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0049989

REPORT ON

RUSSIAN C.I. TANK ENGINE

TYPE "V2" FROM T-34 CRUISER TANK

RECORDED

Military College of Science
SCHOOL OF TANK TECHNOLOGY
Chobham Lane Chertsey

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INCLOSURE 1 TO REPORT NO. 71608
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INTRODUCTION

A V-12, 38 litre C.I. engine is fitted to the heavy infantry tank - the K.V. of approximately 56 tons - and the cruiser tank - the T.34 of approximately 28 tons. These two form the bulk of the Russian built tanks used by the Red Army.

The engine dealt with in this report, the "V-2", was removed from a T.34 tank. The "V-2.K" engine as fitted to the K.V. tank has not yet been examined but is known to be basically similar to the "V-2", differing only in certain details and in its rather higher rated output, i.e. 600 H.P. at 2,000 R.P.M. as compared with 500 H.P. at 1800 R.P.M.

Since the engine has not yet been bench tested in this country, the first two parts of the report have been written without first-hand knowledge of its performance characteristics; it is, however, scheduled to be tested and the test results will be published as a further part of this report. The fuel injector equipment has not yet been examined, but as soon as a suitable opportunity arises for its removal and examination, a report will be prepared and also published as a further part of this report.

General remarks and conclusions on the design of the engine will be found in Part I under the heading "Design", but it must be borne in mind that these have been made without first hand knowledge of its performance or reliability.

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D.M. Pearce, B.A. Cantab.

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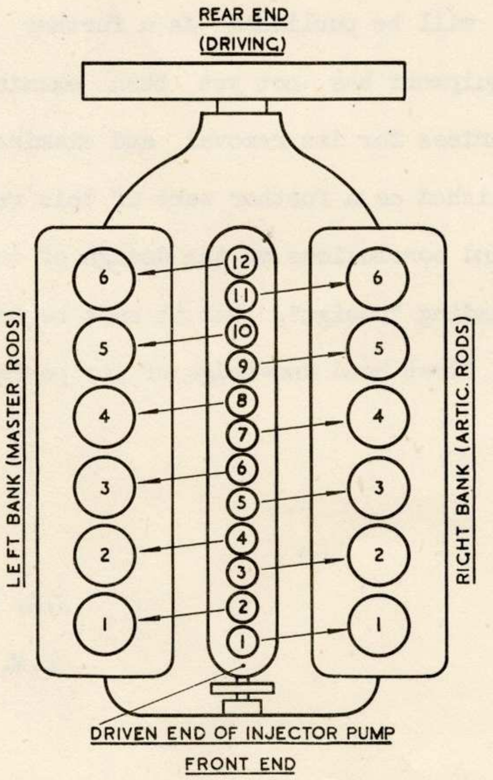
PART I

GENERAL DESCRIPTION, DESIGN, MANUFACTURE AND MATERIALS

LEADING DATA

TYPE	-	"V.2" Water cooled C.I. engine.
NUMBER AND ARRANGEMENT OF CYLINDERS	-	12 - 60° V.
BORE	-	150 mm. (5.9-in.)
STROKE - Master rod bank (left)	-	180 mm. (7.1-in.)
- Articulated rod bank (right)	-	186.7 mm. (7.35-in.)
STROKE/BORE RATIO - Master rod bank	-	1.2 : 1.
- Articulated rod bank	-	1.242 : 1.
CAPACITY PER CYLINDER - Master rod bank	-	3.182 litres (194.5 cu.ins.)
- Articulated rod bank	-	3.300 litres (201.5 cu.ins.)
TOTAL CAPACITY	-	38.88 litres (2375 cu.ins.)
COMPRESSION RATIO - Master rod bank	-	15 : 1.
- Articulated rod bank	-	15.8 : 1.
RATED MAXIMUM B.H.P.	-	500 at 1800 R.P.M.
MAXIMUM R.P.M.	-	2000
MEAN PISTON SPEED AT 2000 R.P.M.		
Master rod bank		2370 ft/min.
Articulated rod bank	-	2450 ft/min.
DIRECTION OF ROTATION	-	Anti-clock from flywheel end.
FIRING ORDER	-	1L - 6R - 5L - 2R - 3L - 4R 6L - 1R - 2L - 5R - 4L - 3R
WEIGHT OF ENGINE (DRY COMPLETE WITH FAN AND DYNAMO)	-	2210 lbs.
OVERALL LENGTH	-	1590 mm. (5-ft. 2½-ins.)
OVERALL WIDTH	-	840 mm. (2-ft. 9-ins.)
OVERALL HEIGHT (excluding air cleaner)	-	1064 mm. (3-ft. 6-ins.)



Cylinder Numbering Diagram

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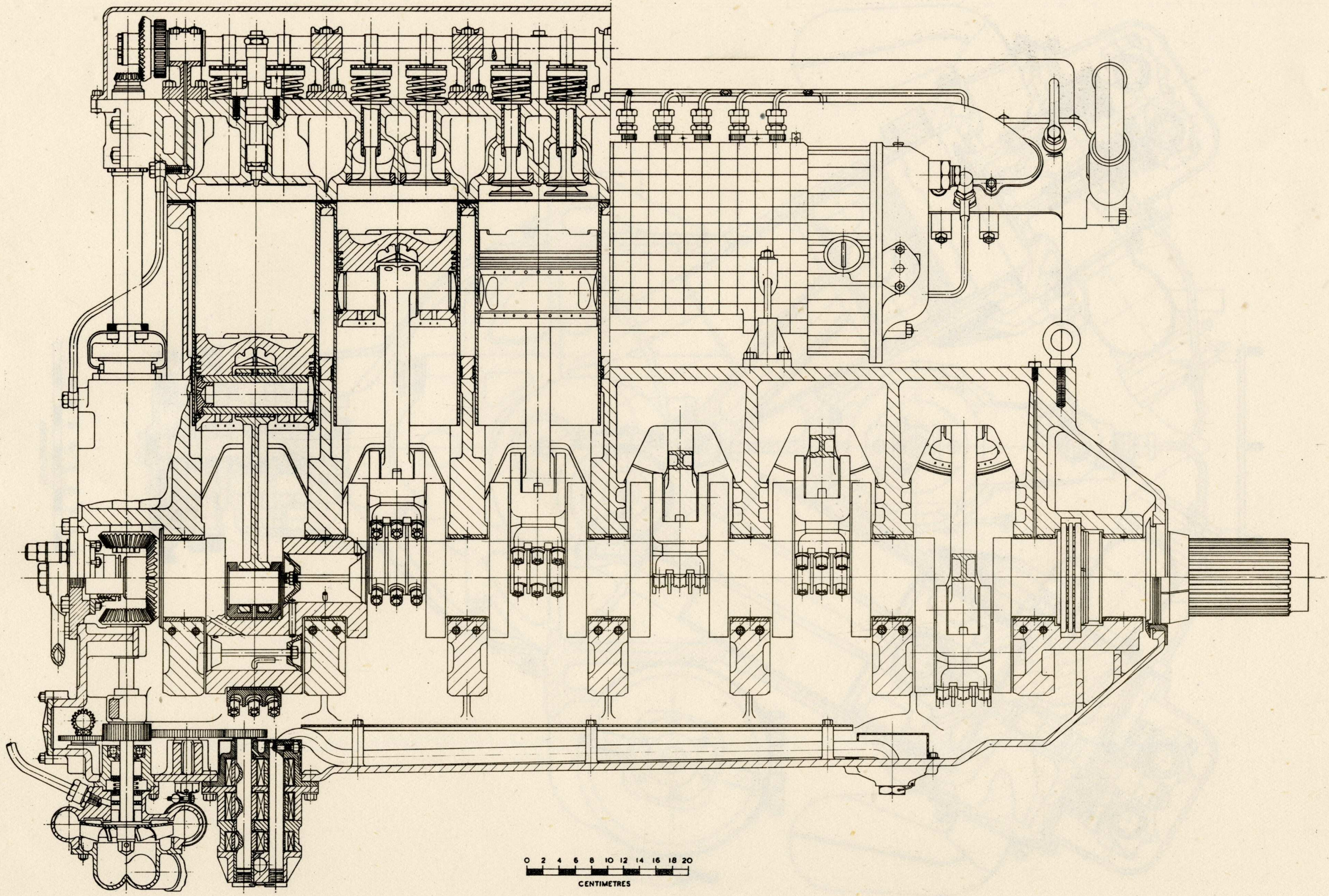

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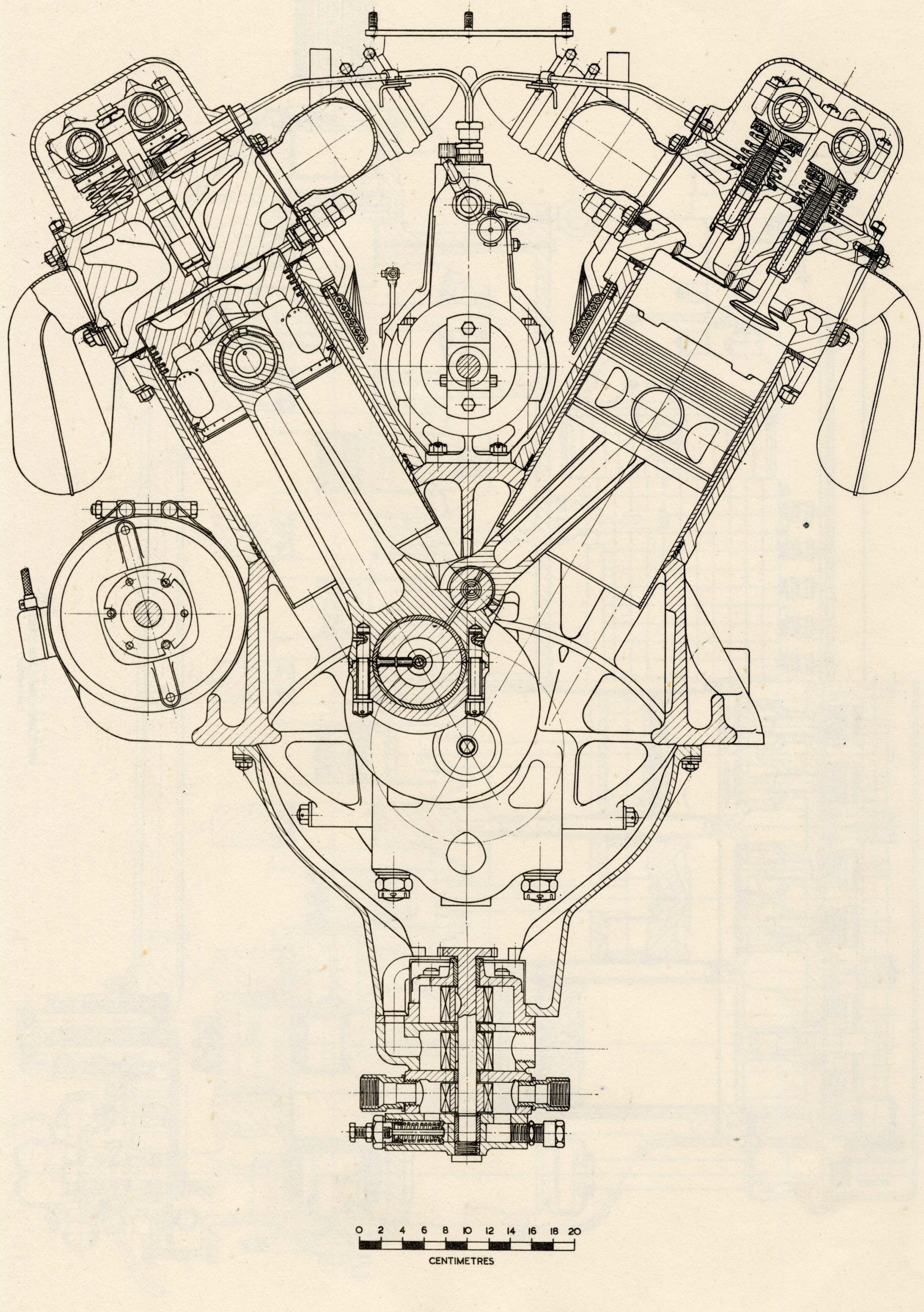

