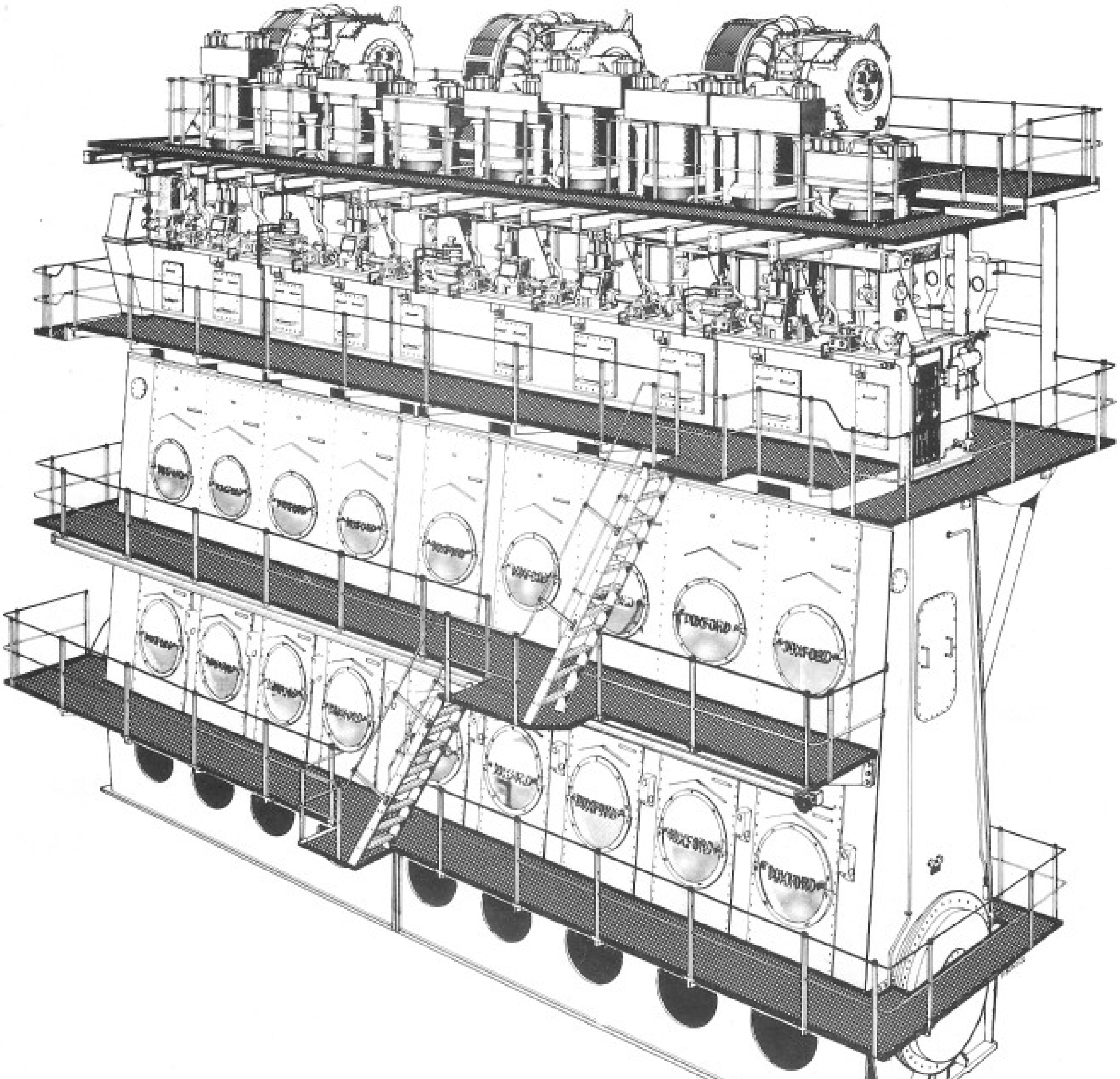


DOXFORD 76J9

A.1.0. PRINCIPLE OF OPERATION

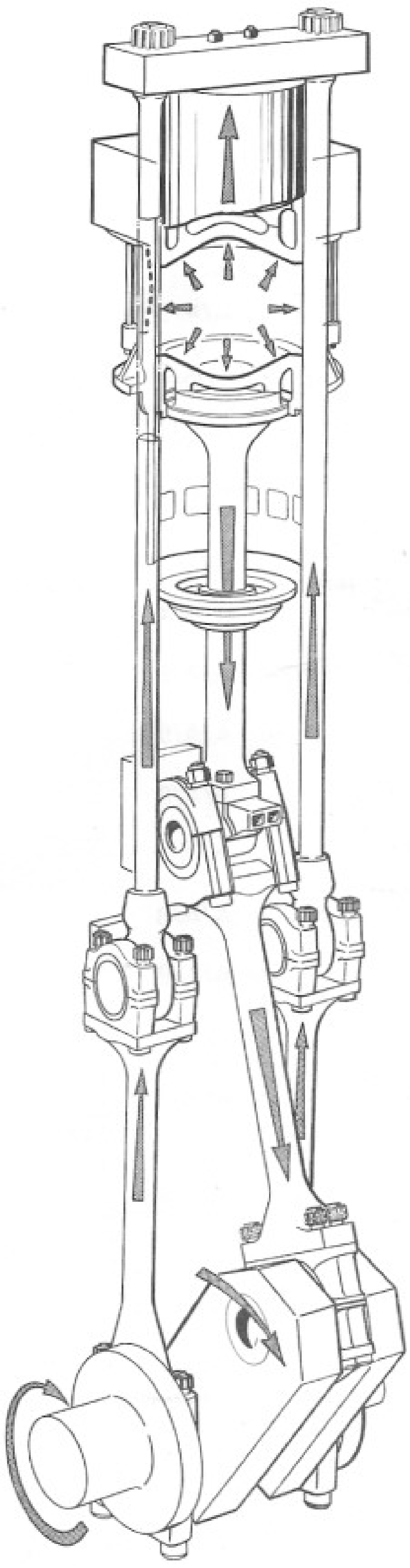


Fig. 1. **Arrangement Of Running Gear.**

The Doxford J Engine is of the two-stroke, single acting, opposed piston type. The working cycle consists of a compression stroke and an expansion stroke, combustion occurs between the pistons, i.e. on one side of the pistons only, there being a pair of opposed pistons in each cylinder.

The pistons in each cylinder are connected to a three-throw section of the crankshaft, the lower piston being coupled to the centre throw by a single connecting rod, crosshead and piston rod. Each pair of side cranks is connected to the upper piston by two connecting rods, crossheads and side rods. Figure 1 shows a pictorial arrangement of the running gear from which its operation will be clear. Thus, the pistons reciprocate about a central combustion space into which fuel is injected.

As the pistons move towards each other, air is compressed in the cylinder and shortly before reaching the point of minimum volume between the pistons (inner dead centre) fuel at high pressure is injected through the injector nozzles. The fuel will atomize and mix with the air in the combustion space. Due to compression the air contained in the combustion space at the point of injection is at an extremely high temperature, causing the fuel to ignite. During the first part of the combustion of the fuel the pressure in the cylinder continues to rise until a maximum value is reached soon after the pistons begin to move apart. After combustion of the fuel in the cylinder is completed, the hot gases continue to expand, thereby forcing the pistons apart until the exhaust ports in the upper liner are uncovered by the upper piston. As the exhaust ports open the hot gases in the cylinder now at a reduced pressure, are discharged to the turbine of the turbochargers, so causing the pressure in the cylinder to drop to a level just below that of the scavenge air. At this point the air inlet ports in the lower liner are uncovered by the lower piston, so allowing air under pressure, which is delivered to the scavenge space by the turbocharger, to flow through the cylinder expelling the remaining burnt gases.

During the inward compression stroke of the pistons the air inlet ports are closed just before the exhaust ports. The air in the cylinder is then compressed and the cycle repeated.

