraulic piston motor connectable to said drive shaft or to said propeller when said large two-stroke diesel engine is out of order to provide take home power.

It is yet another object of the present invention to provide a propulsion system for a large ocean going vessel with a hydraulic supply system with improved flexibility and efficiency.

This object is achieved in accordance with claim 29 by providing a propulsion system for a large ocean going vessel comprising a large two-stroke diesel engine of the crosshead type that is connected to a propeller via a drive shaft, one or more generator sets including a prime mover and generators for producing electricity independently from the operational state of said large two-stroke diesel engine, one or more high-pressure hydraulic pumping stations or pumps driven by an auxiliary diesel motor for producing high-pressure hydraulic fluid for consumers of high-pressure hydraulic fluid associated with the large two-stroke engine.

By using an auxiliary diesel motor to drive a high-pressure pump or pumping station hydraulic power can be generated directly form a prime mover as opposed to via a an electric generator and motor whilst still being able to provide the hydraulic power independently form the operating state of the large two-stroke diesel engine.
It is yet another object of the present invention to provide a propulsion system for a large ocean-going vessel with an improved system for driving auxiliary devices associated with the large two-stroke diesel engine.

This object is achieved in accordance with claim 33 by providing a propulsion system for a large ocean-going vessel comprising a large two-stroke uniflow diesel engine of the crosshead type that is connected to a propeller via a drive shaft, a high-pressure pump or pumping station that provides high-pressure hydraulic fluid, a plurality of cylinders, each cylinder being provided with at least one exhaust valve and with a hydraulic valve actuator for actuating the at least one exhaust valve, a plurality of auxiliary devices associated with said large two-stroke diesel engine that are driven by rotary power, wherein at least one or more of said plurality of auxiliary devices is driven by a positive displacement motor powered by high-pressure hydraulic fluid.

By using hydraulic motors as opposed to electric motors, efficiency can be improved since the amount of power used by the hydraulic motors and the speed at which it is delivered can be more accurately and flexibly controlled than with electric motors.

Further objects, features, advantages and properties of the marine propulsion system and engine according to the invention will become apparent from the detailed description.
BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the present description, the invention will be explained in more detail with reference to the exemplary embodiments shown in the drawings, in which:

Fig. 1 is a side view of a large conventional 8-cylinder two-stroke diesel engine including indications of the length of 9- to 12-cylinder engines,

Fig. 2 is a front view on the engine of Fig. 1,

Fig. 3 is a view of a marine propulsion system in an ocean going vessel with the two-stroke engine of Fig. 1 connected to a propeller via an intermediate shaft,

Fig. 4a is a diagrammatic overview of the components and connections there between of marine propulsion system according to a first embodiment of the invention,

Fig. 4b is a diagrammatic overview of the components and connections there between of marine propulsion system according to a second embodiment of the invention.

Fig. 5 is a graph showing the hydraulic power consumption as a function of the engine load,

Fig. 6 is a cross-sectional view of a hydraulic motor according to an embodiment of the invention that can be used as emergency or take home motor,
Fig. 7 is a diagrammatic overview of the components and connections there between of marine propulsion system according to a third embodiment of the invention,

Fig. 8 is a graph showing the power consumption of the hydraulic pump motor and the generator as a function of the engine load,

Fig. 9 is a diagrammatic overview of the components and connections there between of marine propulsion system according to a fourth embodiment of the invention,

Fig. 10 is a diagrammatic overview of the components and connections there between of marine propulsion system according to a fifth embodiment of the invention, and

Fig. 11 is a diagrammatic overview of the components and connections there between of marine propulsion system according to a sixth embodiment of the invention.

**DETAILED DESCRIPTION**

In the following detailed description, a propulsion system for an ocean going vessel including a large two-stoke diesel engine of the crosshead type, will be described by the preferred embodiments.

Figs. 1 and 2 show a large low-speed two-stroke crosshead in-line diesel engine 10 with a 98 cm piston diameter, which is the core of the propulsion system. These engines have typically from 6 up to 16 cylinders in line. In Fig. 1 a side view of an 8-cylinder engine 10 is depicted, together with additional lines
that indicate the outline of 9-, 10-, 11- and 12-cylinder versions of this engine. Below the engine a scale in meters is shown to provide an indication of the absolute size of these machines that range in length from about 18 meters for an 8-cylinder model to 28 meters for a 14 cylinder model.

The engine is built up from a bedplate 11 with the main bearings for the crankshaft 1 (Fig. 2). The bedplate 11 is divided into sections of suitable size in accordance with production facilities available.

With reference to the features shown by the interrupted lines in Fig. 2 the engine comprises pistons 28 that are connected via piston rods 29 to crossheads 24. The crossheads 24 are guided by guide planes 23. Connecting rods 30 connect the crossheads 24 with the crankpins of the crankshaft 1.