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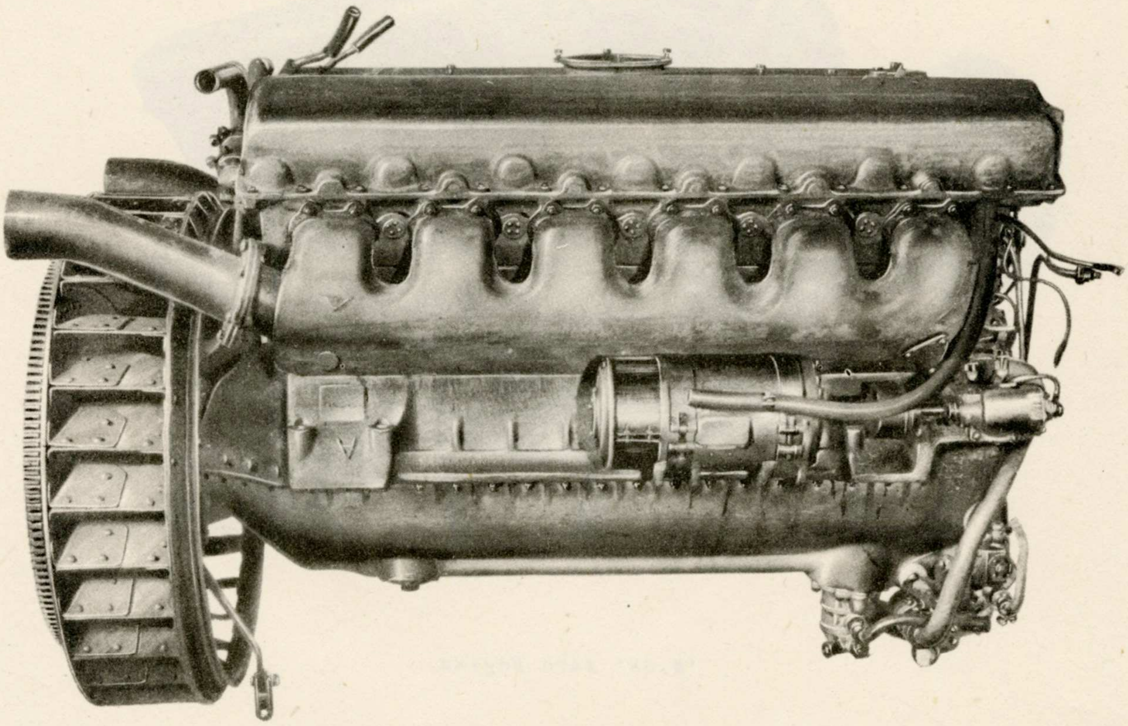
GENERAL DESCRIPTION

The design of the V.12 cylinder engine generally follows orthodox aero engine practice. It is very light, the cylinder heads, blocks, crankcase and sump being light alloy castings. The crankcase is split along the centre line of the crankshaft. Separate blocks and heads are held down by long studs screwed into the crankcase. The blocks are fitted with wet liners. Four vertical valves per cylinder are operated directly by two camshafts. An injector nozzle is situated centrally between the valves in each cylinder. The combustion chamber is of an orthodox open type. Aero-type die pressed pistons and articulated "H" section steel rods with copper lead big-end bearings are employed. The master rods are on the left hand bank. The one piece crankshaft runs in eight copper lead bearings. A ball thrust race is provided at the driving end. No torsional vibration damper is fitted. All the auxiliaries are shaft driven. A master bevel on the free end of the crankshaft drives up to the camshafts, injector pump and governor, air distribution valve and dynamo. Also driven from this bevel and located on the



'V.2' Tank Engine

sump are the water pump, oil pump and fuel feed pump. The 12 cylinder inline Bosch-type injector pump and governor and the air distribution valve are mounted between the cylinder banks. The dynamo is strapped to the side of the crankcase. Dry sump lubrication is employed, there being two gear-type scavenge pumps and one pressure pump. Cooling water is fed into each block by the centrifugal water pump.

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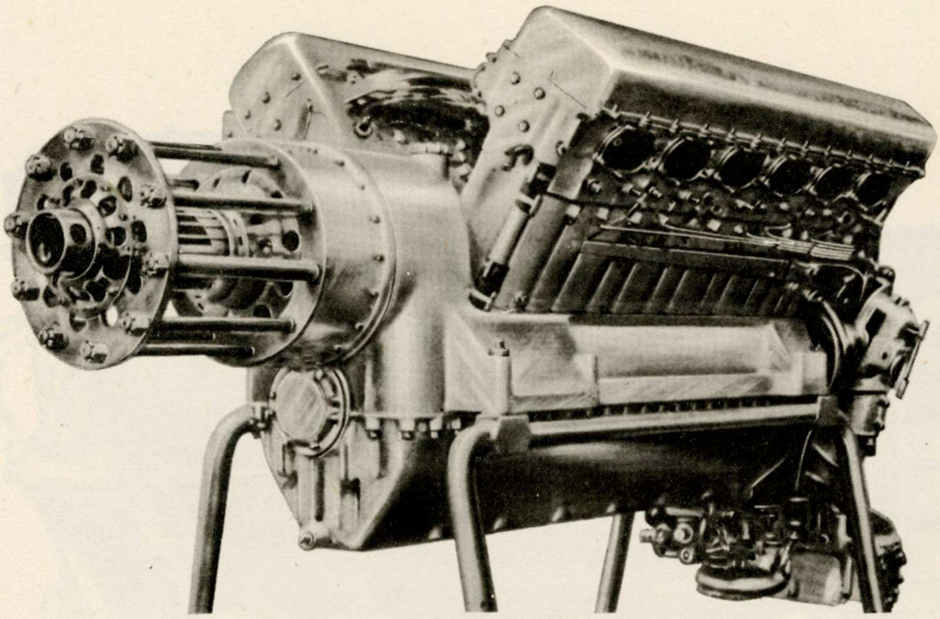
DESIGN

Although the history of the development of this engine is not known, it has evidently been adapted from an aero engine and has not been originally designed specifically for tanks. This has not resulted in a unit that is unsuitable as a tank engine; it is considered, in fact, that its main features make it very suitable for its job. In the first place, the performance characteristics and the low specific fuel consumption of the large multi-cylinder diesel put this engine at some considerable advantage when compared with the petrol engine of equivalent output, although this is to some extent offset by the increased bulk of the former. Its aero engine ancestry, however, has certain drawbacks, notably the inaccessibility of most of the auxiliaries and the relatively high cost of manufacture. In practice this latter may be nullified by the convenience of being able to use up sub-standard and obsolete aircraft components which would otherwise be scrapped.

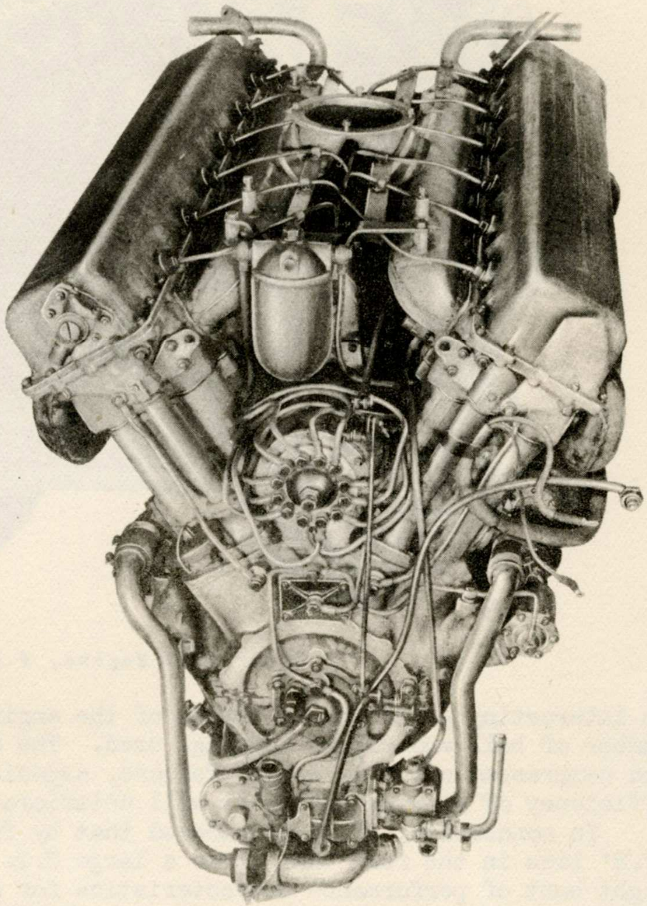
As to the aero engine from which the "V.2" engine has been developed, very little can be said owing to the almost complete lack of information



'M.34' Aero Engine.

relating to Russian aero engines in this country. It is known, that before the war, the Russian aero engine industry was mainly engaged in producing engines of foreign design, notably Wright, Bristol, Hispano-Suiza and Gnome-Rhône. Several engines of so-called original design have been developed although these were probably largely based on foreign models. One of these, the M.34, was shown at the 1936 Paris Aero show. A photograph of this engine is reproduced here since it is clear from the external appearance that the "V.2" engine is very similar in general design. The reduction gear and the supercharger are naturally missing on the tank engine, but the cylinder blocks, heads (allowing for conversion to C.I.), the general grouping of auxiliaries and the engine bearers appear to be virtually the same on each engine. The M.34 is rated at 950 H.P. As no further particulars are known, the two engines may differ radically in the internal design, but in view of their external similarity this seems unlikely. The M.34 is thought to have been originally designed in Italy (Fiat) for the Russians, and on the assumption that it is basically similar internally to the "V.2" the design closely follows Italian in-line Aero engine practice.

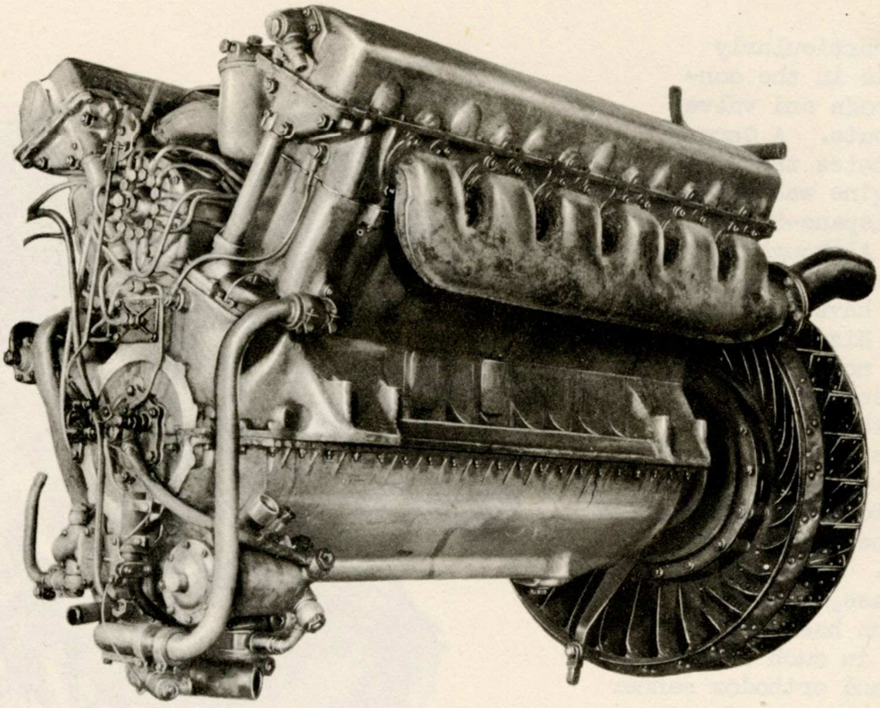
This is particularly noticeable in the connecting rods and valve gear layouts. A German report states that the "V.2" engine was developed from a Hispano-Suiza aero engine. Although design and development may quite possibly have been influenced by Hispano-Suiza there do not appear to be any salient features to support this statement. This same German report also states that the conversion to C.I., was carried out to the designs of Coatalen. This again may be the case, but the conversion has beem carried out in such a straightforward and orthodox manner that there are no features that suggest any particular origin. The Coatalen V.12 C.I aero engine as exhibited shortly before the war at the Paris Aero show had certain points in common with the "V.2", i.e., the same cylinder bore, four valves per cylinder and a similar type of combustion chamber. Mechanically, however, it differed in most respects and it had a very special type of fuel injection equipment.



'V.2' Tank Engine, Front View

Whatever its true origin may be, its design, on the whole, follows principles well tried and established in one or other of the well known in-line aero engines. Largely built of light alloys it is very light, and the lower half of the engine appears somewhat lacking in rigidity. The external design is very clean, but the grouping of the auxiliaries, excluding the injection pump and air distributor valve, is bad from the point of view of accessibility. The injectors are decidedly inaccessible when the engine is installed in the tank. Several examples of detail design are worthy of note. The simple method of locating the driving bevel on the crankshaft and the location of the big-end cap and wrist-pin are unusual. The angle which the centre of the wrist pin makes with the axis of the master rod has been chosen to give T.D.C. on the articulated rod bank 60° from T.D.C on the master rod bank. This has resulted in the stroke of the articulated rod bank being some $3\frac{1}{2}$% greater than that of the master rod bank. The object of this, presumably, has been to achieve identical injection timing on both banks. The design of valve gear has been used on several engines. It is very simple and easy to adjust, although the valve guides probably tend to wear rather rapidly owing to the high side loading.

The type of combustion chamber used is frequently found on the slower speed C.I. engines; it should give a low fuel consumption and good starting from cold. It is evident from the design that there has been no attempt to create any form of controlled swirl or turbulence. This is normally achieved by masking the inlet valves, and it is considered that if this were done the performance at high speed could be improved, and an injector nozzle with fewer holes could be used. The leakage past the injectors and fuel pump is led directly into the engine. Although this may have certain advantages in very cold climates, it seems hardly likely that the accumulative dilution of the lubricating oil would be desirable.



'V.2' Tank Engine, ¾ Front

An interesting point in the design of the engine generally is the very small number of ball and roller bearings used. The dual starting system - electric and compressed air - is a good feature, especially in cold climates when the efficiency of storage batteries will deteriorate.

