engine to be used and also on the prevailing climatic conditions and sea water temperature. Air mean ambient, sea water temperature, frame spaces and width of frames, should be stated at time of ordering.
The length "X" as shown on this drawing is the total length of exposed pipe which is divided in four equal parts, and which should be shaped to follow the hull design as closely as possible before final assembly.
The standard lengths and bores of pipes established are based on a minimum full power boat speed of 5 knots. For vessels having a design speed of less than 5 knots and for other engine duty, special consideration is required and such application should be referred to our Technical Department.

8. **Air-cooled Radiator Systems.**—For the cooling of engines for example in barges, etc., used in inland waterways on which it may be impracticable to use an externally mounted keel cooler system, a Gardner combined radiator and oil cooler with engine-driven fan, is desirable equipment. Such a system is, however, dependent upon the practicability of providing such ducting as will permit of an unrestricted flow of air at external atmospheric temperature to the radiator and the free exit of heated air from the engine room.

9. **Centrifugal Type Pump.**—Where engines are cooled by fresh water through the medium of a keel cooler, an air cooled radiator or sea water cooled heat exchanger, centrifugal type circulating water pumps are fitted.
These centrifugal type pumps are mounted on the manifold side of the engine and driven by helical gears from the valve camshaft. The gears are arranged to drive the pump at crankshaft speed.
The impeller spindle is spring loaded in an endwise direction on to a spherical faced carbon gland to form the water seal. This type of water pump and its maintenance is described in the Instruction Book No. 56·6, paragraph 73 to 76.

10. **Water Temperature Control: Closed Circuit Systems.**—The centrifugal type pump permits the use of automatic temperature control which is performed by a thermostatically controlled valve fitted to the water outlet pipe on the engine.
Until a temperature of 137°F. is exceeded all the circulating water is diverted through the by-pass on the engine, thus there is no circulation through the keel cooler, heat exchanger or radiator so giving a rapid "warm-up".
As the temperature increases the thermostatically controlled valve gradually opens, so closing the by-pass port and opening the main valve, to permit a progressively increasing volume of water to flow through the keel cooler or heat exchanger, etc.
When a temperature of 172° F. is reached the by-pass port is finally closed and all the circulating water is pumped through the keel cooler or heat exchanger.
Water outlet temperature, under normal running conditions, should be 142°F.

11. **Cooling Water Additives.**—While it is generally known that cooling by a closed circuit fresh water system reduces engine water jacket corrosion to minimum proportions, it should, nevertheless be mentioned that a small addition of "Aqua Clear" to such cooling water still further reduces the remaining slight corrosive action, and of course reduces discolouration of the water.
Where engines have to be cooled by circulation of "raw" sea or contaminated fresh water, it is recommended that an "Aqua Clear" dispenser is interposed in the water pump suction pipe.

12. **Direct "Raw" Sea Water Cooling.**—Where engines are cooled by an "open" circuit (direct sea water cooling) system, an engine mounted plunger (ram) type pump is employed to circulate the raw water through the cylinder water jackets and oil cooler, etc. The pump is driven through an eccentric and clip from the valve camshaft and is accessible, silent in operation and so constructed that water cannot enter the engine crankcase. It is equipped with an air vessel, drain tube, snifting valve and safety valve.
When marine engines leave the works the Snifting Valve, Safety Valve and Drain Plug are removed from the water circulating and bilge pumps and are securely attached to the pumps by wire.
This precaution is taken to avoid damage in transit and to drain off any water that may accumulate before the engine is put into use again.
Warning labels are attached to the parts and stress the importance of the Snifting Valve, Safety Valve and Drain Plug being replaced before attempting to run the engine.

The Snifting Valve is fitted on the outward end of the pump body. It consists of a bronze ball resting on a seat and limited in lift by a knurled headed screw. The purpose of this valve is to admit a small amount of air together with the water during the Suction Stroke of the pump and so prevent water hammer. To set the valve correctly the knurled screw should be screwed down by hand as far as it will go; and then unscrewed approximately quarter of a turn and locked in this position. If the valve is set too wide open too much air will be drawn into the pump and so reduce the amount of water delivered, resulting in high discharge water temperatures.

13. **Ram Type Pump Valves and Cup Washers.**—The pump valves are disc-like in form and are made of a special oil-resisting material. If, after long use, they buckle or become "saucer-shaped" they may be reversed so that what was originally the upper face becomes the lower.
If, in emergency, valves which are not of Gardner manufacture have to be used, it is important that they are of the same thickness for which the stop plates were designed; if they are thicker the edges will turn up when the through bolt is tightened. This of course, will prevent them from seating.
The cup washers, of which there are two per pump, are fitted back to back on the ram.
The design of the ram is such that when the cup washers and distance washers are fitted and the castle nut screwed up, it first of all clamps up the cup washers, etc., and finally tightens up solidly metal to metal on the brass washers. If the nut was tightened only on to the rubber cup washers they could be seriously distorted and the nut would not remain tight.
Inspection should be made regularly to see that the wick feed lubricators fitted to the body of the pump are kept filled with lubricating oil.

