

SECTION 5, CHAPTER 8

SERVICING AND RECONDITIONING

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Introduction

1. Internal combustion engines used for the operation of ground equipment are kept serviceable by periodic servicing, by rectification of faults that may occur between periodic servicings, and by work, e.g. top overhaul, for which no specified period has been laid down, but which is deemed necessary. Much of the work entailed by these tasks, i.e. dismantling, cleaning and assembly, has already been dealt with in the preceding chapter, thus, the following information is confined to actual rectification, plus the viewing required to ensure that the components are serviceable.

Setting Valve Clearances

2. Valve clearance must be adjusted only when the tappet is on the base (back) of its respective cam. This is easily seen when the engine has an overhead camshaft, but care is required when the camshaft is not visible. However, because pairs of pistons move together, when one piston is on its power stroke the other one of the pair is on its induction stroke; thus, when the inlet valve of one cylinder is fully open, the inlet valve of the pairing cylinder is fully closed. It is a fairly simple matter to set the engine with a certain valve fully open, and, knowing the other valve which will be on the back of its cam (fully closed), to carry on and adjust the clearance. To simplify this procedure, and to reduce the required turning of the engine to a minimum, a sequence table for valve adjustment is usually included in

the relevant Air Publication; the following is an example:—

Valves Open	Valves to Adjust
Four-cylinder	
1 and 6	3 and 8
3 and 8	1 and 6
2 and 4	5 and 7
5 and 7	2 and 4
Six-cylinder	
1 and 3	10 and 12
10 and 12	1 and 3
8 and 11	2 and 5
2 and 5	8 and 11
4 and 6	7 and 9
7 and 9	4 and 6

3. Having ensured that the valve to be worked on is on the back of its cam, the valve clearance can be set to the figure specified by the engine manufacturer. This is an easy operation for overhead valve engines, and is illustrated at Fig. 1. Having slackened the locknut on the adjusting screw, the screw is adjusted with a screwdriver until the correct clearance, checked with a feeler gauge, is obtained between the heel of the rocker arm and the end of the valve stem. The clearance should be rechecked after the locknut has been tightened.

4. The tappets on a side valve engine are very inaccessible when compared with the overhead valve engine, and it may be found that a mirror is required in order to see properly what one is doing. Fig. 2 shows three thin spanners being used for this

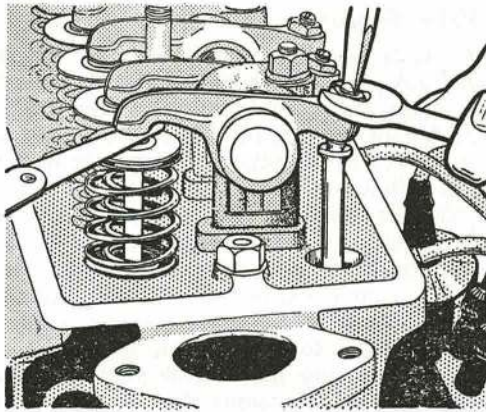


Fig. 1. CHECKING VALVE CLEARANCE—
OVERHEAD VALVE

operation. The bottom spanner fits on the flats and holds the follower, the middle spanner is used to turn the locknut, and the top spanner is used to adjust the clearance; the clearance is checked by a feeler gauge placed between the head of the tappet screw and the end of the valve stem. The clearance should always be rechecked after tightening the locknut. Some manufacturers supply a flat metal plate which, when placed between the flats on adjacent followers, allows the

third spanner to be dispensed with; such a plate if not supplied can be made locally, thus making the task easier.

5. Some engine manufacturers recommend that the valve clearances are set when the engine is cold, some when the engine is at normal running temperature, and others specify that the adjustment must be made whilst the engine is running very slowly. Such instructions will be found in the relevant Air Publication and must be adhered to, because valve clearances do affect considerably the performance of the engine. For instance, if the clearance is smaller than that specified, the valves will open earlier and close later than was intended by the manufacturer, further, there is the possibility that the valves will not close properly, the probable result being burnt valves and/or seats. If the clearances are larger than those specified, then the valves will open later and close earlier than was intended; the valve gear will also be noisy in operation, and needless wear will take place.

Valves

6. After a valve has been cleaned, examine its face for pitting and ridging, the head for

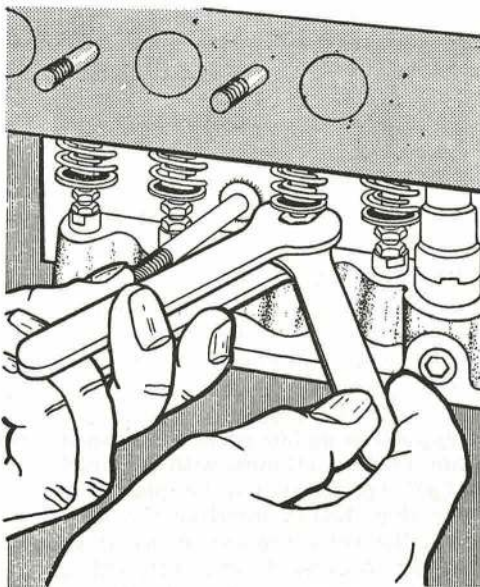


Fig. 2. ADJUSTING VALVE CLEARANCE—
SIDE VALVE

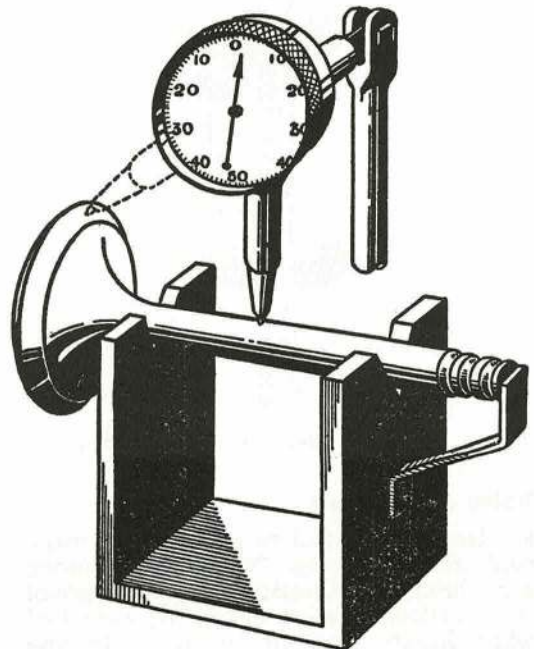


Fig. 3. CHECKING A VALVE

burning and warpage, and the collet seatings and end of the stem for wear. The stem should be measured with a micrometer for wear, taper and ovality. A valve stem should be checked for bow, and the valve head for truth, using a rig as shown in Fig. 3. Rotate the valve and note the reading on the dial, which, in the case of the stem, will be twice the actual error. If the valve stem is true, the head can then be tested in a similar manner.

Valve Seats

7. The valve seatings in the block or the head must be examined for burning and pitting. If the seatings are inserts, inspect for cracks and check for looseness. If valve seats are damaged, burnt or badly pitted, they will have to be refaced, or rectified by the fitting of inserts. Valve seats can be tested for concentricity by using a dial test indicator as shown in Fig. 4.