In conclusion, it is considered that by far the greatest asset of the 'V.2' lies in the fact that it is a large C.I. engine having, therefore, the right sort of performance characteristics for a tank engine. It is rather bulky for its power, but is very light. Modified from what was apparently a rather crude design of aero engine, it has a certain advantage as a tank engine in that it is not particularly delicate or complicated. The conversion from an aero engine to a tank engine could, with advantage, have been carried a stage further by re-grouping certain of the auxiliaries so that they would be more accessible in the tank. On the other hand, the fairly bold change over to C.I. has been well carried out.

MANUFACTURE

The processing and finish of the components generally suggests aero engine rather than heavy vehicle engine practice; stress relieved and ground bolts and studs, polished rods and crankshaft and die pressed pistons may be quoted as particular examples. Judged by aircraft standards, however, the finish is in most cases, very rough.

The surfaces of the sand castings are exceptionally rough and even where surface smoothness is desirable, i.e. in the valve ports etc., the surface is only roughly fettled. On the other hand the castings appear to be quite sound, there being no sign of flaws or blow holes on the machined surfaces. As appearance has obviously not been considered, a coarse moulding sand may be preferred for certain reasons. Although there is no evidence of porosity to the naked eye, the interior surfaces of most castings have been treated with linseed oil or some similar substance. The cylinder head and particularly the cylinder block have intricate cored passages and call for a reasonably high standard of foundry technique. Die castings have been used for certain of the smaller aluminium components. These appear to be sound and indicate production in some quantity. It can be said that there is virtually no unnecessary machining on any of the castings.

The use of die pressed pistons is interesting since this process is comparatively new to most countries. The design calls for very little machining; the skirt is not diamond turned and is comparatively rough. The internal diameter of the bottom of the skirt has a wide tolerance and may be machined away to adjust the weight which, according to the drawing, has a limit of $\pm$ 10 grams. The standard of pressing appears to be satisfactory.

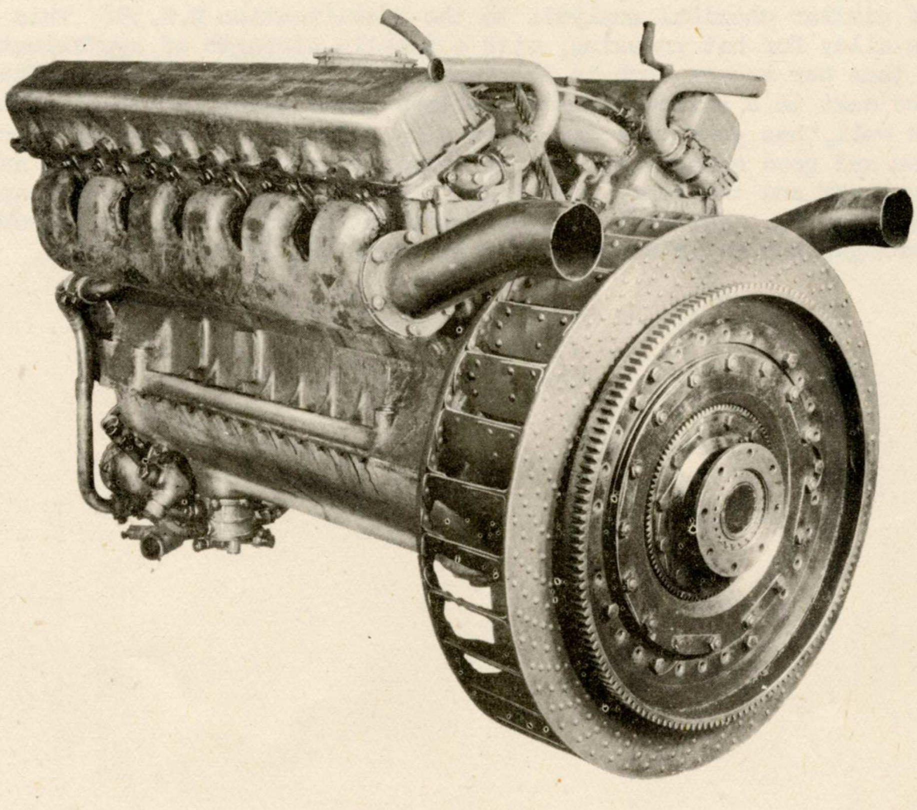
The connecting rods and crankshaft are machined all over and roughly polished, although on the former there are a large number of machining marks, some quite deep, that have not been removed. There is evidence of rather rough hand work in removing sharp edges, burrs etc. The big-end studs have an exceptionally fine finish, and it is considered, therefore, that they are very highly stressed. The webs are turned on the crankshaft which is quite possibly machined from a solid billet. The valve gear has a finish comparable with British aero engines of moderate output. The cam profiles are not very accurately machined and even with tappet clearances individually adjusted to give the best timing, certain opening and closing periods vary by as much as $\pm 5^{\circ}$. The cylinder liners are very roughly turned on their outer diameters and appear to have been cadmium plated. The more highly stressed studs and bolts are all stress relieved and ground and the threads are generally well finished, probably having been ground or milled.

The thick steel backs for the main bearings appear to have been rolled from flat strip. The big-end bearings are of the normal thin walled strip type.

Certain of the less important details, and especially those components that appear to be modifications, have a general finish that is decidedly crude. The air cleaner is an example of particularly rough workmanship.

All bolts, nuts and studs have been blued. Inlet manifolds and water pipes have been enamelled and oil and air pipes plated with cadmium or some similar metal. External surfaces of the aluminium castings have received no surface treatment.

The very large number of inspection stamps on the components suggest an exceptional degree of production control. This may be as a result of employing a large proportion of semi or unskilled labour. As an example of this - a piston bears a total of 20 inspection stamps of six different types, presumably there were others subsequently removed by machining, as well as a large number of marks indicating batch numbers, size, weight etc.



'V.2' Tank Engine, ¾ Rear

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MATERIALS

The scope of the materials examination was severely limited by the need for preserving the engine in sound running condition. Certain aluminium specimens, however, were obtained for metallurgical analysis and hardness figures were obtained for most of the ferrous materials with a Shore Scleroscope. In addition to these, U.S.S.R material specifications for the piston, rings and gudgeon pin were obtained. In view of these limitations only general conclusions may be drawn, but it is not considered that the materials employed are unusual or that they differ very widely from those used by manufacturers of aircraft and diesel engines in this country.

FERROUS MATERIALS

Examination by the Shore Scleroscope has given the following data. The connecting rods appear to be of an alloy steel heat treated to about 60 - 70 tons per square inch U.T.S. The crankshaft is somewhat harder and would probably give about 75 - 80 tons per square inch U.T.S. The uniformity of the hardness figures along the crankshaft indicates accurate heat treatment, and there is no evidence of surface hardness on the crankpins or main bearing journals, which with the rest of the shaft are of the order of 350 - 370 V.D.H.

The gudgeon pins and wrist pins are made from a case hardening steel carburised to give about 725 V.D.H. The U.S.S.R material specification for the gudgeon pin calls for a normal case hardening steel but of rather low carbon content (0.05/0.15%).

The camshaft appears to be heat treated to give about 60 - 70 tons per square inch U.T.S with the cam profiles carburised to about 675 - 725 V.D.H. The journal bearing surfaces have not been surface hardened. There is no apparent difference in the materials of the inlet and exhaust valves which have a uniform hardness of 240 V.D.H indicating an alloy steel heat treated to approximately 50 tons per square inch U.T.S. The valves are not austenitic. The tappet heads have been carburised to give 675 - 725 V.D.H. No reliable hardness figures could be obtained for the cylinder liners although the bores have probably been nitrided. The piston rings are of normal cast iron.

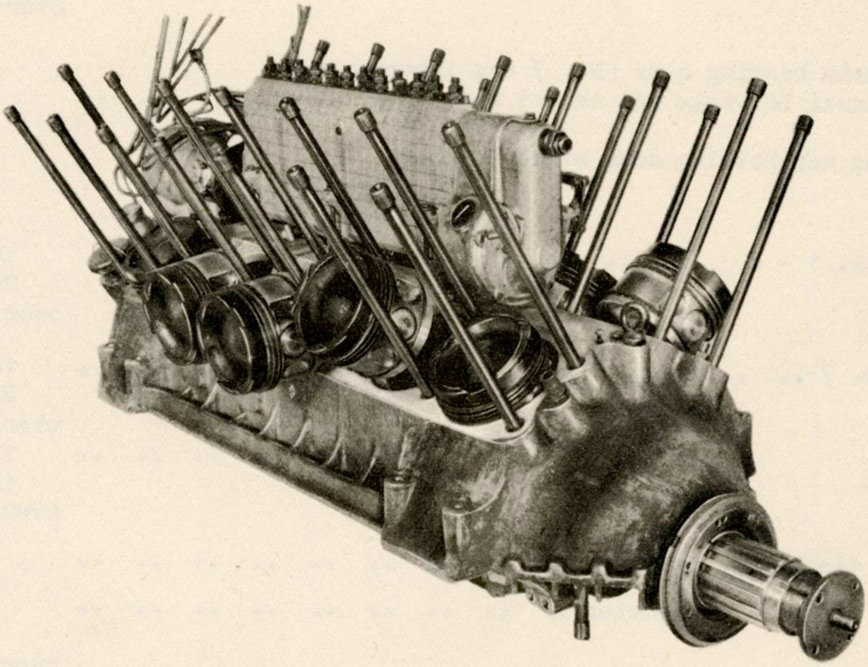
NON-FERROUS MATERIALS

The U.S.S.R material specification for the piston calls for an aluminium alloy of similar chemical analysis to the specification R.R.59. This is a suitable alloy for hot pressing, with a tensile strength of approximately 21 - 22 tons per square inch in the final heat treated condition. The cylinder heads are cast in a silicon eutectic alloy. This alloy is well established; it casts well, has good corrosion resistance, low co-efficient of thermal expansion and good elongation. Other aluminium sand castings, such as the cylinder block and the sump, are of an alloy which comes within the specification D.T.D. 424. Material analyses were not possible for the big-end and main bearings, but it is considered that these are of copper lead.

PART II

DETAILED DESCRIPTION OF ENGINE

CRANKCASE

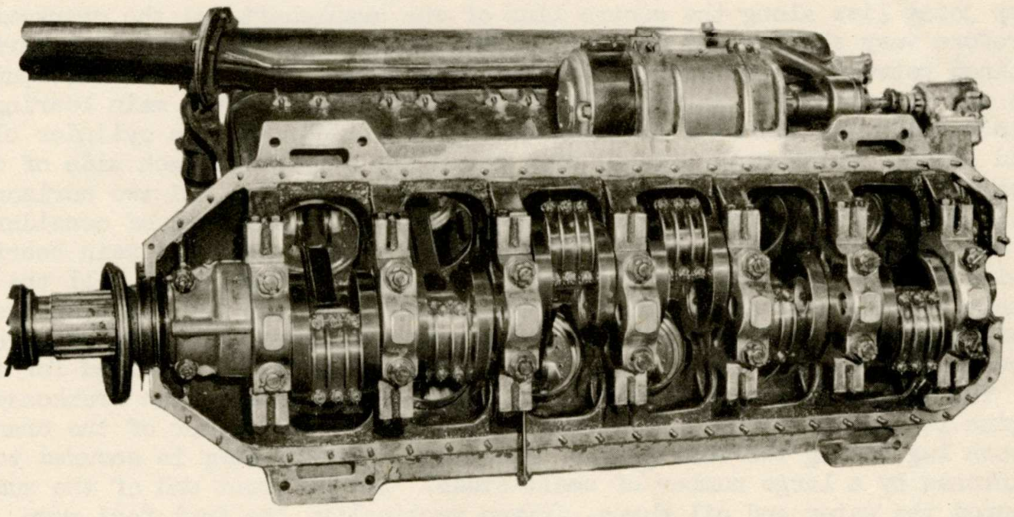


Upper view of Crankcase showing Pistons and Fuel Pump

The crankcase is of cast aluminium and is separate from the cylinder blocks. The sump joint lies along the centre line of the crankshaft and the crankcase is therefore very shallow and does not appear to be very rigid. A flat surface is machined between the 60 degree cylinder block faces to carry the fuel pump and the air distributor. Internally it is divided by the seven main bearing walls into which are threaded the main bearing cap studs and the cylinder block and head studs. These walls extend down below the sump joint each side of the main bearing caps to give a lateral support to the bearings, and two horizontal tie bolts pass through each assembly. The main bearing caps are of considerable depth, and appear to be die pressed of aluminium alloy. The rear main bearing cap, which incorporates the thrust race, is secured by four studs; all the other main bearing caps are secured by two studs. Housings for the bevel gears and shaft drives to the camshafts, injector pump and dynamo are cast integrally with the crankcase, and a small cast iron inspection cover is provided for the gears. The dynamo is strapped to brackets cast on the side of the crankcase. The engine is rigidly mounted from four lugs cast at each corner of the crankcase, each lug having two bolt holes. The cast aluminium sump is secured to the crankcase by a large number of small studs. At the front end of the sump are grouped the water and oil pumps, driven vertically, the fuel feed pump, driven horizontally, and the oil filter.