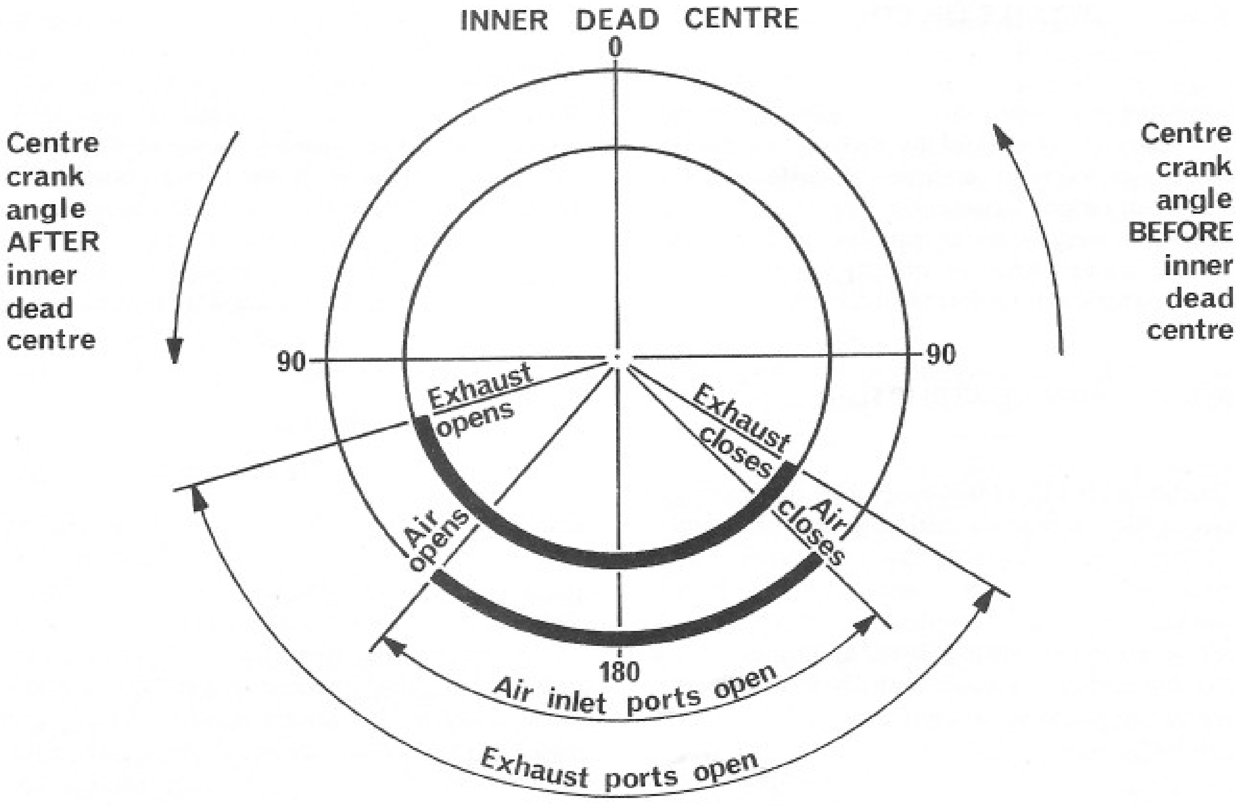


Fig.2. Diagram Showing Typical Port Timing.

The opening and closing of the exhaust and air inlet ports are shown diagrammatically in the typical timing diagram in Figure 2. This diagram is constructed with reference to the inner dead centre position, the unsymmetrical timing of the ports being due to the fact that the side cranks are at an angle of more than 180° from the centre crank. The angle of lead of the side cranks varies with the size of engine.

A.1.1. DESIGN CONSIDERATIONS

The Doxford J Engine is a direct drive marine engine and in common with most of these it is a two-stroke single acting engine. It is, however, the only direct drive marine engine which makes use of the opposed piston principle.

As will be seen from Figure 1, the upper piston requires its own running gear and crank throws. The advantages obtained with this principle are considerable. For equal mean indicated pressure, mean piston speed and cylinder bore the Doxford opposed piston engine will develop 30 to 40% higher power per cylinder than a single piston engine. The first order inertia force from the lower piston is balanced against the corresponding force from the upper pistons and a well balanced engine is obtained. All the forces from the upper piston are transferred through the running gear. Long tension bolts, as used in single piston engines to transfer the forces from the cylinder covers to the bedplate, are not required in the opposed piston engine. The engine structure is therefore simple and relatively free from stresses. No valves are required in the scavenge-exhaust system and the scavenge efficiency of the cylinders is high. The flow areas through the exhaust ports are substantial and fouling, which inevitably takes place in service, has little effect. Thus, the opposed piston engine retains its test bed fuel consumption well throughout its service life. The large port areas also makes the engine well suited for turbocharging.

A.2.0. DETAILS OF CONSTRUCTION

Sectional elevations of the engine are shown in Figure 3. It should be noted that details of design vary in engines of different size and the details shown in Figure 3 do not necessarily apply to all engines in the range. Where components of alternative design are used, details will be found in Chapter B.