14. **Water Temperature Control: Open Circuit Systems.**—Marine engines fitted with ram type pumps have a manually operated temperature control which "shunts" or "by-passes" warm water from the discharge pipe to the suction pipe of the circulation pump, thus raising the temperature of the water going through the engine and oil cooler. It will be readily understood that the by-pass valve serves as a means of controlling, within limits, the temperature of the water in the cylinder jackets and at the point of discharge. This is of special utility when the engine is running at light loads during which the temperature of the discharge water should be maintained at about 130° or 140° F.; that is, when it is just about as hot as the hand can momentarily bear. A direct reading thermometer for the water outlet temperature is incorporated in the water temperature control unit.
Note.—When starting the engine or idling it is important that the control valve be closed, otherwise air may get into the circulation pump and interfere with its operation.

15. **Water Flow Indicator.**—On engines fitted with ram type water circulating pumps a Gardner water flow indicator is fitted in the outlet pipe from the engine and a test cock is also provided for observing the continuity of the water supply through the engine. The test cock is also of use to eliminate air locks when priming the water system.

16. **Water Outlet Pipe—Chokes.**—When ram type water circulating pumps are fitted, all LW marine engine water outlet pipes are equipped with gun metal cadmium plated chokes and it is imperative, when fitting a new pipe, to see that it is equipped with the same number of chokes of the correct bore as those already fitted to the water pipe which is being replaced.
If new chokes are being fitted to an existing water pipe, it is also imperative that the bore of the chokes are of the same size as the existing chokes. **It is not necessary to fit chokes to the water pipes of 2LW to 6LW engines fitted with centrifugal type water circulating pumps.** The following table shows the correct sizes of the bore of the chokes for LW marine engines with ram type water circulating pumps:—

2LW	$\frac{7}{32}$ in.
3LW	$\frac{5}{16}$ in.
4LW	$\frac{7}{32}$ in.
5LW	$\frac{17}{64}$ in.
6LW	$\frac{17}{64}$ in.

17. **Cylinder Water Jackets.**—With "open" circulating systems, after lengthy periods of use, the water jackets will accumulate a certain amount of sediment. The amount and time taken for this to accumulate, varies considerably according to where the craft is operating; i.e. whether in muddy rivers or harbours or sandy estuaries.
In marine engines there is always a likelihood of sand or mud accumulating in the water jackets except in cases where a "closed" system incorporating a water-cooled heat exchanger is fitted. On account of this sediment it is always advisable to observe from time to time that it has not accumulated sufficiently to impede the flow of water through the jackets.
Whenever necessary, therefore, and certainly at each major overhaul, the cylinder block water jacket spaces must be thoroughly cleared by flushing through with clean water. The cylinder doors and all inspection and core plugs should be removed to facilitate this operation. New packings should be used when replacing the cylinder doors, inspection plugs and core plugs.

18. **Bilge Pump.**—This is a ram type pump built into the engine. It is driven through the intermediary of a friction clutch so that it may be started and stopped at will. It is incorporated in the main timing chain cover and is driven by an eccentric from the valve camshaft. The pump is a counterpart of the plunger type water circulating pump except, of course, for the friction clutch and many of the parts are interchangeable with the engine circulating pump.
Engines are not supplied with bilge pumps unless specially ordered; they are then the subject of an extra charge.

19. **Bilge Pump Friction Clutch (when fitted).**—Outside the gearcase of the pump is the operating hand-wheel with a central locking screw. The hand-wheel is attached to a sleeve which screws in and out of the gear case cover.
The designed loading on the clutch spring is such that, when the hand-wheel is in the fully engaged position, a pressure of 20 lb./sq. in. (1·406 kg./sq. cm.) is recorded on the output side of the pump.
If, after long use, it becomes necessary to restore the designed spring loading of the clutch, this can be effected by fitting thin shims between the brass thrust pad in the hand-wheel and the outer end of the screwed sleeve thus permitting additional inward movement of the hand-wheel and sleeve to increase the spring pressure on the clutch cones. From the commencement of clutch engagement to full load engagement requires between half and one complete turn of the hand-wheel. This must not be appreciably exceeded, otherwise excessive load will be imposed on the camshaft end bearing resulting in undue wear of the bearing thrust face.

20. **Duplex Fuel Filter—Type No. 5.**—All LW marine propelling engines are now supplied with this type filter as part of the standard equipment. It is illustrated on page 18 and is fitted in circuit between the fuel supply or "day tank" and the second fuel filter mounted on No. 1 cylinder head of the engine. When installing the Duplex fuel filter care must be taken as regards its accessibility for cleaning and for removal of the sump and filtering element. A minimum of 2·38 in. is required for this purpose as shown in the outline drawing on page 18.
The Duplex filter employs a special form of paper filtering elements which are inexpensive and readily replaced. The securing plug which holds the sumps and filtering elements in place will, when loosened, permit the sump to be drained prior to removal. The change-over valve and the two vent screws in the Duplex Filter head also permits cleaning and replacement of a new element, and also the clearing of air and re-filling of the dismounted unit, whilst the other unit is still in operation. This applies to either of the two units and is of great value when used for marine propulsion installations.
One method of testing paper filtering elements for obstruction after they have been removed from the assembly is by holding the element in a vertical position and closing the lower end by holding it down on a flat surface. Fuel should then be poured into the open upper end and, if it collects and does not run away through the filtering media almost as quickly as it is poured in, then the filter is probably sufficiently choked to cause erratic engine running and the element should be replaced.
Under average conditions, when using a clean fuel supply and a good fuel system, the filtering elements should not require replacement before they have been in use for at least 2,400 hours.
Replacement elements are readily available from the Works, Branch Office Service Depots and from