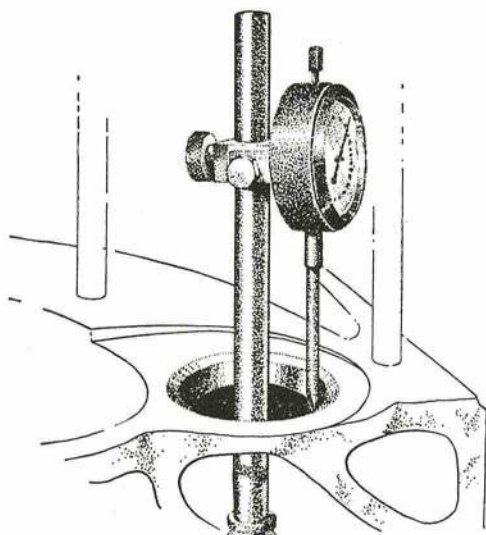


Fig. 4. TESTING CONCENTRICITY OF SEATING

Valve Seat Inserts

8. Inserts are fitted in a variety of ways, such as by pressing, "caulking", screwing and shrinking. Consequently, the relevant Air Publication must always be consulted when inserts have to be fitted, because special equipment will invariably be required, and any machining will have to be done to the specified tolerances.

Valve Guides

9. It is essential that guides are checked and any necessary rectification is done before refacing the valve seatings. Examine the guides for scoring, picking up and corrosion, and check for looseness. Check the bore for size with a plug gauge; if a gauge is not available, use the stem of a new valve to check for excessive wear. Guides may be removed and replaced by using a stepped drift, but a simple extracting and inserting tool if not available, can quite easily be made up locally; this tool is shown being used in Fig. 5. Ensure that a new guide is always fitted to the dimensions given in the relevant Air Publication, and it may be necessary to ream the bore of the guide after it has been fitted.

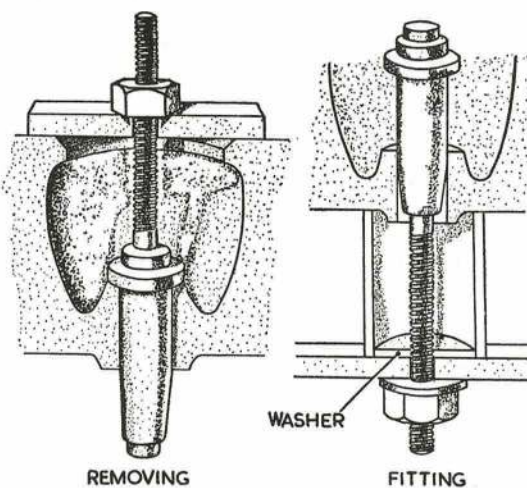


Fig. 5. VALVE GUIDE TOOL

Valve Lapping

10. The valve face is lightly smeared with grinding paste, the choice of rough or fine paste being determined by the experience of the operator. If rough paste is required, the following operations will also have to be applied using fine paste after a satisfactory result has been attained with the rough paste. A light spring should be placed over the valve stem before inserting the valve in its guide, the valve pressed on to its seat, and a slight backward and forward rotating motion imparted to the valve by means of the appropriate tool. A suction type tool is shown in use at Fig. 6, but a screwdriver will be required if the valve head is slotted, and a pronged tool if there are two holes

provided in the valve head. There is also a special kit available which is similar to a drill brace; the appropriate valve tool is secured in the chuck, the aforementioned motion being imparted when the handle of the tool is turned. The spring should be allowed to lift the valve off its seat occasionally, the valve given a half-turn, depressed again, and then the motion continued. The operations are completed when a well defined matt-grey ring on the face of the valve is obtained.

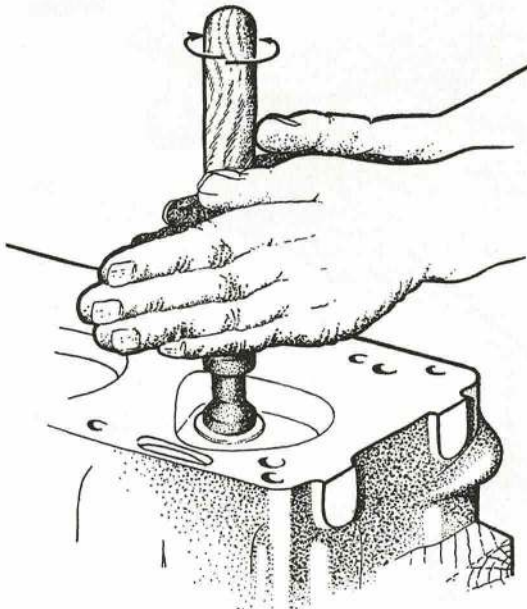


Fig. 6. SUCTION TYPE TOOL

11. In order to find out if the lapping-in has produced a gas-tight joint, one of the following checks can be made:—

(a) Wipe the valve face and seat clean, and make a series of lines across the valve face with a soft pencil. Insert the valve in its guide, press down and rotate it under light pressure about a quarter of a turn. Remove the valve and examine the pencil marks; if the lines across the matt ring have been erased, the joint can be regarded as gas-tight.

(b) This check is very similar to (a), except that in this instance the valve face is lightly smeared with engineers' marking instead of making the pencil marks.

On examination, there should be a complete circle of marking on both the valve face and seating, indicating a good seal.

(c) This check entails assembling the valve to its seat and fitting its springs and collets. Kerosine is then poured into the port and examination made for any leakage.

Note.—It is important that all traces of the paste used for lapping-in are removed. This can be done using kerosine and clean rag.

Refacing Valves

12. Valves must be refaced if it is unlikely that they would rapidly clean up with ordinary lapping-in. If the seatings are in good condition, it is quite practicable to reface valves and lap them in on their seatings. It is usually better to replace a valve that needs extensive refacing, because removal of metal will reduce the diameter of the head, and pooketing will result (Fig. 7). The thickness of the head will also be reduced, and this is important, as the thickness above the face edge should generally not be less than $\frac{1}{8}$ in.

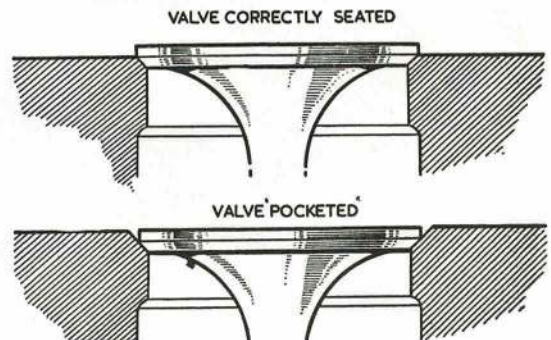


Fig. 7. VALVE SEATINGS

13. Hand cutters have been used in the past for refacing valves, but an electric grinding machine (Fig. 8) is now invariably used. The method of operation is given in the following paragraphs.