A welded design A-shaped crankcase frame 12 is mounted on the bedplate 11. A cylinder frame 13 is mounted on top of the crankcase frame 12. Staybolts (not shown) connect the bedplate 11 to the cylinder frame 13 and keep the structure together. The cylinders 14 are carried by the cylinder frame 13. An exhaust valve assembly 15 is mounted on the top of each cylinder 14. The cylinder frame 13 also carries a fuel injection system 19, an exhaust gas receiver 16, turbochargers 17 and a scavenge air receiver 18. The turbochargers 17 pump air into the scavenge air receiver. Coolers (not shown) and auxiliary blowers 18a are placed between each turbocharger 17 and the scavenge air receiver 18. During operation of the engine, the auxiliary blowers 18a will start automatically whenever the engine load is reduced to 30-40%, and will continue operating until the load
again exceeds approximately 40-50%. A signal from a pressure switch (not shown) controls the activation of the auxiliary blowers. At engine loads above 30-50% of the maximum continuous rating of the engine the turbochargers 17 on their own deliver enough air to the scavenge air receiver 18. At lower loads the auxiliary blowers 18a provide all or part of the required amount of scavenge air to the scavenge air receiver 18.

The crankcase frame 12 is provided between each cylinder with a stiffener in the form of a through-going transverse plate 21 interconnecting the longitudinally extending outer walls 22 of the crankcase frame 12 and extending from the top to the bottom of the A-shaped crankcase frame 12 for increasing the transverse rigidity thereof.

Vertical guide planes 23 for receiving the transverse forces acting on the crosshead 24 (Fig. 2) are mounted on the transverse plate 21, for example by means of welding. The rear side of each guide plane 23 is supported by vertically extending additional walls 25 connecting the guide plane 23 with the transverse plate 21. The guide plane 23, the additional wall 25 and the transverse plate wall 21 form a hollow profile of high torsional rigidity in which the stay bolts 26 are received.

Fig. 3 shows the stern of a vessel 1 with a part of cargo space 2 and an engine room 3 a typical arrangement. The large two-stroke engine 10 is placed just behind the wall separating the engine room 3 from the cargo space 2. A drive shaft 5 (also referred to as intermediate shaft) connects the output shaft of the engine 4 with a propeller shaft 6 that drives the propeller 7. The drive shaft 5 can be shorter than illustrated.
The propulsion system and the large two-stroke engine require a range of auxiliary systems, e.g.

- an electrical system,
- a hydraulic power supply system,
- a heavy fuel oil system,
- a lubricating and cooling oil system,
- a cylinder lubrication system,
- a cooling water system,
- a central cooling water system,
- a starting and control air system,
- a scavenge air system,
- an exhaust gas system, and
- a maneuvering system.

These systems will only be described in amount of detail that is required for the understanding of the present invention. In particular, power consuming and/or delivering systems will be described on more detail. All these systems include electronically controlled components such as valves and motors that are controlled by one or more electronic controllers or by computers (not shown).

Next to power for propulsion, electricity production is the largest fuel consumer on board, followed by the high-pressure hydraulic system in electronically controlled engines.

A first embodiment of the marine propulsion system according to the invention is illustrated by the overview of the components and connections there between in Fig. 4a. The propulsion system includes an electrically controlled two-stroke engine 10.
Electricity is produced by two generator sets 40. The generator sets include a four-stroke diesel engine coupled to an electric generator. Two generator sets 40 are shown in the Fig. 4, but there could be one large, or more than two smaller generator sets. The generator sets 40 also provide electricity when the large two-stroke engine 10 is not running, e.g. when the vessel is in port. When the large two-stroke engine 10 is not running the generator sets provide the heat required to avoid heavy fuel oil in the fuel oil system from hardening (the heavy fuel oil is not fluid below 40° C).

A high-pressure pumping station 44 (symbolized by a single variable displacement pump, but could include more than one pump), delivers high-pressure fuel oil to a common rail 45 via a conduit 47. The pumping station 44 is driven by an electric motor 43 that receives electricity from the generator sets 40. An accumulator 48 (shown as a single accumulator, but could be formed by several accumulators) is connected to the conduit 47 to level out pressure changes.

A conduit 50 is branched off from conduit 47 downstream of the common rail 45 and provides high-pressure fuel oil to variable stroke positive displacement motors 49 that drive the auxiliary blowers 18a. The amount of power required by the auxiliary blowers 18a varies and is highest at just below mid load levels of the large two-stroke diesel engine 10 and zero above 40-45% load levels of the maximum continuous rating of the large two-stroke diesel engine 10. Due to their variable stroke the motors 49 can deliver the required amount of power, and not more than that, to the auxiliary blowers 18a at all load levels of the large two-stroke diesel engine 10. The use of hydraulic motors
49 to drive the auxiliary blowers 18a also allows the auxiliary-blowers to be dimensioned optimally from an energy efficiency point of view since the hydraulic motors 49 can readily be adapted to drive the auxiliary blowers 18a at their optimum rotational speed.

In the shown embodiment, the heavy fuel oil in the common rail 45 is not only delivered to the injectors (not shown) that inject the fuel oil into the cylinders 14 (Fig. 1,2), but also to hydraulic actuators (not shown) in the exhaust valve assemblies 15 (Fig. 1,2) for powering them. The hydraulic actuators (not shown) provide the opening force for the exhaust valves (not shown as such), and by operating them with heavy fuel oil instead of a dedicated hydraulic liquid a separate hydraulic system can be avoided. However, it will be understood that all the described embodiments can be easily modified to include a separate high-pressure hydraulic system for e.g. powering the exhaust valve actuators and a separate high-pressure fuel system, each having its own pump(s) and electric drive motors.