DATA AND DIMENSIONS

Overall length	1350 mm
" height	260 mm
Centre line of crankshaft to block face	245 mm
Cylinder centres	176 mm
Angle between banks	60°
Cylinder holding down studs, number	14 per bank
Diameter	17.5 mm 22.5 mm over threads
Number of main bearing caps (No. 7 cap incorporates two journal bearings and thrust race)	7
Main bearing cap holding down studs, number Nos. 1 - 6	2
No. 7	4
Diameter Nos. 1 - 6	18.5 mm 20.5 mm over threads
Diameter No. 7 .. 2 front	18.5 mm 20.5 mm over threads
2 rear	11.5 mm 13.5 mm over threads
Horizontal tie bolts, number	2 per cap
diameter	8 mm 10 mm over threads
Width of cap	175 mm
Depth of cap	147 mm



Underside of Crankcase showing main bearing Housings, Crankshaft and Rods.

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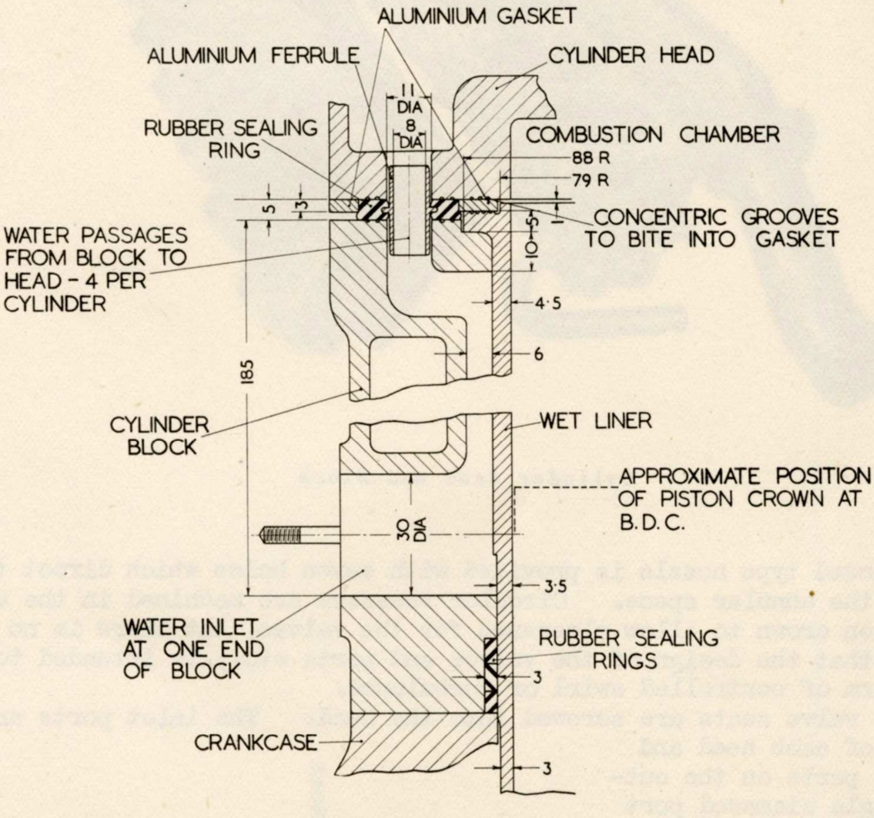
CYLINDER BLOCKS AND LINERS

The cylinder block on each bank is a single aluminium casting with hardened steel wet liners. The block is very light and has a very small water capacity. Holding down studs screwed into the crankcase pass through cored passages in the block and through holes in the head. The block is positioned on the crankcase by four dowels. Each steel sleeve is provided with a flange at its upper end locating in an annular recess in the top of the block. As is shown in the drawing this flange stands proud of the top of the block and is grooved to bite into the aluminium gasket. At the lower end the sleeve is sealed by three rubber rings fitted in a counter bore at the bottom of the block. The lower ring therefore seats on the crankcase face. The lower end of the sleeve extends into the crankcase. Cooling water enters the block at one end and passes through passages cored round each liner. It passes out into the head through a number of holes in the top of the block. These holes are sealed by aluminium ferrules passing through thick rubber washers compressed between the block and head. The water passages and the passages for the holding down studs are separate.



Cylinder Liner and Head Joint

DATA AND DIMENSIONS

Overall length	1100 mm
Depth of liner	276 mm
" " block	217 mm
Depth of water passages (from head face)	185 mm
Cylinder bore	150 mm
Thickness of liner	top 4.5 mm
Thickness of gasket	3 mm
Top of liner to face of block	2.5 mm

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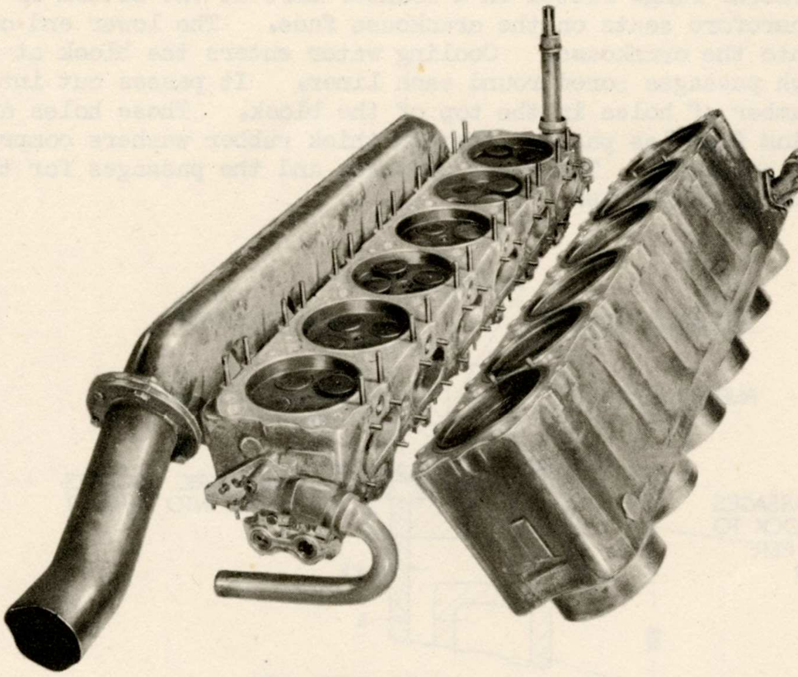
CYLINDER HEADS

A separate cast aluminium head of very light construction is fitted to each bank.

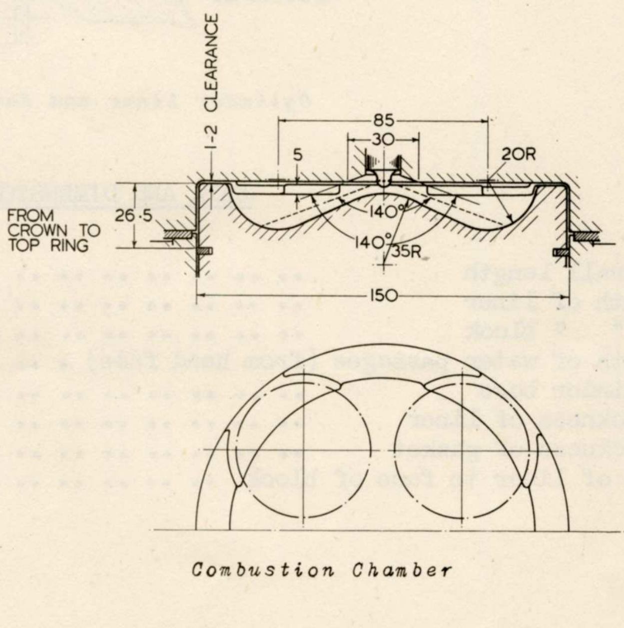
Circular flat topped combustion chambers are machined in the head face and each carries four vertical valves and a central injector nozzle. As is shown in the drawing a combustion space is formed in the piston crown, only a mechanical clearance existing between the edge of the piston crown and the top of the combustion chamber at top dead centre.



Cylinder Head and Block

The closed type nozzle is provided with seven holes which direct the spray into the annular space. Circular recesses are machined in the edge of the piston crown to allow clearance for the valves, but there is no indication that the design of the valves and ports etc., is intended to produce any form of controlled swirl or turbulence.

Bronze valve seats are screwed into the head. The inlet ports are on the inside of each head and the exhaust ports on the outside, a single siamesed port being provided for each pair of valves. The exhaust ports are rather smaller than the inlet ports, and a water space is cored between each pair. There is no water space between each pair of inlet ports. Bronze valve guides are pressed into the head. The top face of the head is machined flat to receive the pedestal bearings for the camshafts, the injector nozzle studs, the valve cover studs, and the holding down nuts.

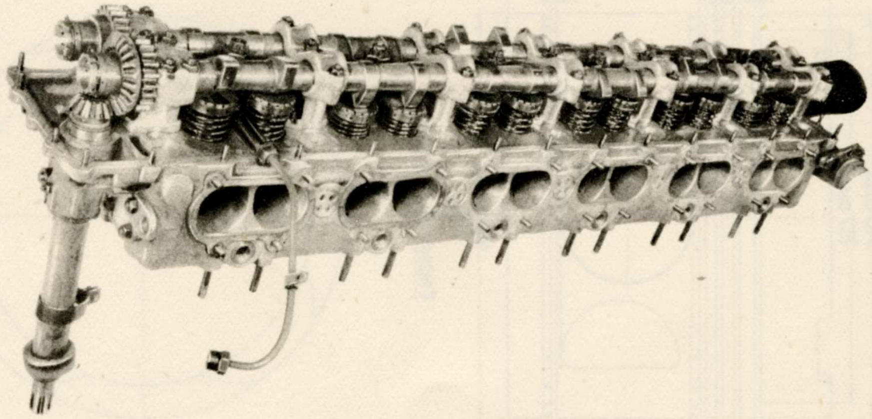


Combustion Chamber

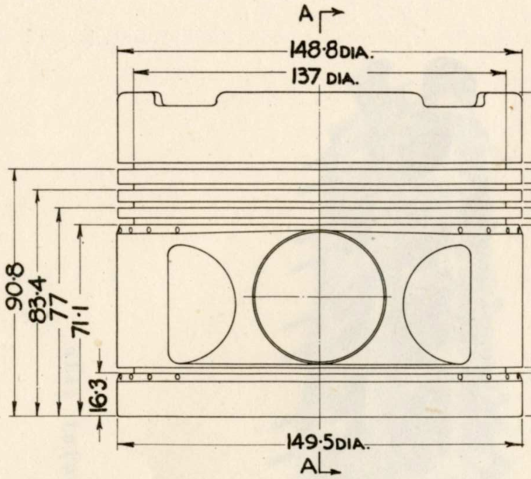
In addition to the main holding down studs, two of which are situated between each pair of cylinders, there are a number of small studs holding the edges of the head to flanges on the upper sides of the block. Below each inlet port is a brass bushed hole drilled through into the combustion chamber and tapped to receive the air valve for the air starting system. The injectors are located in the usual manner with two studs. The cast aluminium valve cover is held down by a number of small studs round the edge. The injector pipes pass through holes in the cover, and long union nuts screwing into the injectors incorporate rubber washers to seal these holes. A separate casting bolted to the end of the head carries the vertical camshaft driving shaft in bronze bushes.

DATA AND DIMENSIONS

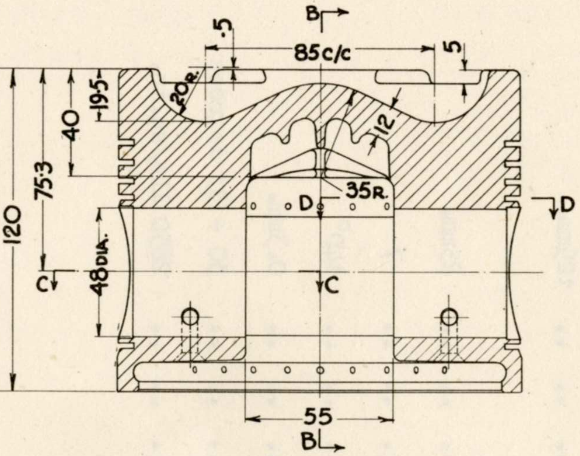
Inlet ports, number	.. ..	12 (6 pairs)
Dimensions	.. ..	55mm dia. (approx)
Exhaust ports, number	.. ..	12 (6 pairs)
Dimensions	.. ..	50mm. dia. (approx)
Depth of head	.. ..	125mm.
<u>Injector Nozzle</u>		
Barrel diameter (holder)	.. ..	25mm.
No. of holes	.. ..	7
Spray angle	.. ..	140°
Diameter of holes	.. ..	0.3mm.
Injection advance	.. ..	30 - 33 degrees
Injection pressure	.. ..	2850 lbs/sq.in.