A.2.1. ENGINE STRUCTURE

The bedplate (1) is built up of two longitudinal box girders which extend over the full length of the engine. The transverse girders which incorporate the main bearing housings are welded to these longitudinal members. A semi-circular whitemetal lined steel shell forms the lower half of each main bearing (2) and is held in place by a keep secured by studs to the bedplate.

The entablature (3) is also a welded steel box construction, arranged to carry the cylinders which are bolted to the upper face. It is bolted to the tops of the columns (4) and to the crosshead guides (5). The entablature forms the air receiver from which the cylinders are supplied with air and its volume is supplemented by the air receiver (6) on the back of the engine, the top face of which forms the back platform. The intercoolers (7) are mounted on this receiver and the air deliveries from the turbochargers (8) are connected to these coolers. Alternatively in the case of engines with end mounted turbochargers the air from the turbocharger is supplied directly to the entablature after passing through the end mounted intercoolers.

A.2.2. CRANKSHAFT

Each cylinder section of the crankshaft (9) is made up of three throws, the two side cranks being connected to the upper piston and the centre crank to the lower piston. The side crankwebs are circular and form the main bearing journals. Each centre crank is made of an integral steel casting or forging for semi-built shafts. For fully built shafts these units are made of two slabs shrunk onto the centre pin. The centre cranks are shrunk onto the side pins.

Lubricating oil is fed to the main bearings and through holes in the crankshaft to the side bottom end bearings. At the after end, the thrust shaft (10) is bolted to the crankshaft. The thrust bearing being of the tilting pad type is housed in the thrust block (11) which is bolted to the end of the bedplate. A turning wheel (12), which engages with the pinion of the electrically driven turning gear, is bolted to the after coupling of the thrust shaft.

A.2.3. CYLINDERS

The cylinder liner (13) is a one piece casting and incorporates the scavenge and exhaust ports in the lower and upper sections respectively. A special wear resistant cast iron is used as cylinder liner material. An exhaust belt (14) round the exhaust ports and a water cooling jacket (15) are clamped to the top and bottom faces respectively of the combustion section of the liner by long studs. The cylinders are secured to the entablature by means of a flange on the jacket passing over studs and secured with nuts.

The cylinders are water cooled. The cooling water enters the jacket and circulates round the top of the lower part of the liner. It then passes through holes drilled at an angle through the liner round the combustion chamber. Above the combustion chamber some of the water is taken directly into the water jacket of the exhaust belt while the remainder is passed through the exhaust bars first and then into the exhaust belt water jacket. Finally the water is returned to the cooling water tank through sight-flow hoppers.

Lubricator injectors are provided for the supply of lubricating oil to both the upper and lower cylinder liners. The lubricating points are equally distributed around the liners and supplied with oil from timed distributor-type lubricators.

The central combustion chamber section of the cylinder liner supports the fuel injectors, the air starting valve, the relief valve and the cylinder indicator connection.

The exhaust belts convey the exhaust gas from the cylinders to cast iron exhaust pipes which are connected to the turbochargers. Flexible expansion pieces are fitted between the exhaust belts and the exhaust pipes as well as between the exhaust pipes and the turbochargers. A grid to stop possible broken piston rings is also fitted at the inlet to each turbocharger. A scraper ring carrier (16) is provided at the upper end of each liner to prevent the passage of the exhaust gases past the upper piston skirt and for scraping the lubricating oil downwards.

A.2.4. PISTONS AND PISTON RODS

The upper and lower piston heads (17) are identical. They have crowns of a dished shape to give a spherical form to the combustion space and are designed in such a way as to be free to expand without causing undue stresses. Attachment of the piston heads to the rods is by means of studs in the underside of the piston crowns so that the gas loads are transmitted directly to the piston rods. The under faces of the piston heads are machined to form cooling spaces between the piston heads and the upper faces of the piston rods, the cooling medium being supplied and returned through drilled holes in the rods.

A cast iron ring is fitted around each piston head to form a bearing surface. Four compression rings are fitted into grooves above this bearing ring and there is one ring below it to act both as a compression ring and as a lubricating oil spreader ring. The ring grooves are chromium plated to minimise wear of the surfaces in contact with the rings.

The lower piston rods (18) have square palms formed on their lower ends for bolting to the crossheads. The upper ends are cylindrical and form the faces to which the piston heads are bolted. Oil for cooling the lower piston is transmitted through the centre crosshead and up the piston rod to the piston head and is returned in a similar way. The centre crosshead bracket also carries the telescopic pipes for the piston cooling oil and lubricating oil to the centre connecting rod bearings.