Conduits that include respective electronic control valves (not shown) connect the fuel injectors and the exhaust valve actuators to the common rail 45. Return fluid from the valve actuators is lead to the tank 42 via conduit 46.

A conduit 52 connects the common rail 45 with a hydraulic motor 53. An electronically controlled valve 51 is placed in conduit 52 for controlling the flow of pressurized heavy fuel oil to the hydraulic motor 53. The hydraulic motor 53 serves as an emergency, or so-called "take home", motor to propel the vessel
in case the large two-stroke diesel engine 10 is out of order. The hydraulic motor 53 is coupled to the drive shaft 5 by a gearbox 57. A clutch 56 allows the hydraulic motor to be engaged with (when operated as take home motor) or disengaged from (when the large two-stroke diesel engine is operative) the drive shaft 5. The hydraulic motor can be of a slow running type, e.g. with an operating range between 0 and 20 to 40 rpm for the largest known types marine propulsion systems, so that the gear ratio of the gearbox can be close- or equal to 1.

A clutch 59 including an axial bearing is placed between the drive shaft 5 and the output shaft of the large two-stroke diesel engine 10. The clutch 59 is engaged when the large two-stroke diesel engine is operative, and disengaged when the large two stroke diesel engine is out of order, so that the hydraulic motor 53 does not have to turn the large two-stroke diesel motor 10 whilst driving the propeller 7. The axial bearing in the clutch 59 is dimensioned to withstand the axial forces that result from the propulsive force generated by the propeller 7 during emergency operation (these axial forces are substantially-lower than those generated during normal operation, which are handled by an axial bearing in the large two-stroke diesel engine 10).

The propulsion system according to this embodiment does not need a startup pumping system that is always included in conventional propulsion systems to provide hydraulic power during engine startup since the electrically powered hydraulic pumping station can operate when the large two-stroke engine is not operative.

Example:
A prolusion system for a large container vessel.

The large two-stroke engine is a MAN B&W Diesel 12K98ME-C, which has 12 cylinders, with a 98 cm bore, a short stroke (approximately 2.8), and is electronic controlled (as opposed to camshaft controlled). This engine has a maximum continuous rating of 68,520 kW at 104 rpm.

Next to power for propulsion, electricity production is the largest fuel consumer on board. The required electric power capacity depends on the details of the vessel, e.g. in connection with electrical power required to cool cargo, and is typically in the range between 4 to 10% with the conventional bulk carriers at the low side of the range and modern container and cooling vessels at the high side of the range. The amount of power for generating electricity is therefore between 2740 and 6850 kW in the present embodiment.

The hydraulic power supply system needs to be able to deliver 1360 kW at 110% load. In order to create a secure margin the pumping station 44 has a maximum output of 1500 kW.

Fig. 4b illustrates a second embodiment of the present invention which is identical to the first embodiment, except that the hydraulic motor 53 is a slow running hydraulic motor (described in greater detail below with reference to Fig. 6) with a hollow output shaft 54 that is directly fitted over the main drive shaft 5, so that a gearbox and clutch can be avoided.
Fig. 5 shows a graph of the hydraulic power consumption of the exhaust valve actuators as a continuous line, the power consumption of the hydraulic motors 49 driving the auxiliary-blowers 18a as a dashed line and the combined hydraulic consumption by a dashed line with short and long dashes. At 45% load, the need for power for the auxiliary blowers peaks at 620 kW. At higher loads the turbochargers 17 take over and the hydraulic motors 49 are stopped, either by regulating the displacement to zero or by cutting off the flow of pressurized heavy fuel oil to the hydraulic motors 49. At loads below 45% the displacement of the hydraulic motors 49 is controlled such that the hydraulic motors 49 deliver accurately the required amount of power to the auxiliary blowers 18a.

The valve actuators consume 716 kW at 45% load and the combined consumption at 45% load peaks at 1336 kW, and peaks again at 1336 kW at 110% load.

**Emergency operation**

The control valve 51 (Fig. 4a and 4b) is changed over to the open position when the large two stroke diesel engine 10 is out of order, and emergency or "take home" power is need to propel the vessel. Practically, the full power of the pump or pumping station 44 is thus delivered to the hydraulic motor 53. The clutch 56 is engaged and the clutch 59 is disengaged (no engagement/disengagement of any clutch in the embodiment according to Fig. 4b).

According to the second embodiment the hydraulic motor 53 is a slow running positive displacement machine with multiple
cylinders in star or fan arrangement shown in Fig. 6. It is however noted that other types of hydraulic motors could be deployed. The hydraulic piston motor 53 includes roller cage pistons 71 formed integral as a roller cage part 72 and a piston part 73. The roller cage pistons 71 run in cylinders 75 arranged in a cylinder block 76. Each roller cage piston 71 presses a roller 77 against an internal cam curve 78 such that a torque on the cylinder block 76 and the cam curve 78 arises. Inside the cylinder block 76 there is a rotatable slide 79 for distributing the high-pressure fuel oil 80 to the cylinders. This type of motor is capable of providing high torque at low speed, e.g. a torque of 636000 Nm at about 30 rpm (2055 kW).