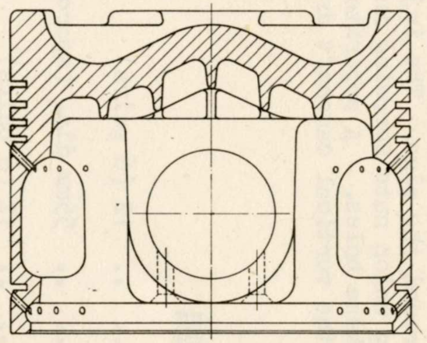
Cylinder Head - inlet side



FRONT ELEVATION



SECTION AA



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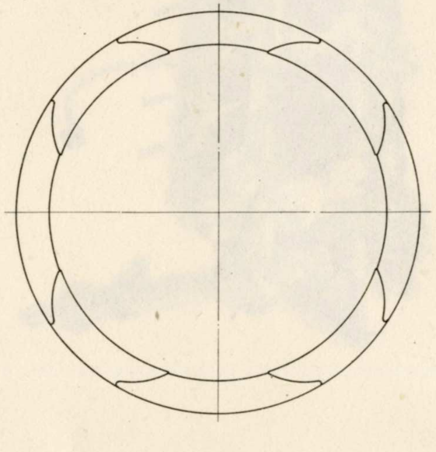
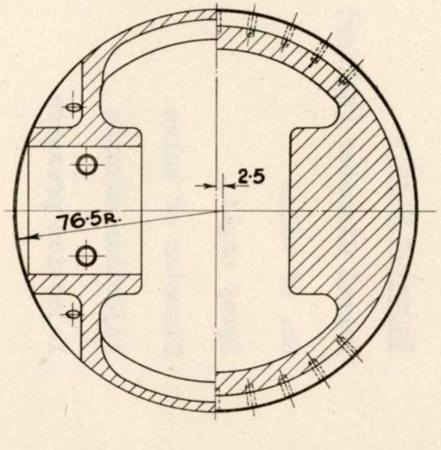


PLAN



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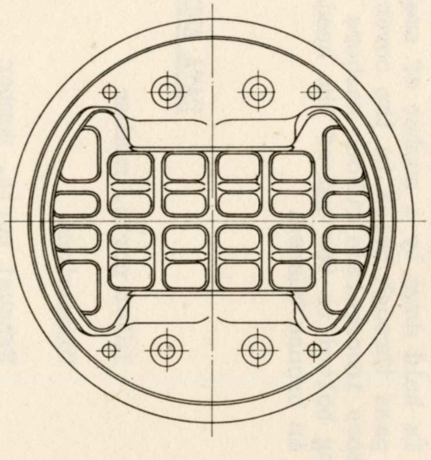

INVERTED PLAN

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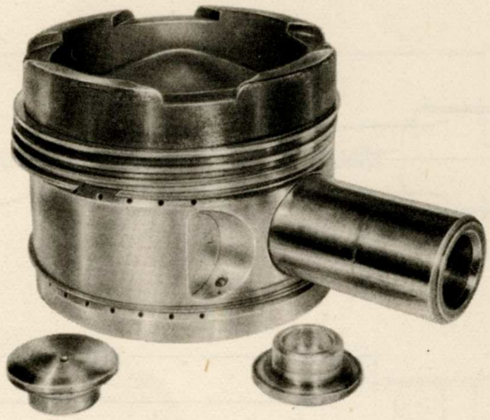
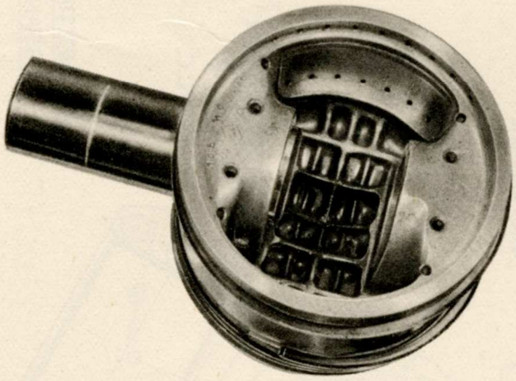
PISTONS



Piston, Gudgeon Pin and Pads

The pistons are machined from aluminium alloy pressings. Two gas rings and two bevel scraper rings are fitted above the gudgeon pin, and a third bevel scraper ring near the bottom of the skirt. It will be seen from the drawing that the skirt is very short, and, conforming to normal C.I. practice the top land is fairly deep. The gudgeon pin bosses are well supported from the crown, the underside of which is heavily ribbed. The inside of the skirt on each side of the gudgeon pin bosses is machined away for lightness; apart from this there is very little internal machining. The outside of the piston is turned to two diameters; the diameter from the crown to the second scraper ring being 0.75 mm. smaller than that of the skirt. The gudgeon pin faces are slightly relieved by eccentric turning, and a semi-circular depression is machined on each side of the pin. The piston rings are provided with a 45° gap and are of normal design. Top and bottom faces are parallel, and apart from the bevelled faces of the scraper, both gas and scraper rings are identical. The lower faces of the two lower scraper ring grooves are bevelled and a number of oil holes drilled through the skirt. The gudgeon pin is fully floating, end movement being located by aluminium pads. These pads fit into the parallel bore of the pin. Two oil holes are drilled into the bore from the underside of each gudgeon pin boss.



Underside of Piston

DATA AND DIMENSIONS

Piston Clearance

Top land	1.2 mm.
Skirt	0.5 mm. (0.003 in. per in. piston dia.)

Ring

Thickness	5.0 mm.
Depth	2.38 mm.
Face Angle of Scraper	2° 38'

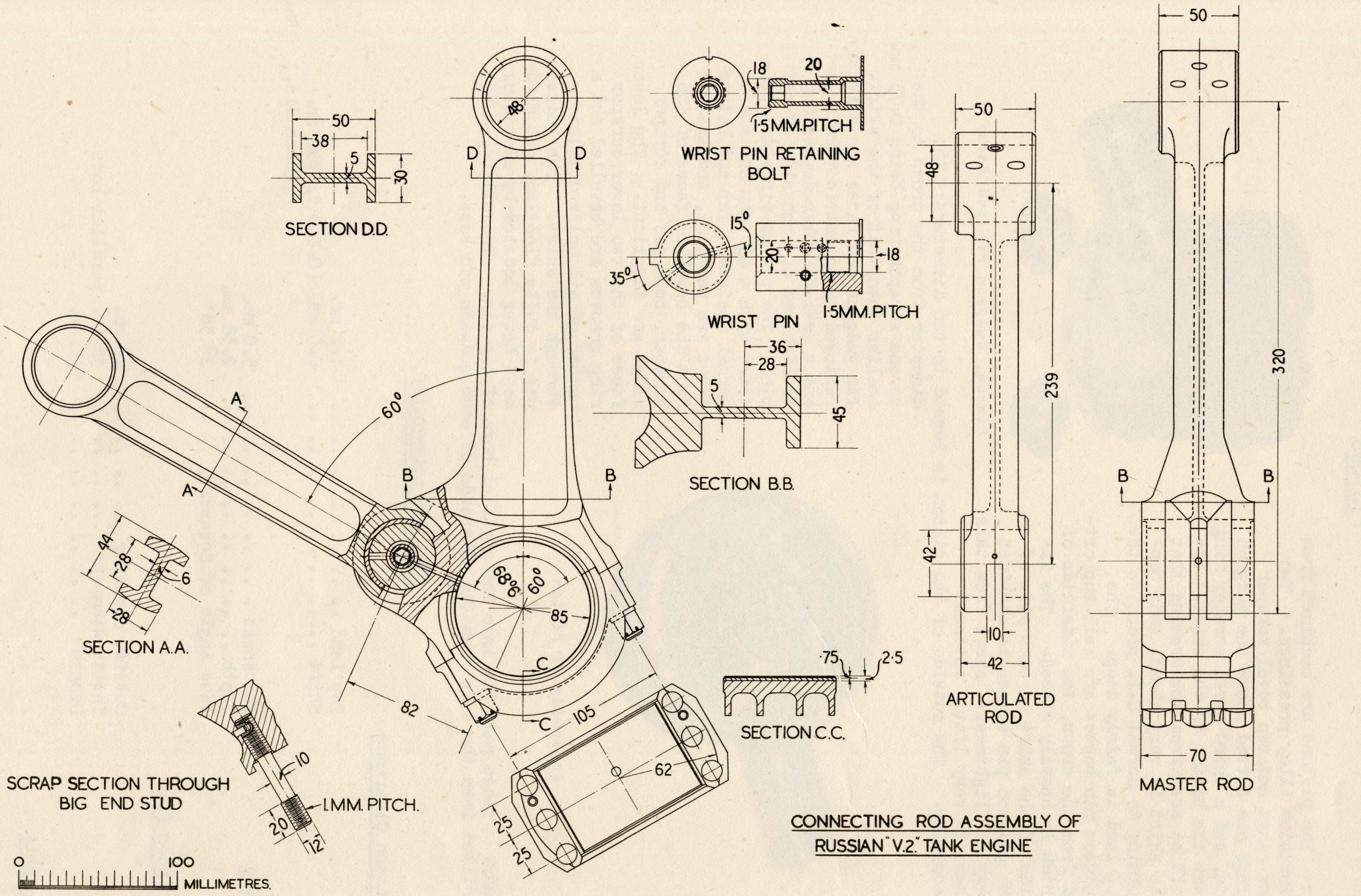
Gudgeon Pin

Outside diameter	48 mm.
Inside diameter	30 mm. parallel bore
Length	132 mm.

Weights

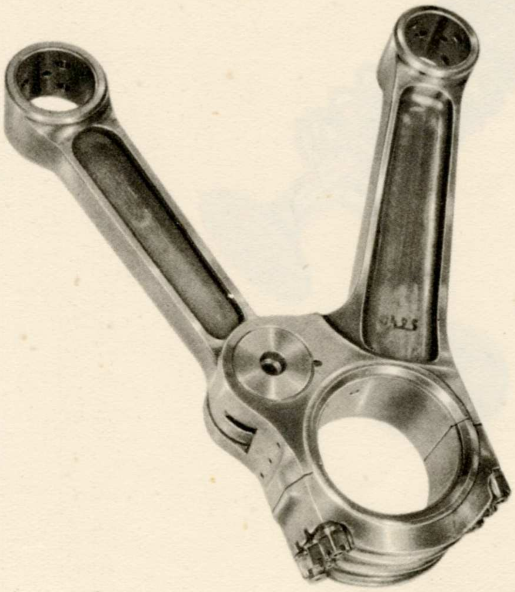
Piston (bare)	5.680 lb.
One Ring	0.086 lb.
Gudgeon Pin and Pads	2.674 lb.
Total	8.440 lb.

49989-18

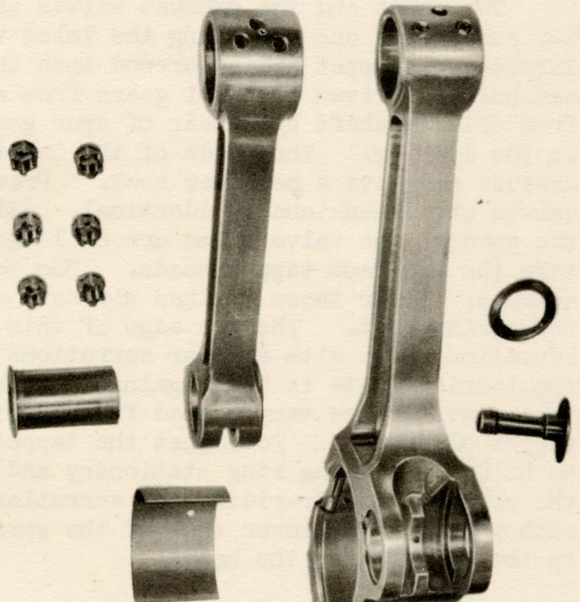


CONNECTING ROD ASSEMBLY OF RUSSIAN "V.2." TANK ENGINE

CONNECTING RODS



The general design of the connecting rod assembly is shown in the drawing. Both the master and articulated rods are steel stampings. The master rod is of deep "H" section and machined all over. The wrist pin is held in two eyes machined on the rod, and central support is given to the pin by a strut situated between the eyes, the articulated rod eye being suitably slotted. A hole is drilled from the big-end bearing into this strut to allow oil to pass from the big-end bearing to the wrist pin bearing. The master rod is split at an angle of 60° to the normal axis and the big-end cap is retained by six studs. The cap is located laterally by a circular spigot turned on the rod and cap faces. Two dowels prevent any twist of the cap on the rod. The big-end studs are threaded and pinned in the master rod, and the cap is retained by castellated nuts. The wrist pin is a driving fit in the two eyes. It has a flange machined on one end and a lug on this flange locates in a milled slot in the side face of the pin eye. This prevents the wrist pin from turning in the eyes and ensures that the oil hole in the pin is opposite the hole in the supporting strut. The bore of the pin is stepped down and tapped at the flange end, and a circular headed bolt threaded in from the other end locates the pin laterally. The articulated rod is of "H" section. The wrist pin end, which is smaller than the little-end, has a slot milled through into the bearing to allow for the supporting strut on the master rod. The wrist pin and little-end bearings are of phosphor bronze located by brass pins. The little-ends of the master and articulated rods are identical and are drilled through the upper part of the bearings for lubrication.