14. Dress the grinding wheel by setting the workhead to 45° and fitting the diamond dresser attachment (Fig. 9). Switch on the grinding wheel motor, and move the centre of the wheel into the diamond. Take

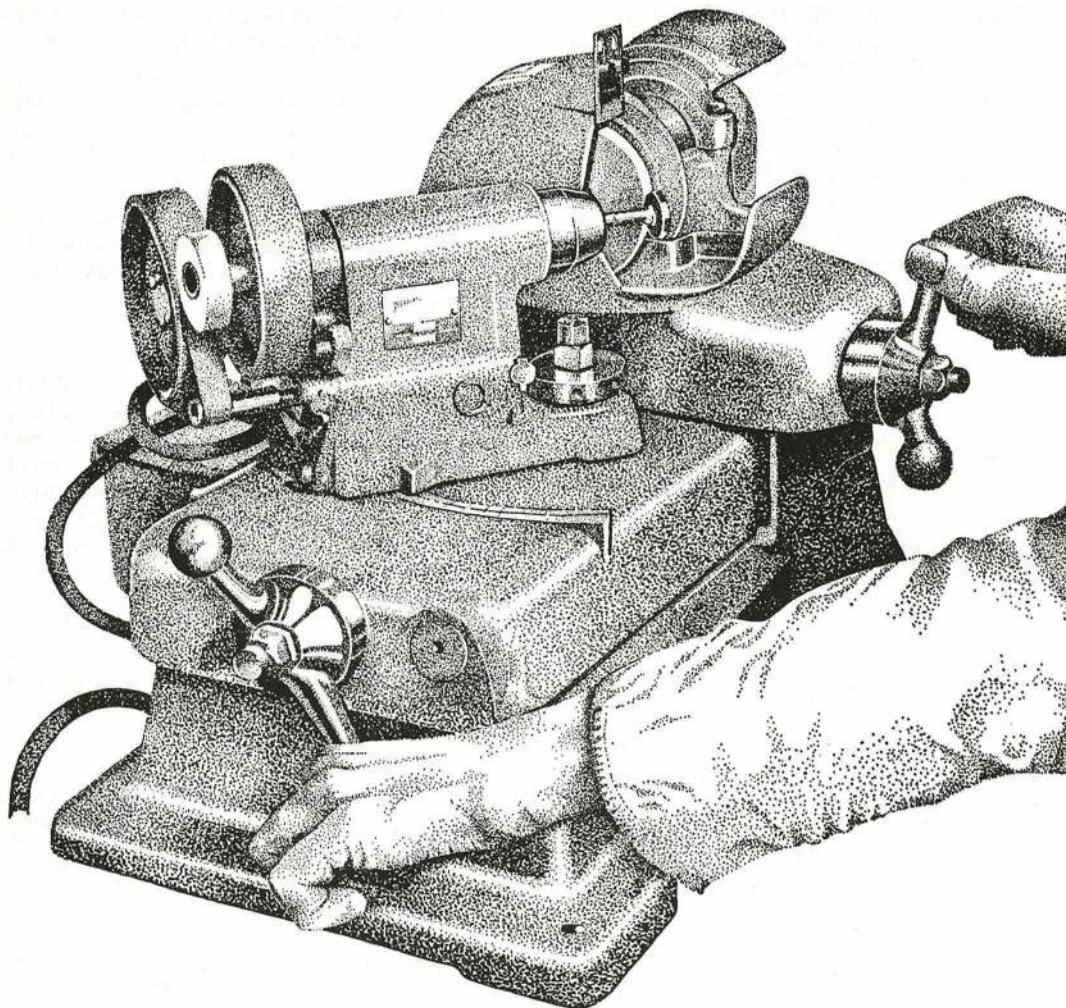


Fig. 8. ELECTRIC GRINDER

light cuts, and traverse the diamond slowly across the face of the grinding wheel until it is smooth and true. One wheel dressing is usually sufficient for a set of valves.

15. Locate the workhead at the exact angle corresponding to the angle of the valve face. Insert the valve in the collet so that the stem is gripped on the same portion that travels in the guide. The stem must pass through the back end of the collet in order to prevent collet breakage; the collet should, therefore, grip the stem immediately below the upper limit of guide travel which can usually be easily seen.

16. Check the travel of the work table to see if the workhead spindle or valve stem fouls the grinding wheel. Any fouling can be prevented by releasing the knurled set-screw, moving the stop rod to the required position and then retightening the screw (Fig. 10).

17. Switch on the workhead and wheelhead motors and bring the valve in front of the wheel. Feed the wheel slowly into the valve, taking a very light cut. Move the workhead table back and forth with short strokes, using the full face of the wheel but always keeping the valve on the wheel; the short

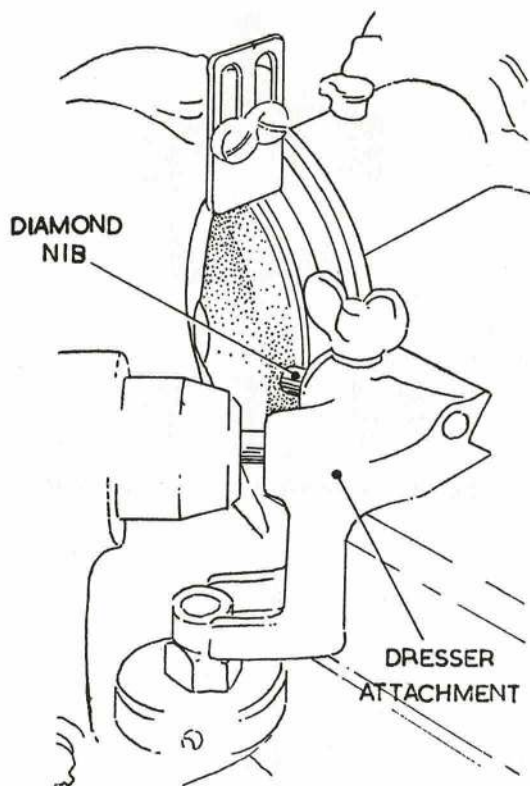


Fig. 9. DRESSING THE GRINDING WHEEL

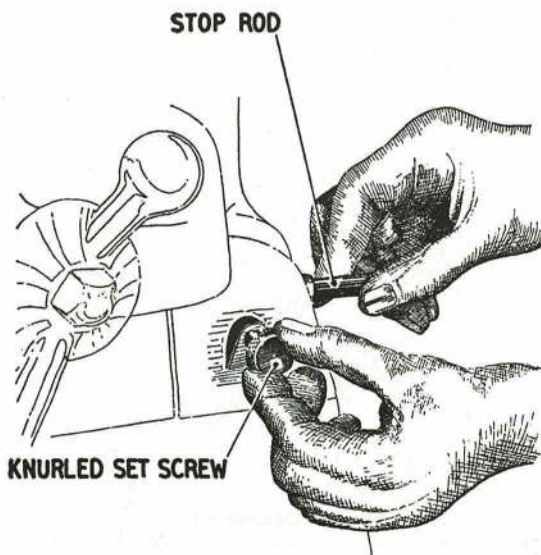


Fig. 10. WORK TABLE TRAVEL STOP

strokes should be done slowly and evenly. To make inspection or when finished grinding, back the wheelhead table away from the valve, NOT the valve off the wheel. Be careful to remove only enough metal to remove any pitting or ridging, thus giving a new true surface.

18. If the thickness of the valve head is reduced below the limit, it may be possible to remove the thin edge by use of the grinding machine, provided the diameter of the head is greater than that of the seat. Do not touch a newly ground valve face as this will cause rusting. Valves which have been refaced but are not required for immediate assembly, should be placed in a rack in order to prevent damage.

19. If the end of the valve stem has worn unevenly, the valve should be fitted in the special attachment on the grinding machine and the end ground flat.

20. **Coolant Fluid.** This is a mixture of approximately fifty parts of water to one of coolant. For practical purposes it is sufficient to pour coolant into the reservoir until it just covers the bottom surface, and then add water until the total level is about $\frac{1}{2}$ -in. from the top of the reservoir. The mixture should then be thoroughly stirred.

Note.—Never run the machine with water alone in the reservoir. The coolant must ALWAYS be present, not only to assist in obtaining a first-class finish, but to prevent the mechanical parts of the pump, etc., from becoming rusty.

Refacing Valve Seats

21. This can be done by using either hand cutters or electric grinding equipment; the latter method must be used if hardened steel inserts are fitted. It is again emphasized that any replacement of valve guides must be done before starting to reface the valve seats.