Vessels with a 12K98ME-C engine would typically need about 30 rpm of propeller speed to provide a minimum amount of vessel speed (4 to 5 knots) and maneuvering capacity at sea under emergency conditions. The torque required to drive the propeller of a vessel equipped with a 12K98ME-C at 30 rpm is about 636000 Nm (2055 kW).

The required propeller speed depends on the type of vessel. For a container with a maximum cruising speed of about 25 to 26 knots at 104 rpm a speed of 4 to 5 knots will be obtained at about 26 rpm propeller speed, whilst a bulk carrier or tanker with a cruising speed of 14 to 15 knots at 104 rpm will require about 34 rpm propeller speed to maintain a speed of 4 to 5 knots (waves or headwinds could however slow down the vessel).

According to a not illustrated embodiment, the function of the auxiliary blowers can be taken over by the turbocharger or turbochargers by driving the latter with hydraulic motors at low
engine loads. The additional power added to the turbocharger via the hydraulic motor allows the turbocharger generate sufficient scavenging air also at low engine loads. Thereby, the auxiliary blowers can be omitted altogether. During high engine loads, a surplus energy in the turbocharger can according to a preferred embodiment be converted into hydraulic energy by operating the hydraulic motors connected to the turbocharger as a hydraulic pump. Thus the surplus energy of the turbocharger at high loads of the large two-stroke ending can be reclaimed and used in the hydraulic system that needs its highest input at high engine loads.

A third preferred embodiment of the marine propulsion system according to the invention is illustrated by the overview of the components and connections there between in Fig. 7. The propulsion system includes an electrically controlled two-stroke engine 10. Electricity is produced by a generator set 40 and by a generator 61 driven by power take-off from the crankshaft via a mechanical transmission 63. The generator set 40 includes a four-stroke diesel engine coupled to an electric generator that has a lower capacity than generator 61. The generator set 40 provides electricity when the large two-stroke engine 10 is not running, e.g. when the vessel is in port, and may also assist the large generator 61 under peak loads. When the large two-stroke engine 10 is not running the generator sets also provide the heat required to avoid heavy fuel oil in the fuel oil system from hardening (the heavy fuel oil is not fluid below 40°).

A high-pressure pump station 65 (symbolized by a single variable displacement pump, but could include more than one pump), delivers high-pressure fuel oil to a common rail 45 via a
The pump station 65 is driven by an electric drive motor 64 that receives electricity from the generator set 40. An accumulator 48 (shown as a single accumulator, but could be formed by several accumulators) is connected to the conduit 47 to level out pressure changes.

The amount of power required by the auxiliary blowers 18a varies and is highest just below mid load levels of the large two-stroke diesel engine 10 and zero above 40-45% load levels of the maximum continuous rating of the large two-stroke diesel engine 10. The auxiliary blower or blowers 18a (only one is shown for simplicity) is also driven by the electric drive motor 64. The electric drive motor 64 is connected to the auxiliary blower 18a via a clutch 67 or other disengageable connection, for disconnecting the auxiliary blower 18a from the electric drive motor 64 when the turbochargers 17 take over the supply of scavenging air above about 40-50% engine load. The electric drive motor 64 is connected to the pump station 65 via a clutch 66 or other disengageable connection, for being able to disconnect the hydraulic pump 65 when the auxiliary blower 18a is driven by the electric motor 64.

Fig. 8 shows a graph of the hydraulic power consumption of the hydraulic pump as a continuous line, the power consumption of the auxiliary blowers 18a as a dashed line and the combined power consumption by a dashed line with short and long dashes (the numbers correspond to a MAN B&W 12K98ME-C Diesel engine). At 45% load, the need for power for the auxiliary blowers peaks at 620 kW. At higher loads the turbochargers 17 take over and the auxiliary blower 18a is disconnected from the electric drive motor 64 by disengaging the clutch 67.
In the third embodiment, the heavy fuel oil in the common rail 45 is not only delivered to the injectors (not shown) that inject the fuel oil into the cylinders 14 (Fig. 1,2), but also to hydraulic actuators (not shown) in the exhaust valve assemblies 15 (Fig. 1,2), for powering them. The hydraulic actuators (not shown) provide the opening force for the exhaust valves (not shown as such), and by operating them with heavy fuel oil instead of a dedicated hydraulic liquid a large part of the hydraulic system can be avoid. However, it will be understood that this embodiment can be easily modified to include a separate high-pressure hydraulic system for e.g. powering the exhaust valve actuators and a separate high-pressure fuel system, each having its own pump(s) and electric drive motors.

Conduits that include respective electronic control valves (not shown) connect the fuel injectors and the exhaust valve actuators to the common rail 45. Return fluid from the valve actuators is lead to the tank 42 via conduit 46.

The propulsion system according to the third embodiment does not need a startup pumping system that is always included in conventional propulsion systems to provide hydraulic power during engine startup since the electrically powered hydraulic pumping station can operate when the large two-stroke engine 10 is not operative.

A fourth preferred embodiment of the marine propulsion system according to the invention is illustrated by the overview of the components and connections there between in Fig. 9. The
propulsion system includes an electrically controlled two-stroke engine 10. Electricity is produced by a generator set 40 and by a generator 61 driven by power take-off from the crankshaft via a mechanical transmission 63. The generator set 40 provides electricity when the large two-stroke engine 10 is not running, e.g. when the vessel is in port, and may also assist the large generator 61 under peak loads.