Glands attached to the underside of the entablature (19), through which the lower piston rods pass, form a seal between the crankcase and the scavenge air space. These glands contain a number of segmental rings held to the body of the piston rod by garter springs. These rings are so arranged that the lower ones scrape oil from the rod back into the crankcase, whereas the upper ones provide an air seal and also prevent the passage of any products of combustion from the cylinders into the crankcase.

The upper piston rods are bolted to the upper piston heads and to the transverse beams (20) which carry the loads from the pistons to the side rods. A cast iron skirt (21) is provided around each upper piston rod to shield the exhaust ports and prevent the exhaust gases passing back into the open end of the cylinder.

For the upper pistons, water is used as the cooling medium and this is conveyed to and from the piston heads through holes in the upper piston rods. Brackets attached to the transverse beams carry telescopic pipes for the cooling water.

A.2.5. RUNNING GEAR

The centre connecting rod (22) has a palm end at the lower end to which the bottom end bearing keeps are bolted; whereas the upper end of the rod has an integral continuous lower half keep to which the upper half bearing keeps are bolted. The side connecting rod (23) is formed with palm ends at both ends of the rod to which the top and bottom end bearings are bolted. The centre connecting rod top end bearings consist of continuous whitemetal lined shells (24) for the lower (loaded) halves whereas two bearing keeps over the ends of the crosshead pins form the upper halves. The side connecting rod bottom end bearings (25) are whitemetal lined and are supplied with lubricating oil from the main bearings through holes passing up the connecting rods to the side top end bearings. The centre connecting rods also have cast steel whitemetal lined bottom end bearings (26) which are supplied with oil through holes in the rods from the top end bearings. The side top end bearings (27) and centre top end bearings (28) are fitted with whitemetal lined thin-shell bearings.