22. **Hand Cutters.** A seating is refaced by mounting the correct angled cutter on a pilot fitted in the valve guide (Fig. 11). Revolve the cutter smoothly in a clockwise direction until all damage has disappeared

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and a new face appears. No lubricant is required, but care should be taken to remove as little metal as possible.

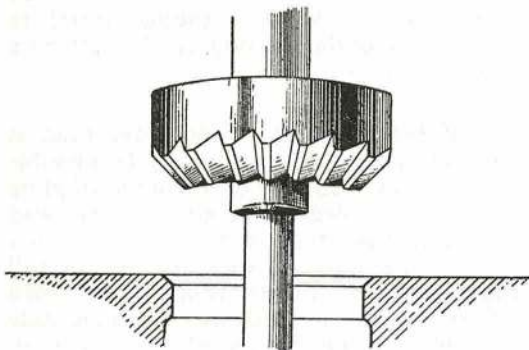


Fig. 11. REFACING CUTTER

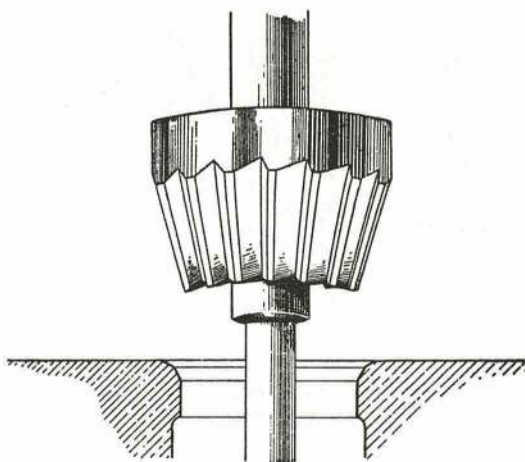


Fig. 13. REDUCING WIDTH OF SEATING

23. The valve should then be inserted in the guide and checked for pocketing. If this condition exists but it is considered that it can be rectified, use the correct cutter for this operation as shown in Fig. 12.

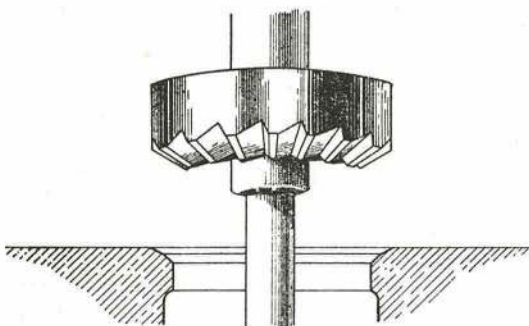


Fig. 12. RECTIFYING POCKETING

24. Check the width of the valve seating and if it is too wide, rectify by using the correct cutter as shown at Fig. 13; ensure that all cuttings are removed. If the valve seating does not need refacing, the valve must then be lapped-in to its seating, although very little attention in this way will be required.

25. **Electric Grinding.** The first operation is to dress the valve seat stone (Fig. 14). Select a stone of the correct size and abrasive and fit it tightly on the sleeve. Set the dressing stand to the correct angle of the valve seating, and ensure that the mandrel is quite clean. Put one or two drops of

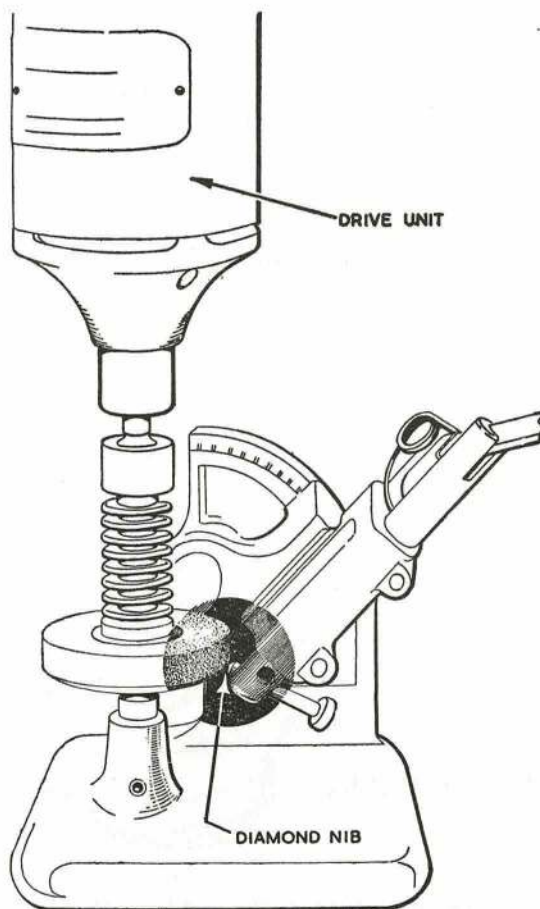


Fig. 14. STONE DRESSING

light oil in the stone sleeve bushing, place the stone and sleeve over the mandrel, and adjust until the diamond just touches the stone. Use the Vibro-Centric unit to drive the stone and sleeve, putting just enough pressure on the unit to overcome its vibrating action. With the stone revolving and taking a light cut, move the diamond slowly across the stone. Turn the adjusting screw two or three notches only, and take another cut. Repeat until the entire face of the stone is new and true. A stone should be dressed whenever it is mounted on a stone sleeve.

26. Select the correct size pilot, screw the split sleeve out as far as possible, insert the

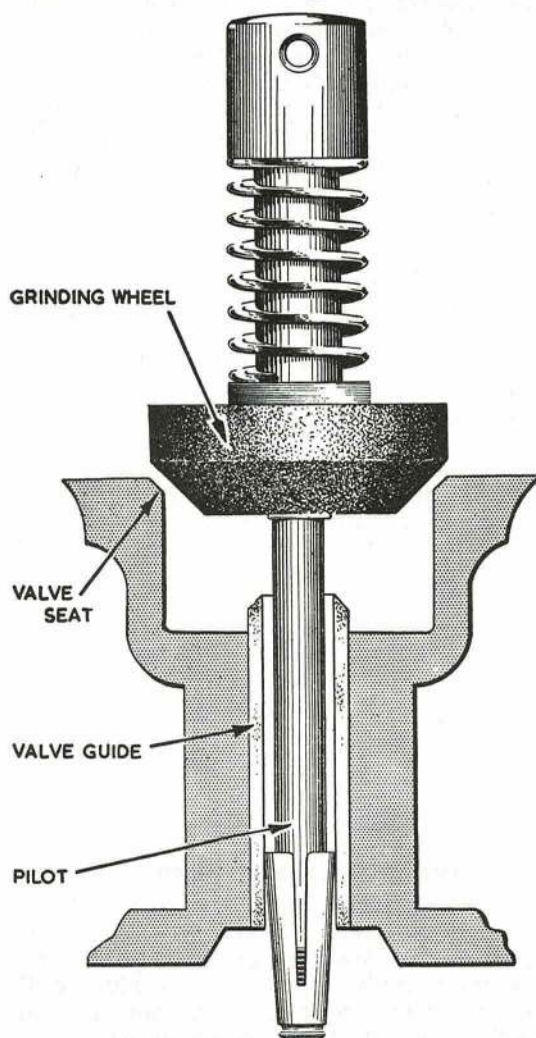


Fig. 15. STONE FITTED ON PILOT

pilot as far as the upper taper will allow it to go, and turn the pilot clockwise until it is tightly locked in the guide (Fig. 15). Wipe the pilot shank with a clean oily rag, and put a slight film of oil on the shank. The stones are designed for dry grinding, and consequently they must be kept from contact with oil or similar matter. If necessary, a stone may be cleaned by dipping it in gasoline and spinning it on the dressing stand until dry.