A high-pressure pump station 44 (symbolized by a single variable displacement pump, but could include more than one pump), delivers high-pressure fuel oil to a common rail 45 via a conduit 47. The pump station 44 is driven power takeoff from the crankshaft via a mechanical transmission 41. The mechanical transmission 41 may comprise gearwheels and/or chains. An accumulator 48 (shown as a single accumulator, but could be formed by several accumulators) is connected to the conduit 47 to level out pressure changes.

A variable displacement pump 69 delivers hydraulic power for hydraulic motors 49 that drive the auxiliary blowers 18a. The variable displacement pump 69 is driven by an electric drive motor 68. A conduit 50 provides high-pressure fuel oil to variable stroke positive displacement motors 49 that drive the auxiliary blowers 18a. The amount of power required by the auxiliary blowers 18a varies and is highest at low load levels of the large two-stroke diesel engine 10 and zero above 40-50% load levels of the maximum continuous rating of the large two-stroke diesel engine 10. The capacity of the variable displacement pump 71 is matched to the requirement of the hydraulic motors 49.
A conduit 70 with a control valve 74 connects the variable displacement pump to the common fuel rail 45 for providing emergency hydraulic power to both the common fuel rail 45 and the hydraulic motors 49 in case the hydraulic pumping station 45 should fail. Typically, the capacity of the variable displacement pump 69 corresponds to the combined demand for hydraulic power of the valve actuators and injectors supplied to the common rail 45 and the hydraulic motors 49 at 15% engine load. If the main pumping station 44 should fail, control valve 74 is opened and the variable displacement pump 69 delivers high-pressure fuel oil to both the common rail 45 and the hydraulic motors 49.

In the fourth embodiment, the heavy fuel oil in the common rail 45 is not only delivered to the injectors (not shown) that inject the fuel oil into the cylinders 14 (Fig. 1,2), but also to hydraulic actuators (not shown) in the exhaust valve assemblies 15 (Fig. 1,2) for powering them. The hydraulic actuators (not shown) provide the opening force for the exhaust valves (not shown as such), and by operating them with heavy fuel oil instead of a dedicated hydraulic liquid a large part of the hydraulic system can be avoided. However, it will be understood that this embodiment can be easily modified to include a separate high-pressure hydraulic system for e.g. powering the exhaust valve actuators and a separate high-pressure fuel system, each having its own pump(s) and electric drive motors.

Conduits that include respective electronic control valves (not shown) connect the fuel injectors and the exhaust valve
actuators to the common rail 45. Return fluid from the valve actuators is lead to the tank 42 via conduit 46.

The propulsion system according to the fourth embodiment does not need a startup pumping system that is always included in conventional propulsion systems to provide hydraulic power during engine startup since the electrically powered hydraulic pump 69 in a manner similar to the emergency operation with valve 74 in the open position during engine startup.

Fig. 10 illustrates a fifth embodiment of the invention. The large two-stroke diesel engine 10 is accompanied by one or more generator sets 40 (only one shown) and by one or more pumping sets 106 (only one shown). The pumping sets 106 includes a large variable displacement pump 107 that is directly driven by an auxiliary diesel engine 108, preferably a 4-stroke diesel, that is significantly smaller that the large two-stroke diesel engine 10. Most of the high-pressure fluid for the hydraulic system is generated by the pumping set 106. A minor part of the high-pressure fluid for the hydraulic system is generated by a high-pressure variable displacement pump 44 that is driven by and electric motor 43. Alternatively (not shown) pump 44 could be driven by power takeoff from the crankshaft. The presence of two high-pressure pumps or pumping stations with different driving units provides redundancy for the hydraulic system guarantees that there is enough hydraulic power to operate the large two-stroke diesel engine at take home power level, e.g. 50-60% of the maximum load. In this embodiment the hydraulic system drives the hydraulic exhaust valve actuators and the auxiliary blowers during normal engine operation. The installed hydraulic power will therefore be at least double (i.e. about
3.6 to 5% of max main engine output) of that typically installed in conventional propulsion systems (about 1.8 to 2.3% of max main engine output). Both hydraulic pumps 44 and 107 can be operated independently of the running state of the large two-stroke diesel engine.

The construction of the fifth embodiment allows for a large installed hydraulic power than can eventually be used to power a hydraulic motor of take-home propulsion. Thus, should the large two-stroke engine against expectations be out of order, hydraulic power can be produced by both the pumping set 108 and the electrically driven pump 44. In such a situation an electronically controlled valve 51 opens and the hydraulic power is fed to two slow running hydraulic motors 53 that are preferably of the type as described with reference to Fig. 16. The hydraulic motors 53 are provided with drive shaft 54 with a though going bore that is preferably fitted over and connected to the drive shaft 5. The hydraulic motors 53 are capable of driving the drive shaft at about 25 to 33% of the max operative speed of the large two-stroke engine and have a maximum power output of about 2 to 5% of the maximum output of the large two-stroke diesel engine. This is enough to ensure that a vessel in which the propulsion system is installed remains maneuverable.