The centre crosshead pins (29) are made of

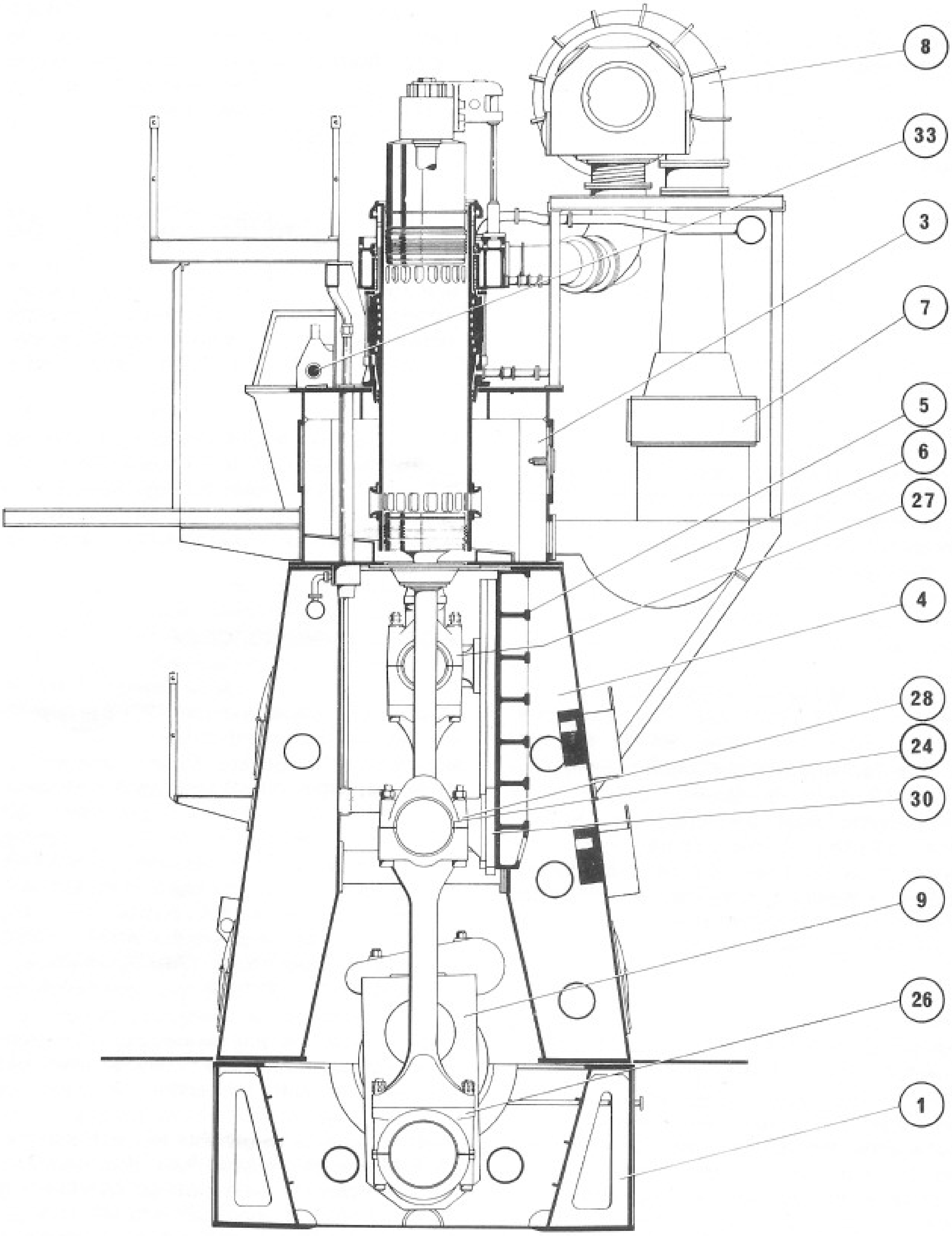
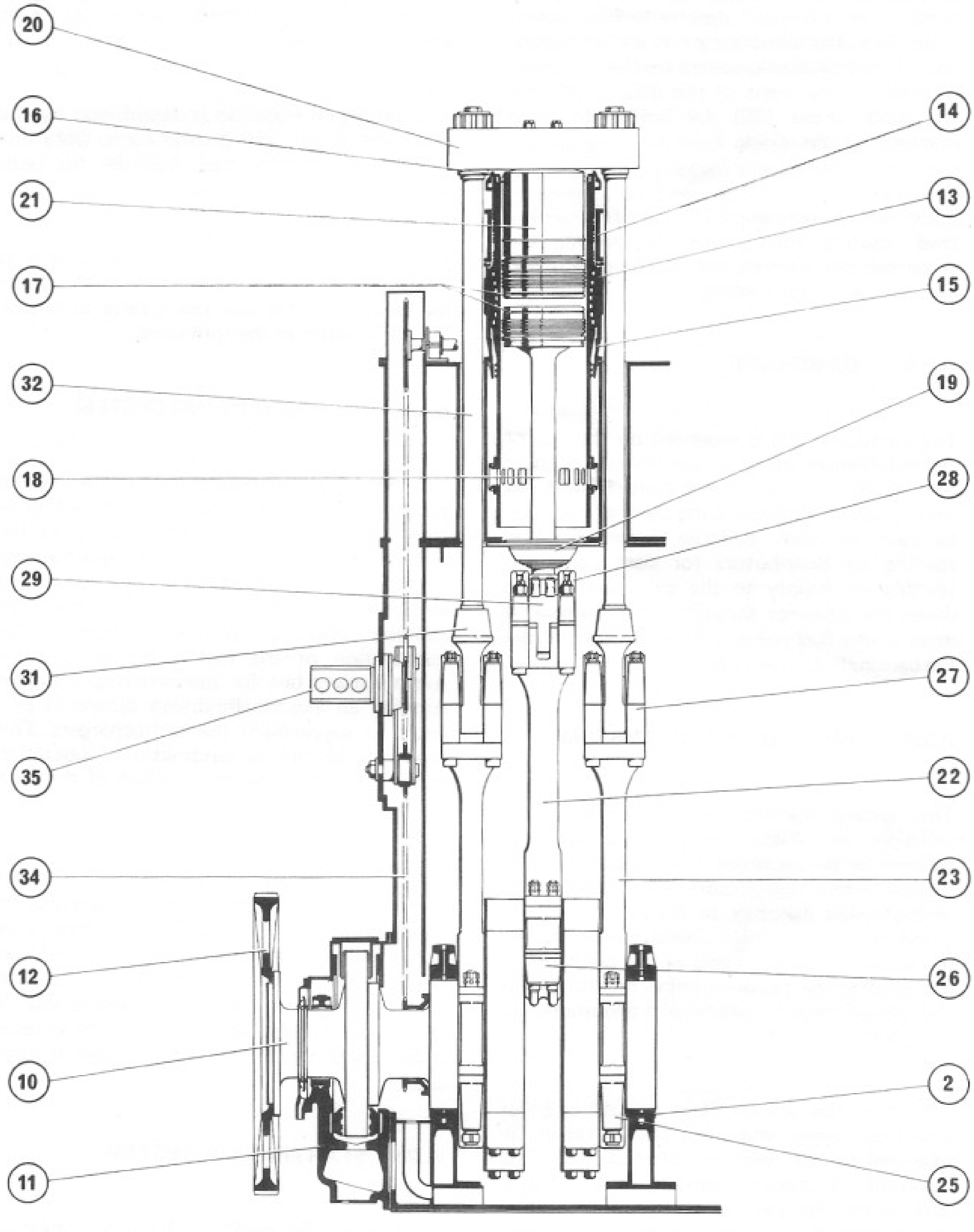