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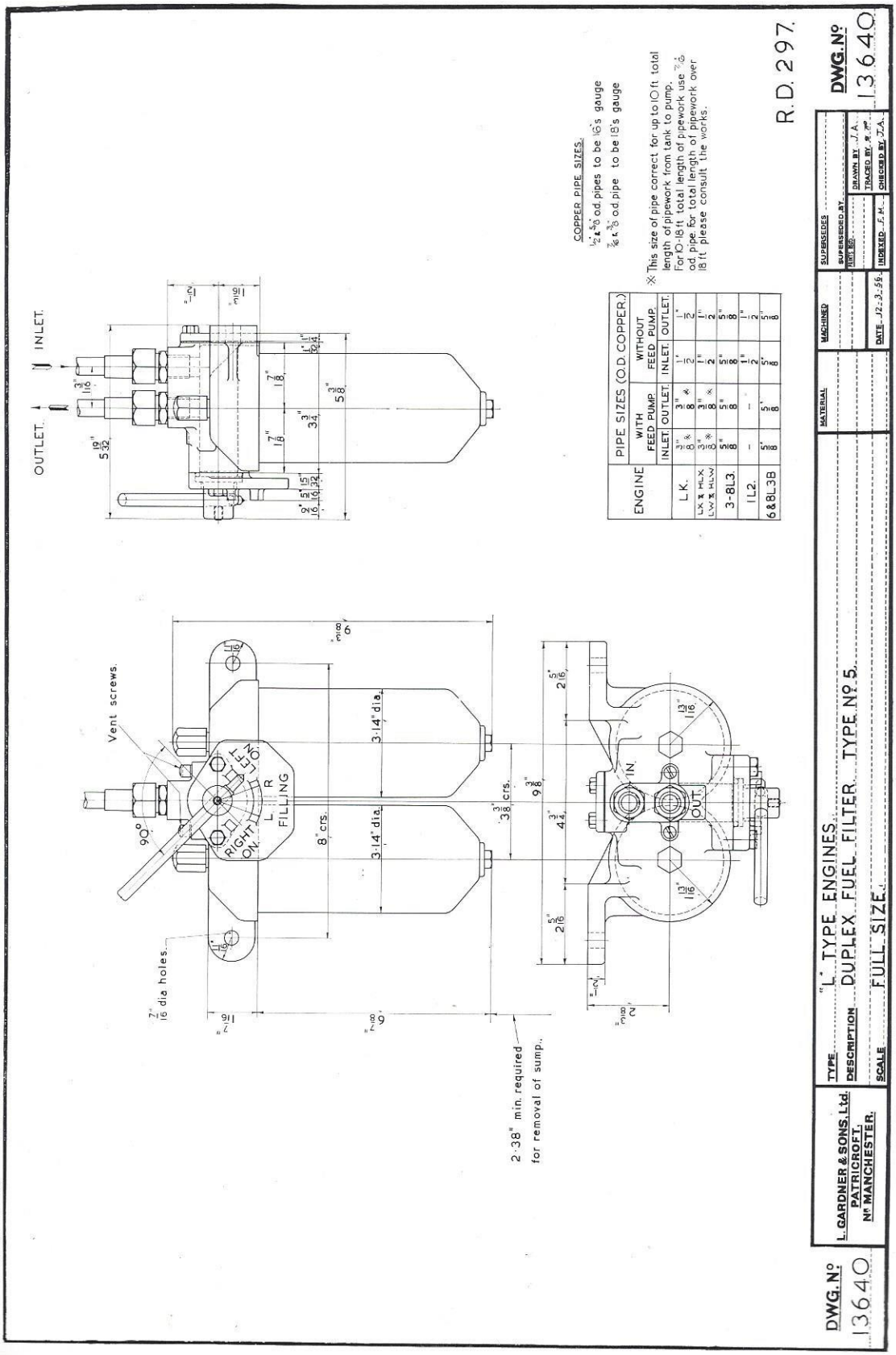

ENGINE	PIPE SIZES (O.D. COPPER.) WITH FEED PUMP. INLET.	OUTLET.	WITHOUT FEED PUMP. INLET.	OUTLET.
L.K.	3/8 ※	3/8 ※	1/2	1/2
LX & HLX	3/8 ※	3/8 ※	1/2	1/2
LW & HLW	3/8 ※	3/8 ※	1/2	1/2
3-8L3.	5/8	5/8	5/8	5/8
1L2.	—	—	1/2	1/2
6&8L3B	5/8	5/8	5/8	5/8