The hydraulic motors 53 will therefore rotate with the drive shaft at all times, i.e. also when the large two-stroke engine 10 is operative. In order to reduce resistance/frictional losses in the hydraulic motors 53 when they merely rotate along the drive shaft 5 inactively, the roller cage pistons 71 are lifted by hydraulic pressure manipulation so that they are not in contact with the cam curve 78.
If the hydraulic motors 53 are of a type that cannot tolerate running at the maximum speed of the large two-stroke engine or if they cannot be reversed, a clutch or disengageable connection (not shown) is disposed between the hollow output shaft 54 (many of the large-two-stroke diesel engines can be reversed, this is a requirement for propulsions systems with a fixed pitch propeller).

Fig. 11 illustrates a sixth embodiment of the invention. The large two-stroke diesel engine 10 is accompanied by two generator sets 40. An electric motor 43 drives a large hydraulic high-pressure pump 44 of the variable displacement type. The high-pressure fluid from the high-pressure pump 44 is fed into the common rail 45. Apart from the auxiliary blower motors 49 and the exhaust valve actuators, the hydraulic system also powers two hydraulic motors 81 that drive the centrifugal type seawater pumps 81 (two pumps for redundancy) via conduit 52. The seawater pumps 81 pump seawater from the seawater inlet 83 via a central cooler 84 and back to a seawater outlet 85. The central cooler 84 is a shell and tube or plate heat exchanger made of a seawater resistant material.

The hydraulic system powers via conduit 52 also two hydraulic motors 86 that drive the central centrifugal type cooling water pumps 87. The central cooling water pumps 87 pump fresh water through the central cooler 84, through the lubrication oil cooler 88, through the jacket water cooler 89, through various parts (not shown) of the large two-stroke engine 10 and back.
Further, the hydraulic system powers via conduit 52 also two hydraulic motors 90 that drive the lubrication oil pumps 91 (two for redundancy). The lubrication oil pumps 91 pump lubrication oil through the oil cooler 88, through various parts and components of the large two-stroke engine 10 and back.

Two hydraulic motors 92 powered via conduit 52 drive two centrifugal type jacket water pumps 93. The jacket water pumps 93 pump water through the jacket water cooler 89, via the cylinder liners, the cylinder covers and the exhaust valves and back. The jacket cooling water is also used to warm the fuel oil drain pipes.

One or more hydraulic motors 95 (only one shown) power via conduit 52 one or more ballast pumps 94 (only one shown). The ballast pumps 94 pump fluid from and to various ballast tanks (not shown) disposed around the vessel for leveling the vessel.

One or more hydraulic motors 97 (only one shown) power via conduit 52 one or more cargo pumps 97 (only one shown), as used in e.g. tankers.

One or more hydraulic motors 98 (only one shown) power via conduit 52 one or more compressors 99 (only one shown) to produce compressed air for e.g. the control and start air system.

One or more hydraulic motors 100 (only one shown) power via conduit 52 one or more capstans 101 (only one shown) to raise and lower anchors. The capstans may be used to payout or haul in
other chains or cables located in various places around the vessel, or may be wire rails of cranes.

The use of hydraulic motors in various locations of the vessel that are fed directly with high-pressure fluid from the hydraulic system of the large two-stroke diesel engine has the effect that many heavy duty electrical cables, connections, switches and electric motors can be avoided on the vessel, with the advantage - in particular on vessels that carry flammable cargo - of improved fire prevention due to the absence of spark generating components in hydraulic systems.

The hydraulic effect in conventional propulsion plants with an electronically controlled large two-stroke diesel engine is typically about 1.5% of the maximum capacity of the large two-stroke diesel engine. With the extensive use of hydraulic motors instead of electric motors in the embodiments described above the hydraulic effect can be in the range of from about 3% to about 6% of the maximum capacity of the large two-stroke diesel engine.

The term "high-pressure" as used above in "high-pressure pump" and "high-pressure hydraulic fluid" covers any pressure above 8 BAR.

Although the present invention has been described in detail for purpose of illustration, it is understood that such detail is solely for that purpose, and variations can be made therein by those skilled in the art without departing from the scope of the invention.
CLAIMS:

1. A large turbo charged multi-cylinder two-stroke diesel engine of the crosshead type comprising one or more auxiliary blowers for scavenging of the cylinders at low engine loads, one or more hydraulic pumps or pumping stations for supplying the hydraulic system and/or the lubrication and/or the fuel system with pressurized fluid, and one or more electric motors that drive both the one or more auxiliary blowers and the one or more hydraulic pumps or pumping stations.

2. An engine according to claim 1, wherein each of the auxiliary blowers is connected to a respective electric motor via a clutch.

3. An engine according to claim 2, further comprising a controller configured to engage and disengage the clutch.

4. An engine according to claim 3, wherein the controller is configured to engage the clutch when the engine load drops below a first threshold, and configured to disengage the clutch when the engine load rises above a second threshold.

5. An engine according to any of claims 1 to 4, wherein the one or more hydraulic pumps or pumping stations are of the variable displacement type, the displacement of said hydraulic pumps or pumping stations being controlled by the controller, and the controller being configured to control the displacement of the pumps to ensure that the torque required from the one or more electric engines does not exceed a predetermined threshold.
6. An engine according to any of claims 1 to 5, wherein said one or more electric motors drive said one or more hydraulic pumps or pumping stations at all engine operation states, thereby allowing the engines to startup without an engine startup pumping station.