WEIGHTS

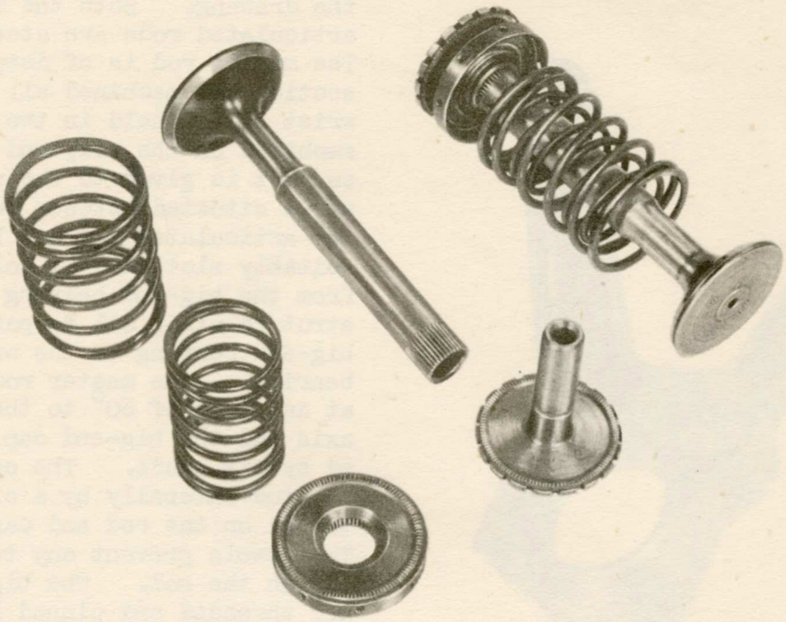
Master Rod (complete with cap and bearings) .. .. 9.26 lb.

Articulated Rod .. .. 4.25 lb.

Wrist Pin and Retaining Bolt .. .. 1.4375 lb.

Complete Connecting Rod Assembly . .. . 14.94 lb.

VALVE GEAR

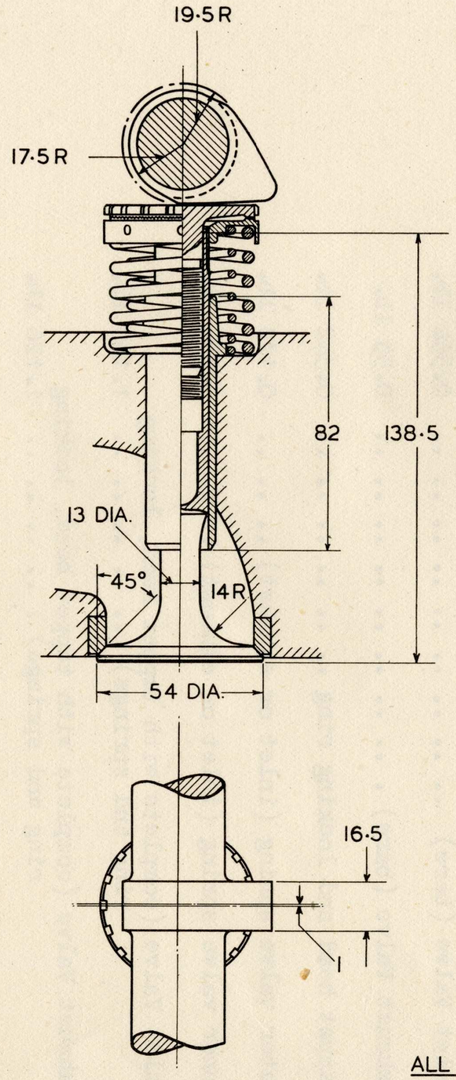


Inlet and Exhaust Valves with Tappet Head Locking Plate and Springs

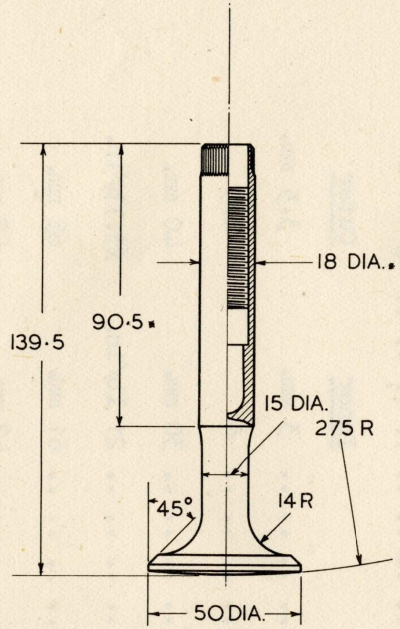
Two inlet and two exhaust valves are situated vertically in each head. Two camshafts, one operating the inlet valves and the other the exhaust, act directly on tappet heads screwed into the top of the valve stems. One camshaft is driven by bevel gears from a vertical shaft, the other is driven from this camshaft by a pair of spur gears. Details of the valves are shown in the drawing. The heads of the inlet valves are rather larger than the exhaust and have a narrower neck. From the valve stems up, however, both valves are dimensionally identical. Since all the cam thrust is taken by the guides, the valve stems are of large diameter and are bored and tapped to take the mushroom tappet heads. The top outer diameter of the stem is splined. Over these splines slides a circular locking plate which forms the top spring seat. The top edge of this plate is serrated radially. These serrations mate with similar serrations on the underside of the tappet head. The locking plate is held against the tappet head by the valve spring, and thus prevents the tappet head from turning in the valve stem and altering the tappet clearance. To adjust the tappet clearance, therefore, it is necessary to hold the locking ring stationary and screw the tappet head in or out of the valve stem over-riding the serrations. Two valve springs are fitted to each valve. The lower ends of the springs seat directly in recesses machined in the top face of the head.

The exhaust and inlet cam profiles are identical and the timing diagram is symmetrical. The profile is of orthodox harmonic construction, the base circle being ground away to allow a large tappet clearance. Both camshafts are supported in pedestal bearings held by studs to the top face of the head. The camshafts run directly in these bearings which appear to be of die pressed aluminium alloy. The bearings are split, and each pedestal forms bearings for the two camshafts. The shafts are supported between each pair of cams. Flanges are machined on the camshaft on each side of the driving end bearing to take end thrust. The camshafts are drilled throughout their length and are very light. Each is splined at one end to take the driving pinion.

49989-21



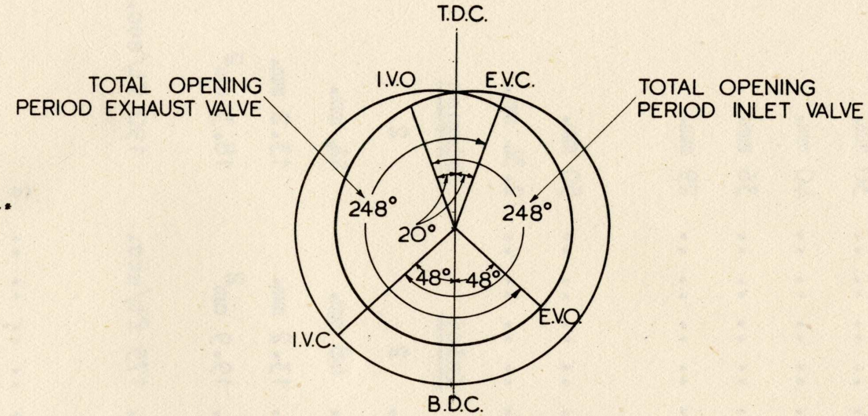
INLET VALVE ARRANGEMENT



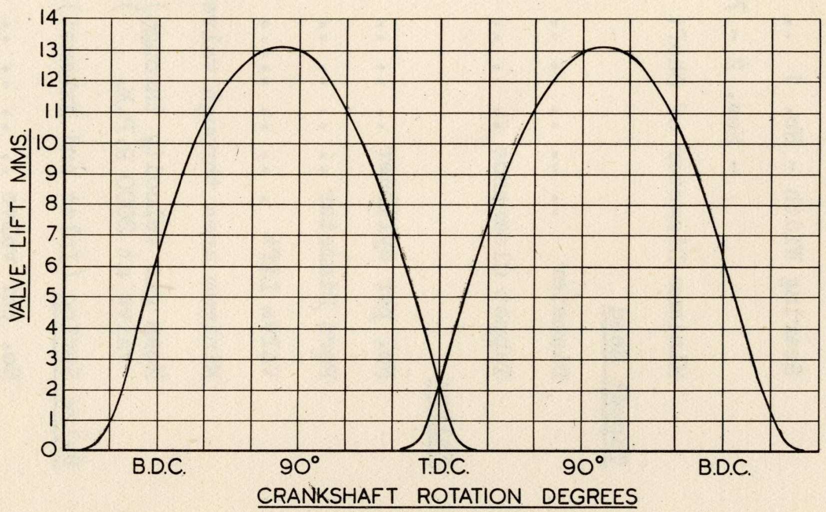
EXHAUST VALVE

*THESE DIMENSIONS ALSO APPLY TO INLET VALVE

ALL DIMENSIONS IN MILLIMETRES



VALVE TIMING DIAGRAM



VALVE LIFT DIAGRAM

DATA AND DIMENSIONS

Camshaft

Bearing Diameter	30 mm.	
Bearing Width - No. 1	40 mm.	
- Nos. 2 - 7	36 mm.	
Minimum Diameter of Shaft	29 mm.	

Tappet Head

Diameter	50 mm.
Tappet Clearance	2.34 mm.

Valves

	Inlet	Exhaust
No. per cylinder	2	2
Port Diameter	48 mm.	44 mm.
Valve Lift	13.2 mm.	13.2 mm.
Minimum area through valve	19.9 cm^2	18.3 cm^2
Mean gas velocity through valve at 2000 R.P.M.	175 ft/sec.	190 ft/sec.

Valve Spring (Inlet and Exhaust)

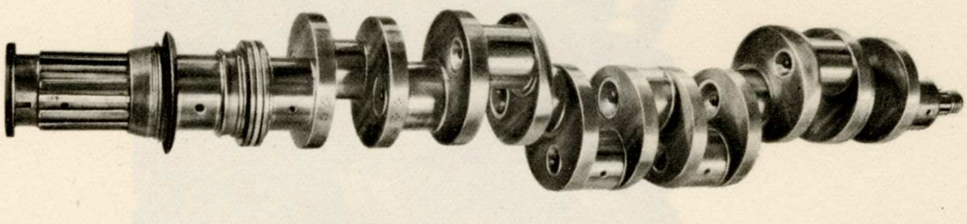
No. per valve 2

	Inner	Outer
Diameter of wire	3 mm.	3.5 mm.
No. of active coils	6	4.5
Mean diameter	30 mm.	40 mm.
Rate	21 lb/in.	23.lb/in.
Free length	61 mm.	65 mm.
Fitted length	42 mm.	42 mm.

Weights

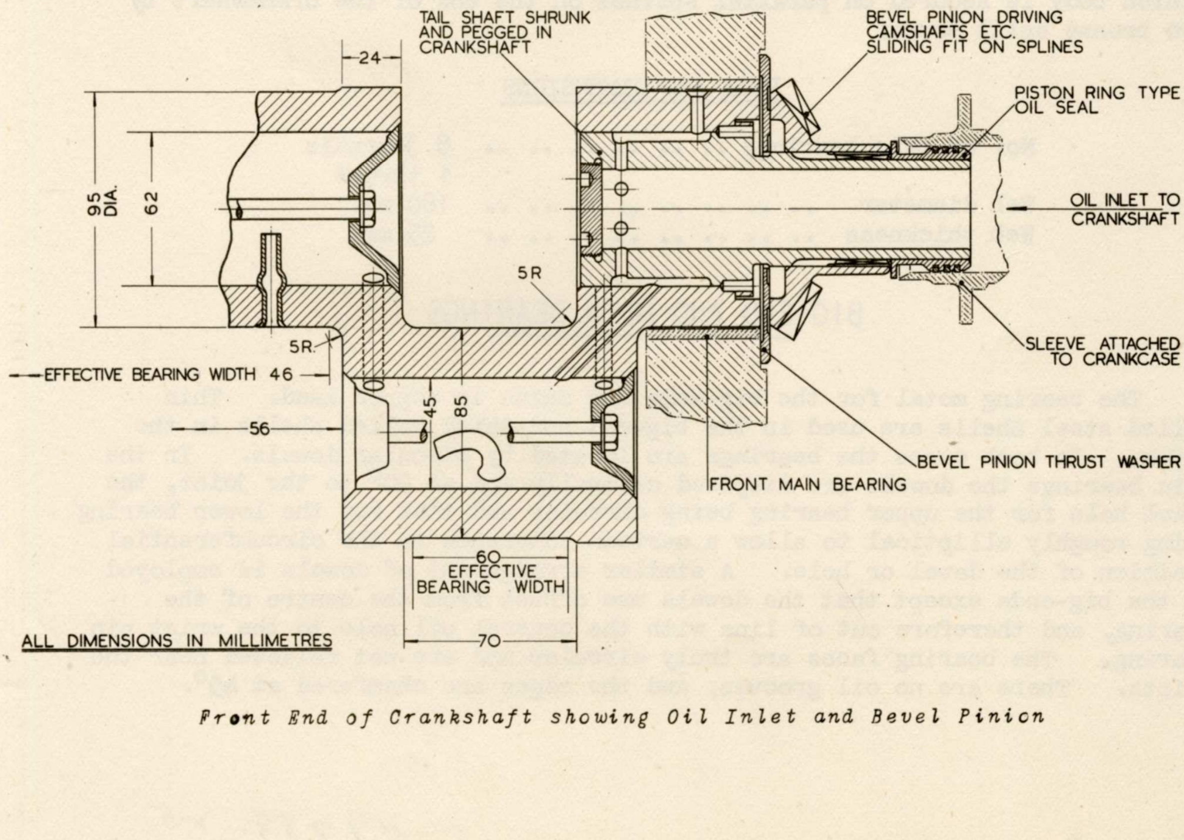
Inlet Valve (bare)	0.554 lb.
Exhaust Valve (bare)	0.55 lb.
Tappet head and locking ring	0.342 lb.
Outer valve spring (inlet or exhaust)	0.139 lb.
Inner valve spring (inlet or exhaust)	0.095 lb.
Inlet Valve (complete with tappet head, locking ring and springs)	1.130 lb.
Exhaust Valve (complete with tappet head, locking ring and springs)	1.126 lb.