27. Insert the hexagon drive spindle into the stone sleeve socket, and during grinding

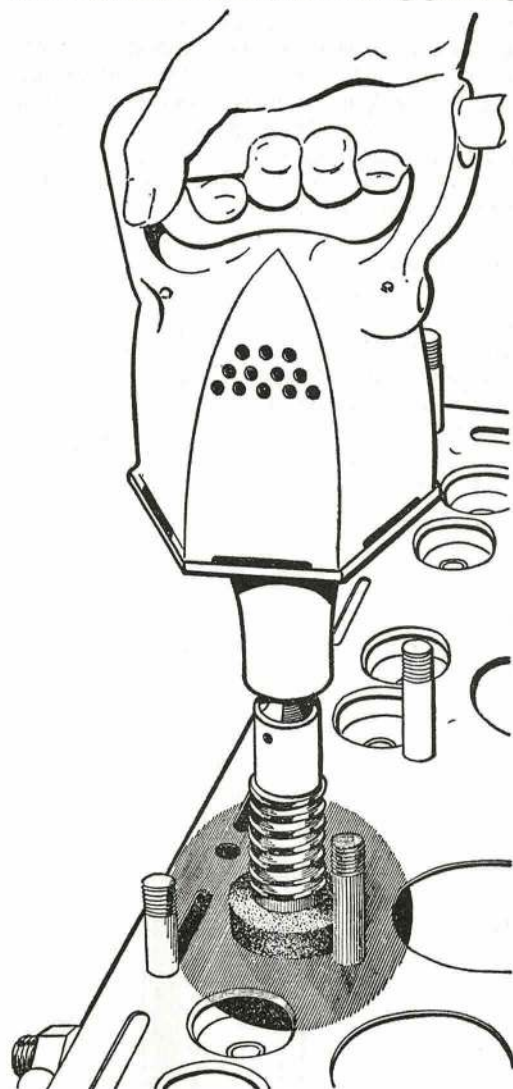


Fig. 16. GRINDING SEAT

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partly support the weight of the drive unit so that the vibrating mechanism can operate freely. **DO NOT PRESS ON THE DRIVE UNIT.** Only a few seconds are required to recondition the average cast iron block seat (Fig. 16), and slightly longer for steel inserts. Stellite seats may require grinding for several minutes, depending on their condition, and when working on stellite the stone should be dressed lightly after each seating.

28. The finish left by the regular grinding stone is usually satisfactory for practical purposes, but a finer finish can be obtained by finishing with a fine abrasive stone, but only for a few seconds. The seat should then be checked for width, any rectification necessary being done with a 20° stone. It is quite unnecessary to lap-in with abrasive compound when both valves and seats have been refaced by grinding.

Valve Springs

29. Valve springs should be examined for cracks, and tested for strength. A valve spring testing machine should be used if available, otherwise a rig as shown at Fig. 17 can be made up locally. A direct indication of a spring's strength is obtained by applying a specified weight and measuring the length

of the spring. The correct loading weight and limits of length can be obtained from the relevant Air Publication. Some manufacturers recommend checking valve springs by measuring their free length and making comparison with the length of a new spring.

Rockers and Push Rods

30. If the engine is fitted with overhead valves, the rockers should be examined for wear on their operating pads and adjusting screws. Slightly worn operating pads can be rectified by stoning or grinding to profile, and worn adjusting screws should be renewed. Rocker bearing bushes should be dimensionally checked for wear and clearance with the shaft, and the results compared with the Schedule of Fits and Clearances. Ball and cup ends of push rods should be examined for wear, and all rods checked for straightness; slightly bent rods may be straightened. Ensure that all oil ways are clear, particularly any small delivery passages to the valve and push-rod ends of the rockers.

Cylinder Head

31. Examine the cylinder head for cracks, particularly between the valve seats. Examine all studs, insert valve seatings and sparking plug bushes (if fitted) for security and damage. If otherwise serviceable, the head should be suitably mounted on a surface table and checked for bowing; this can be done either by the use of a dial gauge or a straightedge. It must be borne in mind that if a straightedge is used, and it is resting on one end and the centre of the head, the measurement made with feeler gauges at the other end will be twice the actual amount of bow over the whole length of the head. Distortion of the head is rectified either by grinding or planing. The manifold should also be checked on a surface plate, using feeler gauges to detect distortion at the ports and carburettor attachment flange.

Crankcase and Cylinder Block

32. These items should be examined for cracks, corroded or leaking core plugs (expansion or Welch plugs), and any damaged or loose studs. To remove a plug, drill a hole in the centre and lever out the plug with a suitable tool. When fitting a new plug, its edge is usually coated with jointing compound and the plug placed in position

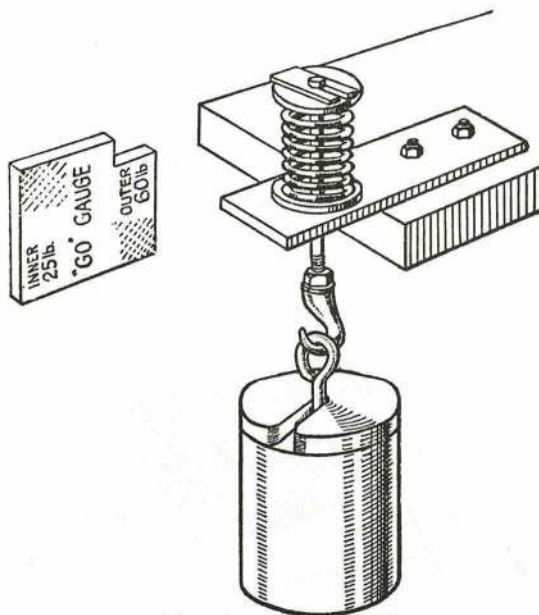


Fig. 17. SPRING TEST RIG

with the bulge on the outside. A blow with a small hammer direct, or with a blunt punch at the centre, will expand the plug sufficiently to make a watertight joint. If too heavy a blow is used the plug will be useless, and will have to be replaced by another new one.

33. The upper and lower faces should be checked for bow by means of a straightedge. Where applicable, the block should also be mounted on a surface table, the front and rear faces being checked for truth with a dial gauge.

34. The cylinder bores should be examined for pitting, scoring, overheating or damage, and if wet type cylinder liners are fitted they should be examined externally for damage by corrosion. The bores should be checked for wear, taper and ovality with a cylinder gauge, three readings being taken across the thrust face and three at right angles to this face. The clearance between a cylinder and its piston can be obtained by subtracting the diameter of the piston from that of the cylinder bore. The piston should be measured midway between the gudgeon pin and the bottom of the skirt, but at right angles to the gudgeon pin. The cylinder diameter should be the biggest reading obtained of the worn part of the cylinder bore.

35. In the past, worn bores of cylinders have been bored oversize, and oversize pistons and rings fitted in stages up to the maximum oversize allowed for pistons. Future policy in the Service is: for engines not already fitted with liners, when the necessary fit between pistons and cylinders cannot be obtained by replacement standard size pistons and rings, the cylinder block is to be bored out and fitted with standard size liners, pistons and rings.