7. A large turbo charged multi-cylinder two-stroke diesel engine of the crosshead type comprising one or more auxiliary blowers for scavenging of the cylinders at low engine loads whilst one or more turbo chargers scavenge the cylinders at higher engine loads, a hydraulic pump or pumping station driven by electric motors and/or by power takeoff from the crankshaft and/or by a separate diesel engine, and one or more hydraulic motors driving the one or more auxiliary blowers.

8. A large turbo charged multi-cylinder two-stroke diesel engine according to claim 7, wherein the one or more turbochargers are driven by the hydraulic motors at low engine loads for scavenging of the cylinders at low engine loads whilst the one or more turbo chargers scavenge the cylinders at higher engine loads without assistance of the hydraulic motors.

9. A large turbo charged multi-cylinder two-stroke diesel engine according to claim 7, comprising a main pumping station for providing hydraulic power to exhaust valve actuators, said main pumping station being driven by power takeoff from the crankshaft or by one or more electric drive motors, and a secondary pumping station driven by one or more electric motors, said secondary pumping station providing hydraulic power to the hydraulic motors driving the one or more auxiliary blowers and/or the fuel injectors, and either said primary or said
secondary pumping station providing emergency hydraulic power to both the hydraulic motors driving the one or more auxiliary-blowers and to the exhaust valve actuators when the other pumping station is out of order.

10. A large turbo charged multi-cylinder two-stroke diesel engine according to claim 7, further comprising a generator set with its own prime mover for producing electricity, a hydraulic power station driven by one or more electric drive motors that can provide hydraulic power when the large two-stroke diesel engine is inoperative as well as operative.

11. A large turbo charged multi-cylinder two-stroke diesel engine according to claim 7, further comprising an emergency hydraulic system formed by the pump driving the auxiliary blower motor and including a conduit connecting the pump driving the aux blower motor auxiliary to other parts of the hydraulic system.

12. A large turbo charged multi-cylinder two-stroke diesel engine according to claim any of claims 7, further comprising a drive shaft connecting the large turbo charged multi-cylinder two-stroke diesel engine to a propeller, one or more auxiliary diesel generator sets for providing electrical power; at least one of said pumping stations for delivering fluid under pressure being driven by electric motors, at least one hydraulic motor configured for driving the intermediate shaft or said propeller shaft for providing take home power when the large turbo charged multi-cylinder two-stroke diesel engine is out or order.
13. A large turbo charged multi-cylinder two-stroke diesel engine according to claim 7, wherein said hydraulic motor for driving the crankshaft for take home power purposes is a slow running hydraulic motor.

14. A large turbo charged multi-cylinder two-stroke diesel engine according to claim 7, wherein the slow running hydraulic motor is coupled directly to the drive- or propeller shaft, or is substantially geared 1 to 1 with the drive shaft or the propeller shaft.

15. A large turbo charged multi-cylinder two-stroke diesel engine according to claim 13 or 14, wherein a clutch or disengageable connection is provided between the crankshaft and the drive shaft.

16. A propulsion system for a large ocean going vessel, comprising:

a large turbo charged multi-cylinder two-stroke diesel engine of the crosshead type;

one or more electricity generators powered by power takeoff from the large turbo charged multi-cylinder two-stroke diesel engine and/or one or more auxiliary diesel generator sets for providing electrical power;

one or more auxiliary blowers for scavenging the cylinders at low engine loads, said auxiliary blowers being driven by a hydraulic motors;
one or more high-pressure pumps or high-pressure pumping
stations powered by electric motors delivering high-
pressure fuel oil;

hydraulic valve actuators for actuating the exhaust valves;

wherein either both or one of said hydraulic valve
actuators and said hydraulic motors are operated with high-
pressure fuel oil delivered by said one or more high-
pressure pumps or high-pressure pumping stations.

17. A propulsion system according to claim 16, wherein the
electrically powered high-pressure pumps or high-pressure
pumping stations have a capacity sufficiently large to cover the
demand for high-pressure fluid of all the hydraulic valve
actuators and/or all hydraulic motors under various load
conditions.

18. A propulsion system according to claim 16, wherein the power
takeoff is directly or indirectly from the crankshaft and/or
from the turbocharger shaft.

19. A propulsion system according to claim 16, wherein the power
plant comprises:

a drive shaft disposed between the crankshaft of the large
two-stroke engine and a propeller of the ocean going
vessel;

a hydraulic motor connected or connectable to drive the
drive shaft;
whereby the capacity of said hydraulic motor for driving the drive shaft and the capacity of the electrically powered high-pressure pumps or high-pressure pumping stations is sufficiently large to serve as take home power for the vessel in case the large two-stroke engine is out of order.

20. A propulsion system according to claim 16, wherein the high-pressure pumping stations can provide hydraulic power when the large two-stroke diesel engine is inoperative as well as operative.

21. A propulsion system for a large ocean going vessel comprising a large two-stroke diesel engine of the crosshead type that is connected to a propeller via a drive shaft, one or more generator sets including a prime mover and generators for producing electricity independently from the operational state of said large two-stroke diesel engine, a high-pressure hydraulic pumping station or pump driven by one or more electric motors, and a hydraulic piston motor connectable to said drive shaft or to said propeller shaft when said large two-stroke diesel engine is out of order to provide take home power.