CRANKSHAFT



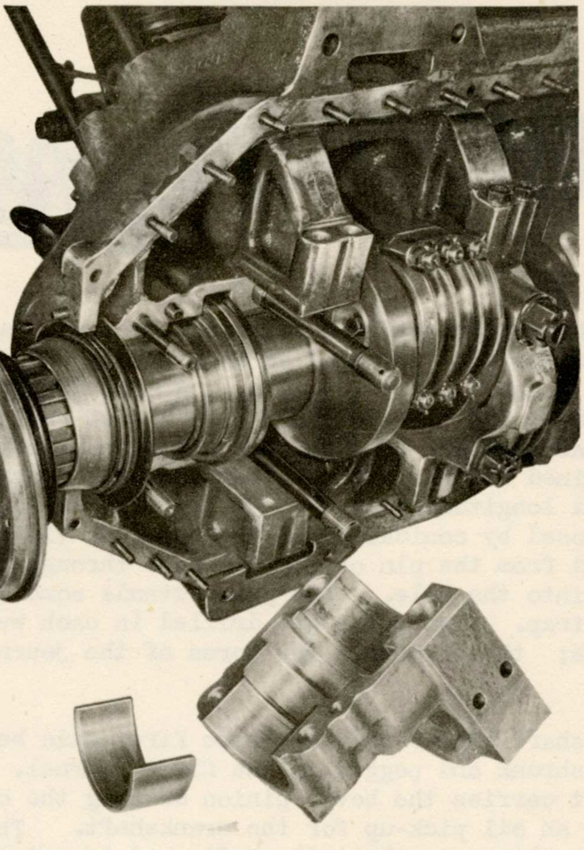
The six throw crankshaft is supported in eight main bearings. The throws are at 120° and they are arranged as in a normal 6 or V.12 engine, with numbers 1 and 6, 2 and 5 and 3 and 4 in pairs. A main journal is provided between each throw, and at the rear end is a ball thrust race between two main bearings. The shaft is machined all over and has circular eccentric webs. Generous radii are machined between the webs and pins and journals. Large diameter holes are bored longitudinally through the pins and journals, the ends of the bores being closed by conical aluminium caps and tie bolts. A single oil hole is drilled from the pin or journal face through to the bore, and a copper pipe expanded into the hole. The pipe extends some distance into the bore to form a sludge trap. Two holes are drilled in each web at right angles to the crankshaft axis; these connect the bores of the journals with those of the pins.

The crankshaft itself ends after the first main bearing, and a separate tail shaft is shrunk and pegged in the first journal. As shown in the drawing, this shaft carries the bevel pinion driving the camshafts and auxiliaries, and also forms an oil pick-up for the crankshaft. The bevel pinion is a sliding fit on splines on the tail shaft, and is not located longitudinally on the shaft. End location is provided on the thrust side by a steel thrust washer seating against the turned side face of the end bearing housing and cap. Thus, correct meshing of the bevel gears is independent of end float in the crankshaft. The tail shaft is hollow and carries at its end a bush fitted with three piston ring type oil seals. These rings are free to rotate and fit into a sleeve attached to the end of the crankcase, oil being fed into the centre of the sleeve. The oil pressure keeps this sleeve up against the bevel pinion, which is thus held against the thrust washer.



Front End of Crankshaft showing Oil Inlet and Bevel Pinion

#9989-24



Flywheel End of Crankshaft showing Rear Mains and Thrust Race

A single row ball thrust race with an aluminium cage locates against a shoulder on the rear end of the crankshaft. This shoulder transmits the clutch thrust through the race to the side face of an annular groove turned in the rear main bearing housing and cap. The thrust race appears to be held against this shoulder by a conical split ring over which is shrunk a steel collar. A piston ring type oil seal and a dished oil flinger are provided where the crankshaft passes through the end of the crankcase. The clutch body is secured on parallel splines on the end of the crankshaft by two bronze split cones.

DATA AND DIMENSIONS

No. of main bearings	8 journals 1 thrust
Web diameter	180 mm.
Web thickness	25 mm.

BIG-END AND MAIN BEARINGS

The bearing metal for the big-ends and mains is copper lead. Thin walled steel shells are used in the big-end and thick walled shells in the mains. In both cases the bearings are located by circular dowels. In the main bearings the dowels are disposed centrally and at 90° to the joint, the dowel hole for the upper bearing being circular and that for the lower bearing being roughly elliptical to allow a certain tolerance in the circumferential position of the dowel or hole. A similar arrangement of dowels is employed on the big-ends except that the dowels are offset from the centre of the bearing, and therefore out of line with the central oil hole to the wrist pin bearing. The bearing faces are truly circular and are not relieved near the joints. There are no oil grooves, and the edges are chamfered at 45°.

DATA AND DIMENSIONS

Main Bearings

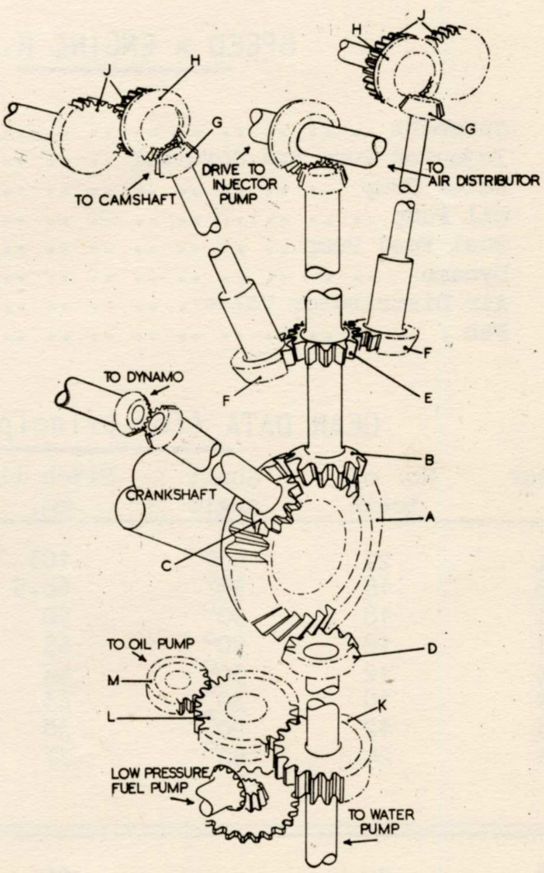
Diameter	95 mm.
Width	46 mm.
Thickness of bearing metal	0.75 mm.
Thickness of shell	4.25 mm.

Big-End Bearings

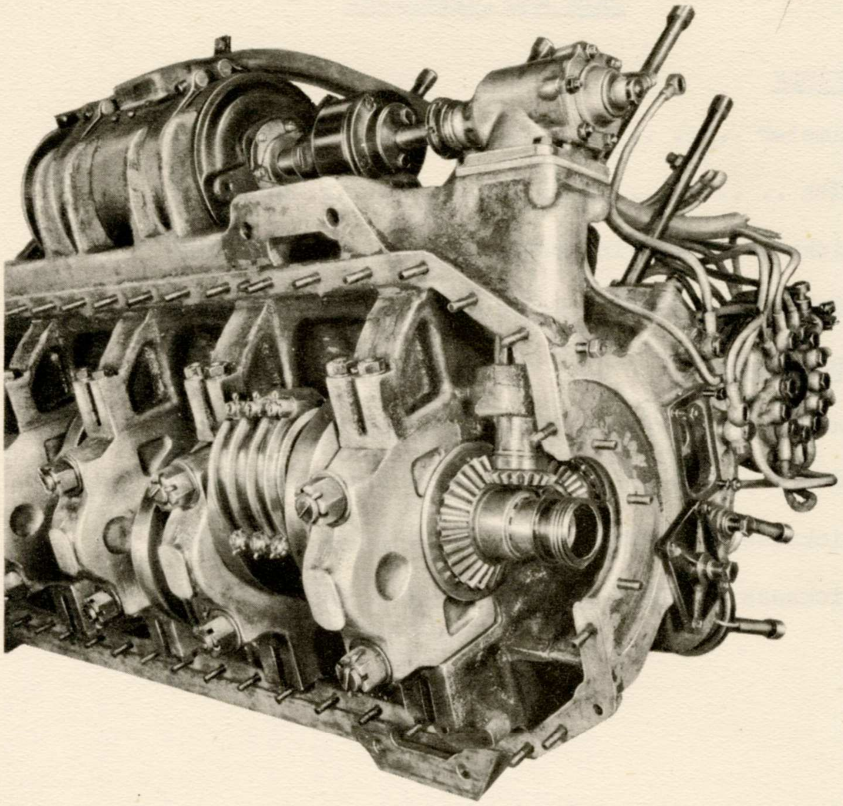
Diameter	85 mm.
Width	60 mm.
Thickness of bearing metal	0.75 mm.
Thickness of shell	1.75 mm.

CAMSHAFT AND AUXILIARY DRIVES

The camshafts and auxiliaries are all driven off a master bevel pinion attached to the front end of the crankshaft. The general layout of these drives is shown in the sketch. The master pinion drives three bevels, one on a vertical shaft driving up to the camshafts etc., the second on a vertical shaft driving down to the auxiliaries in the sump and the third on a shaft driving up at an angle to the dynamo. In most cases the shafts run in plain bronze bearings, the number of ball races employed being very small. All pinions have straight teeth and in most cases the pinions are integral with the shaft. The vertical shafts to the camshafts are driven through sliding splines and are fully enclosed in steel tubes.



Auxiliary Drives



Front End of Crankshaft showing Bevel Drives

SPEED x ENGINE R.P.M.

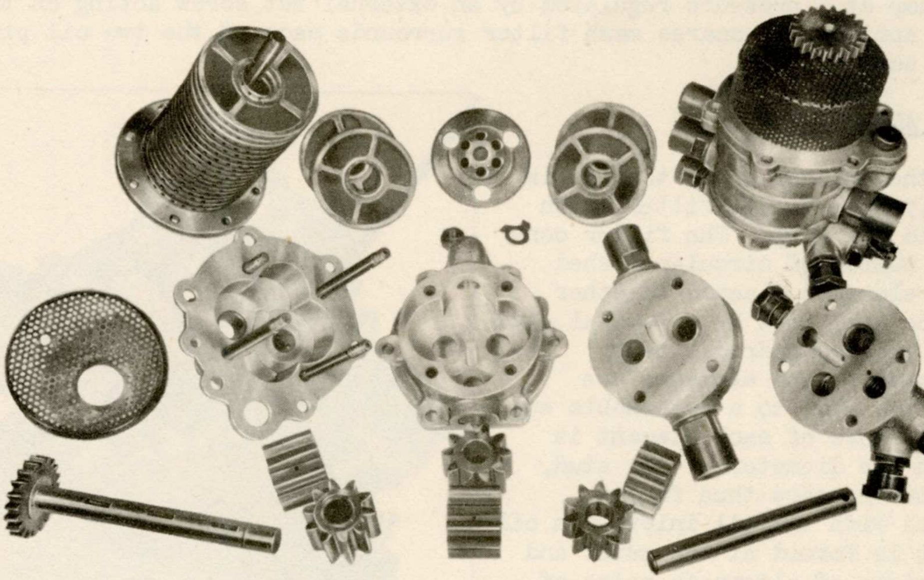
Camshaft	0.5
Injector Pump and Governor	0.5
Water Pump	1.5
Oil Pump	1.725
Fuel Feed Pump	0.68
Dynamo	1.5
Air Distributor Valve	0.5
Fan	1.0

GEAR DATA (for principal gears)

Gear	No. of teeth	Shaft angle	Pitch dia. mm.	Module mm.	Face width mm.
A	27	90°	103	3.8	22
B	18	90°	68.5	3.8	11
C	18	90°	50	2.8	7
D	18	90°	63	3.5	7
E	12	30°	42	3.5	14
F	18	30°	63	3.5	14
G	12	90°	38	3.2	14
H	24	90°	77	3.2	14
J	22	-	66	3.0	14
K	23	-	57.5	2.5	18
L	36	-	90	2.5	8
M	20	-	50	2.5	8

49989-87

LUBRICATION

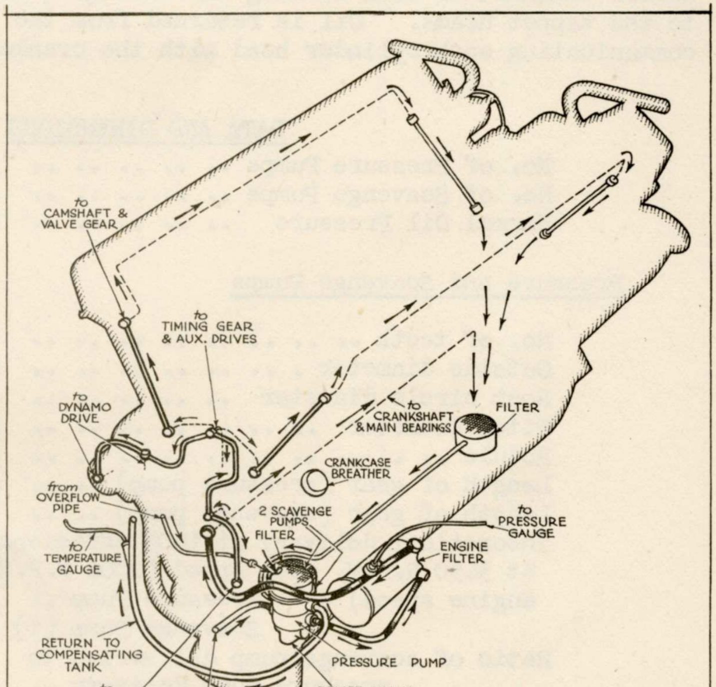


Oil Pumps and Filter

Dry sump lubrication is employed. Two scavenge pumps draw the oil from a pick-up at each end of the sump and deliver it to two tanks situated on either side of the engine. A single pressure pump draws oil from these tanks and delivers it through a filter to the engine bearings. No oil cooler is provided. The circulation system is shown in the diagrammatic sketch.