36. The most satisfactory way of truing up cylinder bores is to regrind them on a special internal cylinder grinding machine. This method ensures true parallelism of all the cylinder bores. Alternatively, reboring cylinders can be done by using a cylinder boring bar (Fig. 18); this method is widely used in the motor industry, and very often the cylinders are bored without removing the engine from the vehicle. As most

portable boring bars are set up and clamped on the face of the cylinder block, all cylinder head studs must be removed and the face checked to see that it is flat and at right-angles to the axis of the cylinder bores. If the face is inclined, suitable adaptors are used to bring the boring bar into alignment with the bores. The bar is usually fitted with a quick centring device enabling the bar to be set centrally in the bore with the minimum of trouble. A very important detail in operating the bar is the correct setting of the cutter; this is usually done with the aid of a micrometer. Various means are used to trap the metal dust whilst reboring, and the block must be cleaned thoroughly after the operation.

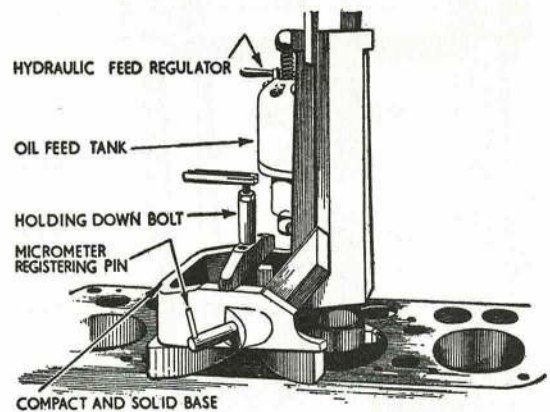


Fig. 18. CYLINDER REBORING

37. Where a cylinder liner is already fitted, either as standard in manufacture or during a previous repair, the cylinder liner will be renewed as necessary. The renewal of wet liners or sleeves presents no difficulty, and on some engines using this type, provision is made for the sleeves to be rotated 90° from the position in which they were originally fitted in order to counteract slight ovality.

38. When cylinder bores are to be fitted with dry liners, the bores must first be enlarged to the correct diameter, this diameter being such as to give an interference fit between the liner and the bore. If dry liners are already fitted they can be removed for renewal with the aid of a press, the block bores being then checked for correct size. When fitting new liners, it is usual to smear

the top of the bores with oil or other lubricant to facilitate entry of the liners, and then use a press with a dolly (Fig. 19). Some manufacturers recommend that the liner is cooled and/or the cylinder block heated, to aid the pressing-in operation. The top rim should be flush with the top face of the block, and it may be necessary to machine the rim if it protrudes. The size of the bores should then be checked and, if necessary, the bores should be honed to the limits given in the Schedule of Fits and Clearances.

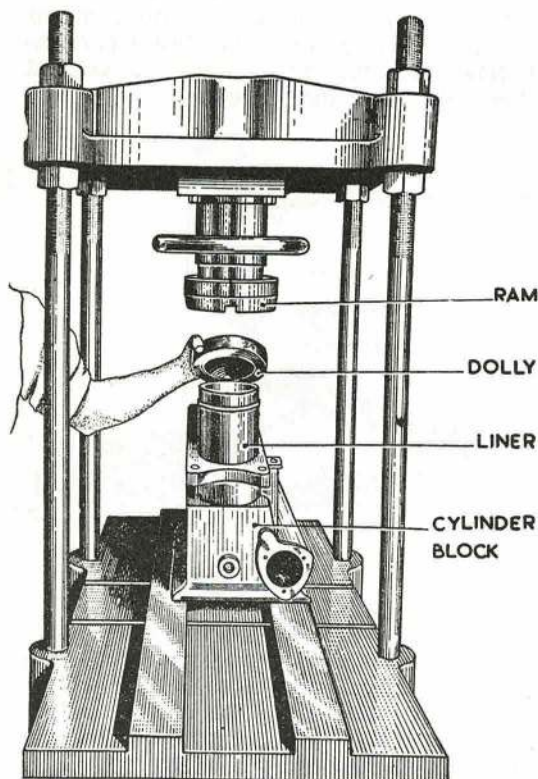


Fig. 19. PRESSING IN CYLINDER LINERS

Pistons, Rings and Gudgeon Pins

39. Examine pistons for scoring, cracks, picking-up, and signs of overheating or burning. Inspect the ring grooves for condition, and check that the circlip grooves are not burned. Slight scoring and picking-up may be removed by stoning. Check for wear and ovality by measuring the diameter of pistons with a vernier or micrometer, the measurements to be taken at the points stated in the Schedule of Fits and

Clearances. Check the gudgeon pin and its bosses for wear and ovality, using a micrometer for the pin and a plug gauge for the bosses. If the pin is fitted with soft metal end caps, examine these for condition and tightness. Piston clearance in the cylinder is obtained as stated in para. 34. Another method is to place the piston in the cylinder and use long feeler gauges attached to a small spring balance, the clearance being checked using a 4lb. pull.

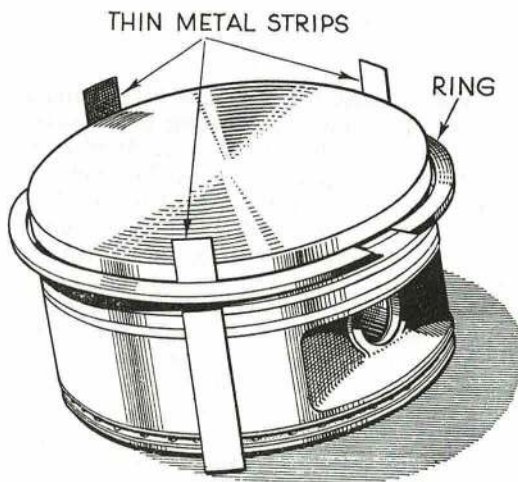


Fig. 20. FITTING AND REMOVING PISTON RINGS

40. Care must be taken when fitting and removing piston rings not to scratch the piston; Fig. 20 illustrates how thin metal strips can be used to aid these operations. It is usual to fit new rings after removal of the used rings, but if the rings are to be used again they should be marked so that they can be refitted the same way up in the groove in which they were originally fitted. Piston rings showing scoring, blackened or discoloured patches, either on the working surfaces or the sides, should be replaced by new ones. At a repair depot, piston rings are fitted by selective assembly, but used or new rings must be checked as follows:

(a) Place the ring in the smallest working part of the bore, square it up with a piston, and measure the gap with feeler gauges (Fig. 21). If the gap is too small it should be enlarged by filing one end only of the ring, care being taken to maintain a true mating joint, and this will be aided if a filing jig is used.

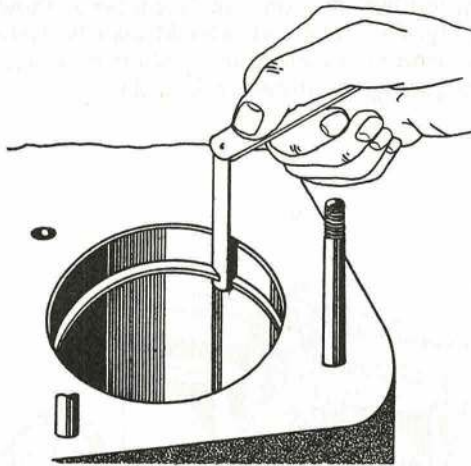


Fig. 21. CHECKING RING GAP

(b) Measure the side clearance of each ring in its groove, ensuring that the minimum clearance exists right round the groove. One method of checking with feeler gauges is illustrated (Fig. 22). If there is insufficient side clearance and other rings are not available, one side only of the ring should be rubbed down on fine emery on a surface plate; the rubbed down side should be fitted downwards on the piston. Excessive side clearance causes oil pumping, and consequent heavy oil consumption.