22. A propulsion system according to claim 21, wherein said hydraulic motor is a slow running displacement machine.

23. A propulsion system according to claim 22, wherein the slow running hydraulic piston motor has a hollow driveshaft that is fitted over the drive- or propeller shaft, and is either directly connected to the drive- or propeller shaft or is
connected to the propeller shaft via a clutch that allows the hydraulic motor to be alternatively engaged and disengaged to the drive- or propeller shaft.

24. A propulsion system according to claim 23, wherein the hydraulic motor comprises roller cage pistons running on a lobed cam, and whereby the roller cage pistons are lifted when the hydraulic motor is inoperative.

25. Use of a slow running hydraulic motor connectable to the drive shaft or to the propeller of a large ocean going vessel motor to provide take-home power when a main engine of the vessel is out of order.

26. A use according to claim 25, wherein the drive shaft is disengageable from a main engine.

27. A use according to claim 25, wherein said slow running hydraulic motor is a positive displacement machine with multiple cylinders in star or fan arrangement.

28. A use according to claim 27, wherein the hydraulic piston motor comprises a housing, at least one cam disk with an internal cam curve, at least one cylinder block with a number of cylinders and pistons running in these cylinders, roller cages with hydrostatic bearings, rollers running between the cam curve and the roller cage, which surrounds the roller with a winding angle, and guide members for the rollers.

29. A propulsion system for a large ocean going vessel comprising a large two-stroke diesel engine of the crosshead
type that is connected to a propeller via a drive shaft, one or more generator sets including a prime mover and generators for producing electricity independently from the operational state of said large two-stroke diesel engine, one or more high-pressure hydraulic pumping stations or pumps driven by an auxiliary diesel motor for producing high-pressure hydraulic fluid for consumers of high-pressure hydraulic fluid associated with the large two-stroke engine.

30. A propulsion system according to claim 29, wherein the propulsion system further comprises high-pressure hydraulic pumps or pumping stations driven by electric motors or by power take-off from the crankshaft.

31. A propulsion system according to claim 29, wherein the consumers include one or more of the group comprising: hydraulic motors, fuel injectors and hydraulic actuators.

32. A propulsion system according to claim 29 or 31, wherein said hydraulic motors drive one or more of the group comprising: cooling pumps, cargo pumps, capstans, lubrication pumps, and auxiliary blowers.

33. A propulsion system for a large ocean going vessel comprising:

- a large two-stroke uniflow diesel engine of the crosshead type that is connected to a propeller via a drive shaft;
- a high-pressure pump or pumping station that provides high-pressure hydraulic fluid;
a plurality of cylinders, each cylinder being provided with at least one exhaust valve and with a hydraulic valve actuator (9) for actuating the at least one exhaust valve (4);

a plurality of auxiliary devices associated with said large two-stroke diesel engine that are driven by rotary power;

characterized that at least one or more of said plurality of auxiliary devices is driven by a positive displacement motor powered by high-pressure hydraulic fluid from said .

34. A propulsion system according to claim 33, wherein said auxiliary devices include one or more of the group comprising, cooling water pumps, lubrication oil pumps, auxiliary blowers, take home motors, and compressors.

35. A propulsion system according to claim 33 or 34, wherein said vessel comprises a plurality of rotary power driven devices that are not associated with the large two-stroke diesel engine, said not-associated devices being driven by positive displacement motors driven by high-pressure hydraulic fluid from said high-pressure pump or pumping station.

36. A propulsion system according to claim 33, wherein the devices aboard the vessel that are not associated with the large two-stroke engine include one or more of the group comprising: ballast pumps, cargo pumps, capstans and wire rails.
--- = sum of valve actuators and blower motors
- - - - = consumption by valve actuators
- - - - - = consumption by auxiliary blower motors

Hydraulic power consumption (kW)

0  
650  
1300  

Engine load (%)  
45  100

Fig. 5
Fig. 8
### A. CLASSIFICATION OF SUBJECT MATTER

**INV. F00B39/10**
**F00B37/10**
**F00B67/10**
**F00B39/08**
**F00L9/02**
**B63H21/14**

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
**F00B** **FOIL** **B63H** **FO1M**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
**EPO-Internal, WPI Data, PAJ**

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<tr>
<td>X</td>
<td>DE 23 24 670 A1 (SMITS, JOOST BASEN HASSELO, DJAKARTA) 5 December 1974 (1974-12-05) pages 5-6; figures 1,2</td>
<td>29-32</td>
</tr>
<tr>
<td>A</td>
<td>US 5 616 056 A (MEISSNER ET AL) 1 April 1997 (1997-04-01) the whole document</td>
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<tr>
<td>A</td>
<td>EP 0 257 385 A (GEBRUDE SULZER AKTIGESELLSCHAFT; GEBRUDE SULZER AKTIGESELLSCHAFT) 2 March 1988 (1988-03-02) the whole document</td>
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Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search: 24 May 2006
Date of mailing of the international search report: 02/06/2006

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<td>DE 2324670</td>
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<td>NONE</td>
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<td>US 5616056</td>
<td>01-04-1997</td>
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