OIL PUMP

The triple gear type oil pump is bolted to the underside of the sump and is driven by spur gears off the vertical shaft which drives the water pump. The main body consists of four aluminium castings held together by four long bolts. The top two house the two scavenge pump gears, the one below, the pressure pump gears and the bottom one the pressure relief valve. The driving gears are keyed to the driving shaft which runs in bronze bushes pressed into the aluminium casings. The driven gears are fitted with bronze bushes, and run on a stationary shaft located by a set screw at the top. All the gears are of steel and are straight toothed. They are identical, except for the two pairs of scavenge pump gears which are longer than the pair of pressure pump gears.



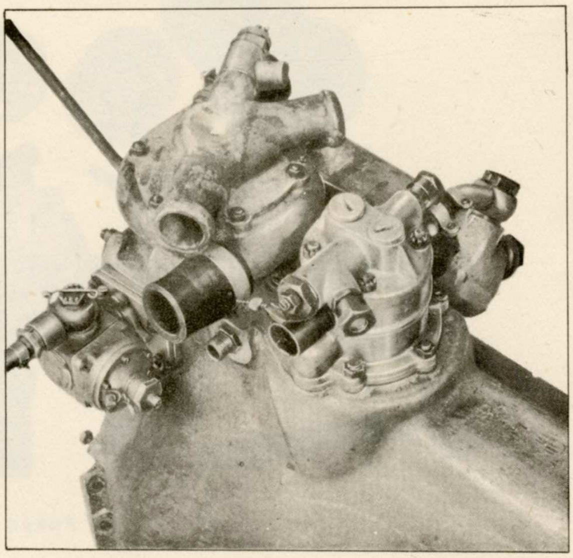
Oil Circulation

49989-28

End thrust of the gears is taken only on the machined faces of the aluminium castings. A spring loaded conical seat release valve by-passes across the pressure pump at a pressure regulated by an external set screw acting on the end of the spring. A coarse mesh filter surrounds each of the two oil pick-ups in the sump.

OIL FILTER AND CIRCULATION

From the pressure pump the oil is fed directly into an oil filter which is bolted to the sump. The filter consists of a number of circular dished wire gauze elements clamped together in alternate positions by a central stud and housed in a cylindrical cast aluminium case. The elements are secured by the stud to a detachable end plate. The bore of each element is larger than the diameter of the stud, and the annular space thus formed communicates with the oil inlet. An oil tight joint is formed at the outer and inner diameters of alternate pairs of elements, presenting in effect a total filter surface of the form of a circular bellows. In the event of a complete blockage in the filter a spring loaded release valve allows the oil to by-pass it.



Underside of Sump showing Oil, Water and L.P. Feed Pump

From the filter the oil is delivered to the crankshaft oil pick-up and thence through the hollow shaft to the main and big-end bearings. (Details of the oil pick-up and the oilways in the shaft are given in the section dealing with the crankshaft). From this pick-up, a pipe leads oil to the timing gear and dynamo drive bearings and, via internal oilways and two pipes, to the front camshaft bearings on each head. The oil passes through the hollow camshaft to each bearing and through a hole in the heel of each cam to the tappet heads. Oil is returned from the valve gear via a pipe communicating each cylinder head with the crankcase.

DATA AND DIMENSIONS

No. of Pressure Pumps	1
No. of Scavenge Pumps	2
Normal Oil Pressure	85 - 130 lb/in^2.

Pressure and Scavenge Pumps

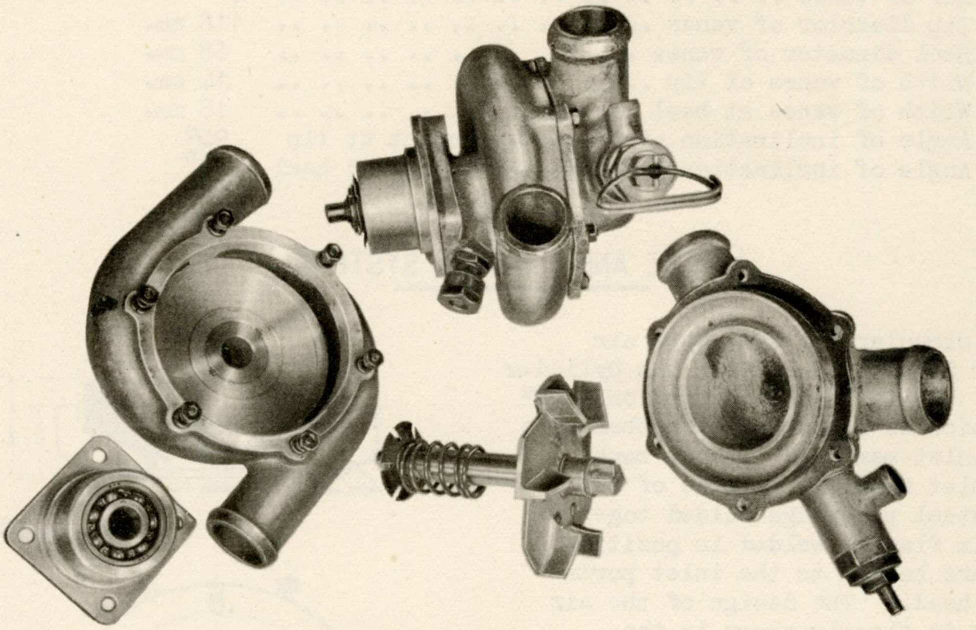
No. of teeth	10
Outside diameter	48 mm.
Root circle diameter	31 mm.
Pitch diameter	40 mm.
Module	4
Length of gear (pressure pump)	25 mm.
Length of gear (scavenge pump)	35 mm.
Theoretical delivery at 100% effeciency at 3450 R.P.M. pump speed (2000 R.P.M. engine speed) - Pressure Pump ..	22.5 galls/min.
Scavenge Pump (1)	32 galls/min.
Ratio of scavenge pump deliveries to pressure pump delivery ..	2.84 : 1

Oil Filter

Gauze mesh	25 x 25 mesh/cm.
Total filter surface area	1265 cm^2

49989-29

ENGINE COOLING



Assembled and Exploded views of water pump

A single centrifugal water pump bolted to the underside of the sump draws water from two radiators, one situated on each side of the engine, and delivers it to the lower front end of each block. From the rear end of each head a single pipe returns the water to the top of the adjacent radiator. Details of the water passages around the cylinder liners and to the head are shown in a drawing in the section dealing with the cylinder blocks. It will be noted that these passages are sufficiently small to cause a rapid circulation round the liners and into the head. The water capacity of the head is larger than that of the block, and circulation therefore less rapid. Water passages are cored around the injector bosses, exhaust and inlet ports and only partially round the valve seats.

WATER PUMP

The water pump is driven by a vertical shaft from the master bevel on the crankshaft. The main body is an aluminium casting; it incorporates two volutes each leading into a delivery pipe to one of the cylinder blocks. A detachable end cover is bolted to the main body, and incorporates two inlet pipes each drawing from one of the radiators, and a spring loaded valve for draining the system. The cast aluminium impeller is rivetted to a steel boss splined to the shaft. The top of the shaft runs in a ball race located in a separate aluminium housing which also incorporates an oil gland. A water gland is housed in the main body and a coil spring applies pressure to the packing rings in both glands. The glands are non-adjustable. A bronze bush is pressed into the main body below the gland. The impeller vanes are not shrouded and are of an unusual design. They are inclined backwards, but their curvature is in the reverse to normal practice so that whilst the heel makes an angle of approximately 50° with the tangent, the tip is approximately radial.

DATA AND DIMENSIONS

Water capacity of engine	17.20 litres
" " " one block	3.00 litres
" " " one head	5.56 litres
Cross sectional area of inlet to block	9.65 cm^2
" " " " " to head	12.0 cm^2
" " " " outlet from head . ..	8.60 cm^2

49989-30

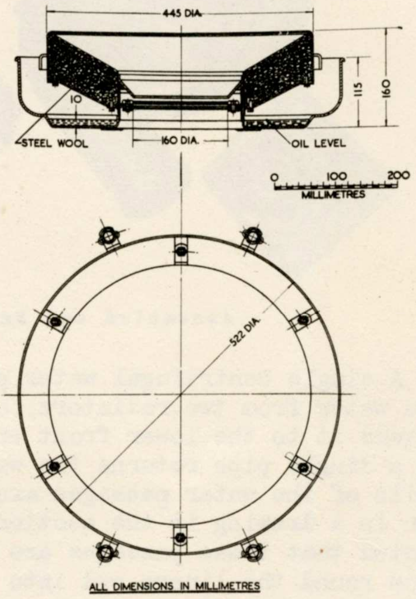
Pump

No. of vanes	6
Tip diameter of vanes	118 mm.
Heel diameter of vanes	68 mm.
Width of vanes at tip	14 mm.
Width of vanes at heel	18 mm.
Angle of inclination of vanes to tangent at tip	90°
Angle of inclination of vanes to tangent at heel	50°

INTAKE AND EXHAUST SYSTEMS

A circular oil bath-type air cleaner is mounted between the cylinder banks. It is flange mounted on a "Y" pipe which is connected by rubber hose to an inlet manifold on each bank. Each inlet manifold is made of two sheet steel pressings welded together with six flanges welded in position; these are bolted to the inlet ports on the head. The design of the air cleaner is clearly shown in the drawing. The air passes over the oil before passing through an annular space filled with coarse steel wool. The steel wool is held in place at the top and bottom by perforated steel plates.

The exhaust manifolds are of similar construction to the inlet manifolds and each leads into a pipe passing directly through the tail plate. No silencers are fitted.



Air Cleaner

FUEL AND INJECTION EQUIPMENT

It is hoped that the injection equipment will be examined in detail by a specialist firm at some later date. A brief description, however, is given below.

The equipment appears to be of Bosch design. The 12 cylinder in line pump is mounted between the cylinder banks upon three aluminium pedestals and is driven through an orthodox Bosch-type fibre coupling. The pump has a 10 mm. barrel diameter. A centrifugal governor is integrally mounted at the free end. The overflow, due to leakage, of the pump is taken by a pipe to the engine crankcase.

The nozzle holders have a very long reach, and, apart from the fact that the leak off goes directly into the valve chamber, they appear to be of normal Bosch design. Details of the nozzles are given under the section dealing with the "Cylinder Head."

Fuel is delivered to the injection pump through a Bosch-type felt element filter, by a small engine-driven vane-type feed pump mounted on the side of the sump above the water pump.

ENGINE STARTING AND ELECTRICAL EQUIPMENT

The engine may be started by an axial type electric starter mounted on the gearbox and engaging with the flywheel ring gear or by compressed air. The electric starter together with the dynamo will be the subject of a seperate report. The air starting equipment consists of a disc-type distributor valve driven at half engine speed off the shaft that also drives the injection pump. This valve distributes air to each cylinder on the expansion stroke. Air under a maximum pressure of about 2000 lb/in^2 is delivered to the valve from two steel cylinders, which can only be refilled from an external source.

WEIGHTS OF COMPONENTS

CYLINDER HEAD (bare)	105 lb.
CYLINDER BLOCK AND LINERS	120 lb.
CRANKSHAFT (including thrust race and oil retaining cones)	200 lb.
CAMSHAFT	11.69 lb.
PISTON (bare)	5.680 lb.
One Ring	0.086 lb.
Gudeon pin and pads	2.674 lb.
Total	8.440 lb.
MASTER ROD (complete with cap and bearings)	9.25 lb.
ARTICULATED ROD	4.25 lb.
Wrist Pin and Retaining Bolt	1.4375 lb.
Complete Connecting Rod assembly	14.94 lb.
INLET VALVE (bare)	.554 lb.
EXHAUST VALVE (bare)	.55 lb.
Tappet head and locking ring	0.342 lb.
Outer valve spring (inlet or exhaust)	0.139 lb.
Inner valve spring (inlet or exhaust)	0.095 lb.
Inlet Valve (complete with tappet head, locking ring and springs)	1.130 lb.
Exhaust Valve (complete with tappet head, locking ring and springs)	1.126 lb.