(c) With a ring in its groove, check that the ring does not stand proud of the lands at any point of its circumference.

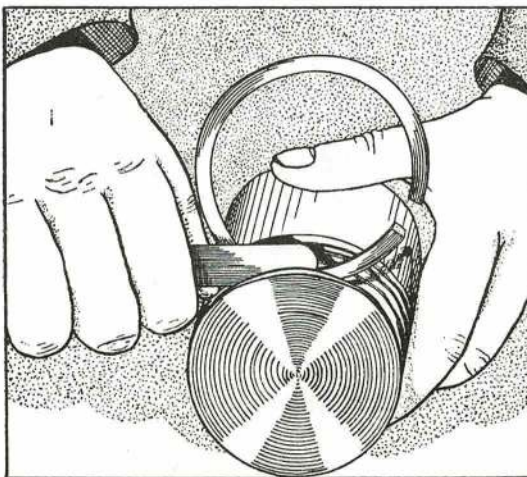


Fig. 22. CHECKING SIDE CLEARANCE

Connecting Rods

41. The small ends of the connecting rods of some engines are bushed; these should be examined for scoring and picking-up, and checked for wear and ovality either with a plug gauge or by measurement. The bushes can be removed either by driving them out with a stepped drift or by the use of a press (Fig. 23). When fitting a new bush, care must be taken to ensure the correct alignment of any lubrication holes, and the bush should finally be reamed to size.

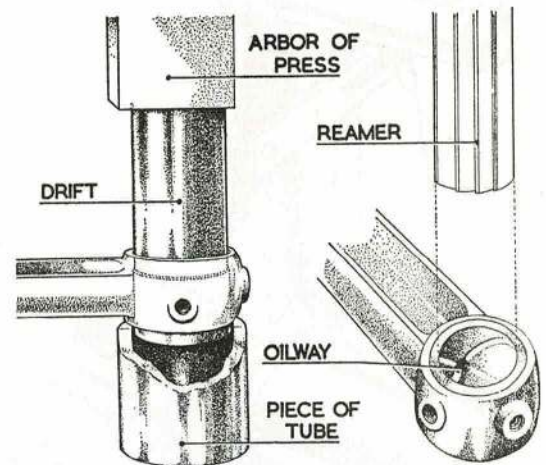


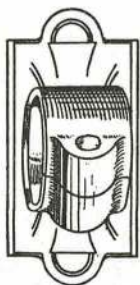
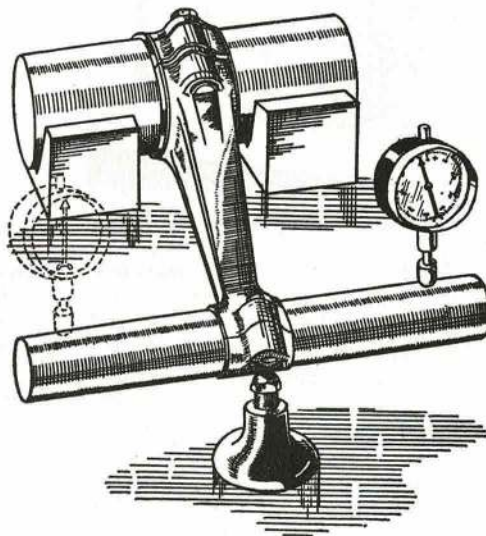
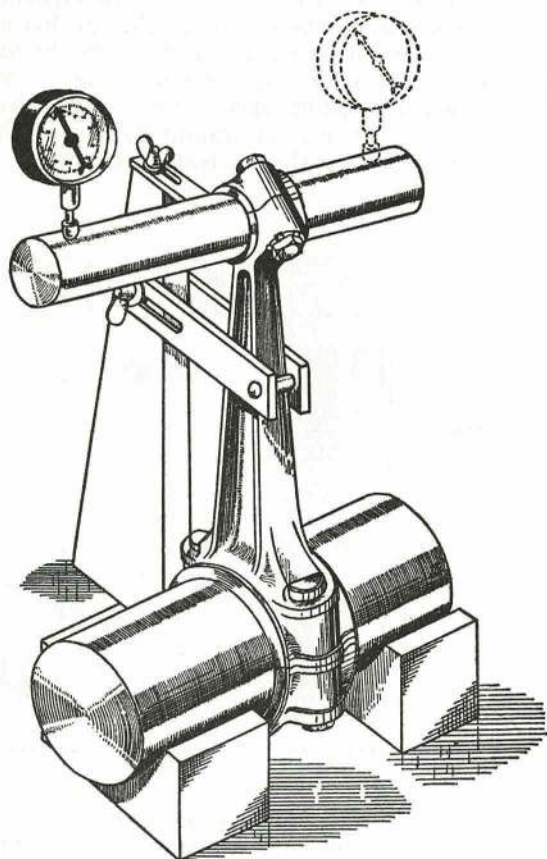
Fig. 23. RENEWAL OF SMALL END BUSHES

42. Most modern big-end bearings are of the detachable precision-made type, steel backed and white metal or lead-bronze lined, the object being to provide bearings which do not require a hand-fitting operation. Examine the bearings for fretting on the back faces, scoring and flaking of the bearing faces, and check for wear, taper and ovality. If these precision checks are within the limits, the results must be compared with the results obtained regarding the crankpin diameter, and the clearance between the components obtained. Wear must not be absorbed by filing the bearing caps. Rectification must be by fitting a new set of bearings, or by regrinding the crankshaft and the use of undersize bearings. Bolts and nuts should be inspected for condition, unless it is definitely stated that new ones should be fitted.

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43. Connecting rods should be checked for parallelism and twist between big and small ends. This should be done on an alignment jig or by using mandrels, "V" blocks, and a

dial test indicator on a surface table as shown in Fig. 24. The rods should also be tested for bend in the plane of rotation by using a straightedge as shown in Fig. 25.



LACK OF
PARALLELISM



TWISTED

Fig. 24. TESTING FOR PARALLELISM AND TWIST

44. Seriously bent or twisted connecting rods should always be rejected, but slight inaccuracies may be corrected by

using a press or, if this is not available, by means of a bending iron as shown in Fig. 26.

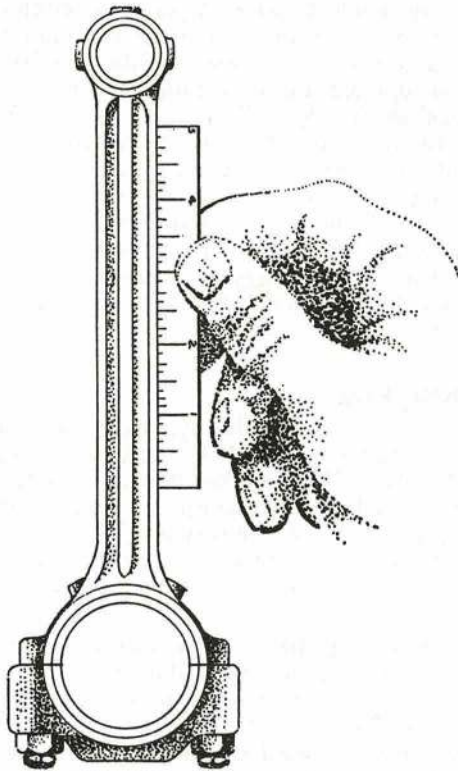


Fig. 25. TESTING FOR BEND

Crankshafts and Main Bearings

45. When sealing caps are fitted to the journal and crankpin bores, the retaining bolts should be removed to enable the bores to be cleaned. The caps should be retained in their order of removal as the seating faces mate with their respective bore seats. The following information applies to precision type bearings. The bearings should be examined for signs of fretting on the back denoting looseness in the housings, and the bearing faces for signs of wear or excessive scoring. Assuming that the bearings are in a satisfactory condition visually, temporarily assemble them to their respective housings and tighten down the nuts to normal running tightness. Check the bore of each bearing, the results obtained being required for comparison with the diameter of the journals as well as checking for size with the Schedule of Fits and Clearances.