Fig.3. Sectional Elevations Of The Doxford 'J' Engine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nitriding steel and hardened by this process. At the top the pins are bolted to the palm end of the piston rods with the crosshead brackets sandwiched in between. Also, two long studs pass through the crosshead pins horizontally and secure the pins to the brackets at the back. The telescopic pipes for lubricating and cooling oil are supported by the crosshead brackets at the front of the piston rods and the guide shoes (30) are bolted to these brackets at the back.

Each side crosshead (31) is made up of a steel casting into which is shrunk the crosshead pin, the side rod (32) being screwed into the top of the casting.

A.2.6. CAMSHAFT

The camshaft (33) is mounted on the top of the entablature and is driven through a roller chain (34) from the crankshaft. It operates timing valves for controlling the fuel injection to each cylinder, cylinder lubricators and starting air distributors for controlling the starting air supply to the cylinders, it also drives the governor through a step-up gear. A drive to the fuel pump (35) is also taken from the camshaft driving chain.

A.2.7. FUEL INJECTION SYSTEM

This system operates on the common rail principle in which timing valves, operated by cams on the camshaft, control the injection of fuel from a high pressure manifold through spring-loaded injectors to the cylinders. Fuel is delivered to the high pressure main by the multi-plunger pump fitted at the after end of the engine, the pressure being maintained at the desired value by means of a pneumatically operated spill valve.

Two fuel injectors are fitted to each cylinder and these open when the timing valves are operated by the cams on the camshaft. The duration of opening of the timing valves and hence the period of injection of fuel into the cylinders is controlled by the governor. Either a centrifugal governor with a hydraulically operated output or an electronic governor with a pneumatic actuator can be fitted. In the former case the governor input is set pneumatically from the control station, in the latter case it is set electrically. In this way the speed of the engine can be adjusted as required. Means of adjusting the setting of the timing valves by direct mechanical linkage are also provided.

The timing of injection is determined by the positions of the timing valve cams. Only one cam is required for each cylinder for both ahead and astern running.

A centrifugally operated overspeed trip is fitted to the sprocket wheel which drives the camshaft. This operates a valve to release the air pressure to the spill valve.

A.2.8 TURBOCHARGING SYSTEM

All engines are turbocharged on the impulse system. This means that the exhaust gases from the cylinders are led directly to the turbine ends of the free running gas turbine/ air compressor sets which supply scavenging and charging air to the cylinders. Under normal running conditions all the air required for combustion of the fuel is supplied by the turbochargers but for manoeuvring and slow running an electrically-driven blower is provided to supplement the turbochargers. This auxiliary blower is automatic in operation and is controlled by the position of the main control lever.

The turbochargers may draw air through filter-silencers mounted on the blowers or through air supply trunks from the deck. They deliver air through coolers circulated with sea water which reduces the temperature of the air entering the engine, so increasing its density and allowing the engine to develop more power without excessively high temperatures.

A.2.9 STARTING AIR SYSTEM

Starting of the engine is by compressed air which is admitted to the cylinders through pneumatically operated valves. The starting valves are controlled by a rotary distributor, driven from the camshaft, which governs their timing and their duration and sequence of opening for starting the engine either ahead or astern. Control of the pilot air for operation of the starting system is effected by a valve at the control station which is moved in the required direction by a hand lever to start the engine.

A.2.10 CONTROLS

Levers for starting and speed control, together with fuel pump output and fuel pressure controls, are grouped together in a control box. This will be situated at some convenient position in the vicinity of the engine.

When bridge control equipment is fitted the controls are actuated pneumatically, starting, reversing and speed control of the engine being effected by movement of the bridge telegraph.