Note.—Whenever bearing nuts are tightened, the operator should always

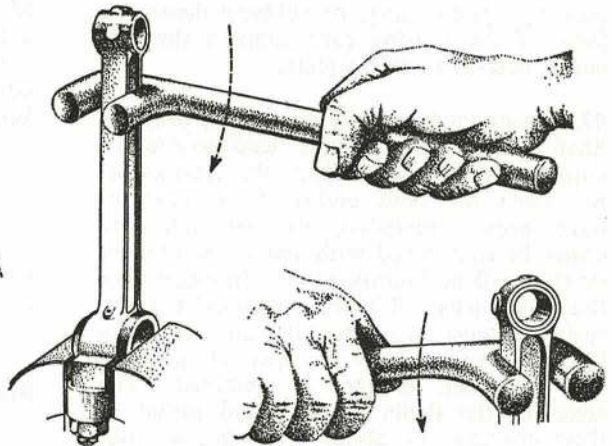


Fig. 26. USING A BENDING IRON

use a torque loading spanner and tighten to the prescribed loading, or use the particular spanner stated by the manufacturer.

46. Journals and crankpins should be inspected for scoring, measured with a micrometer for wear, taper and ovality, and the clearance found between the journals and main bearings. These results should be checked with the Schedule of Fits and Clearances, in order to determine if any rectification is necessary. Under no circumstances should the bearing caps be filed to take up wear. Rectification may require the fitting of a new set of bearings if the journals are satisfactory, or regrinding of the journals and the fitting of undersize bearings.

47. The crankshaft should be supported on "V" blocks on a surface table, and a dial test indicator used to check the shaft for bow. Care must be taken to ensure that wear is not mistaken for an indication of bow. If the bowing is not serious a press may be used to straighten the shaft.

48. Although the majority of modern engines are fitted with bearings of the precision type, other types still exist using different methods of reconditioning. Where shims are provided between the two halves of the bearing, wear can be rectified by removal of the necessary number of shims until the correct fit is obtained. Alternatively, where no shims are provided, it may be permissible to take up excessive

play by lightly filing, or rubbing down the faces of the bearing caps using a sheet of emery laid on a surface plate.

49. Some engines have brass shell bearings lined with white metal, lead-bronze or copper-lead alloys. When the crankshaft has been reground and/or these bearings have been remetalled, the bearings will either be line bored with special equipment or they will be "scraped in". In either case the brass shells will have to be first fitted into their housings, using marking and removing the high spots until as near as possible 100 per cent. contact is obtained. The edges of the shells should stand proud of their housings by about 0.001-in., so that the necessary "pinch" is obtained to ensure correct bedding down, and to prevent the shells from working loose.

50. **Scraping-in Main Bearings.** The main bearing journals are lightly coated with marking, and the crankshaft is then laid in the top halves of the bearings, which are housed in the crankcase. The shaft is rotated several times and then removed, the high spots being scraped down before replacing the shaft and trying again; this procedure should be continued until the

bearings show at least 75 per cent. contact. When there are three or more bearings the end ones should be done first, the remainder being replaced and scraped-in one at a time. When all the top half bearings are marking satisfactorily, the caps should be done in a similar manner, starting with the centre one. During the scraping-in it may be necessary to "let up" the cap to compensate for metal removed. When all main bearings are finished, oiled and tightened down, it should be possible to turn the shaft without too much effort.

Starter Ring

51. As stated previously, many engines have a starter ring fitted to the flywheel, and if the teeth of the starter ring are damaged then it will be necessary to remove the damaged ring and fit a new one; the relevant Air Publication should be consulted before starting this work.

52. **Removing Ring.** One method of removing the starter ring is shown at Fig. 27. The flywheel is placed in a suitable container of clean cold water, supported on three metal blocks placed under the starter ring. Arrange the flywheel so that it is submerged

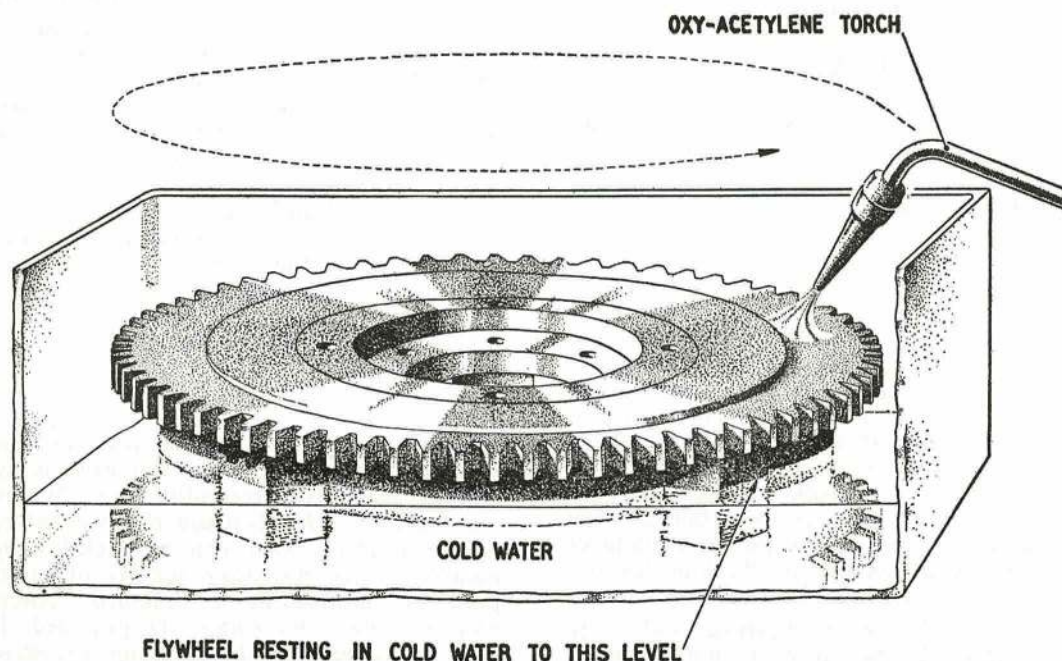


Fig. 27. REMOVING STARTER RING

in the water, but with the starter ring about $\frac{3}{16}$ -in. above the surface. Heat the ring evenly around its circumference by means of an oxy-acetylene torch, and the flywheel will drop out of the heated ring.

53. Fitting Ring. This method of fitting a starter ring ensures that any heat treatment will not be affected. The fitting of the ring can be quite easily effected whilst cold. The immersion of the ring in boiling water or raising it to that temperature by other means will, however, assist the operation, but greater heating than this should be

avoided. The flywheel should be placed on a solid base, the starter ring being offered up squarely and tried for the most favourable position for its entry on the spigot. Four equally spaced "G" clamps should be fitted around the ring as shown in Fig. 28. The starter ring should then be lightly tapped on to the spigot using a soft metal drift, taking care to keep the ring square and to follow its progress on to the spigot by tightening up the clamps. Having thoroughly started the ring on the spigot, the clamps can be removed and the ring driven fully home against its flange on the flywheel.

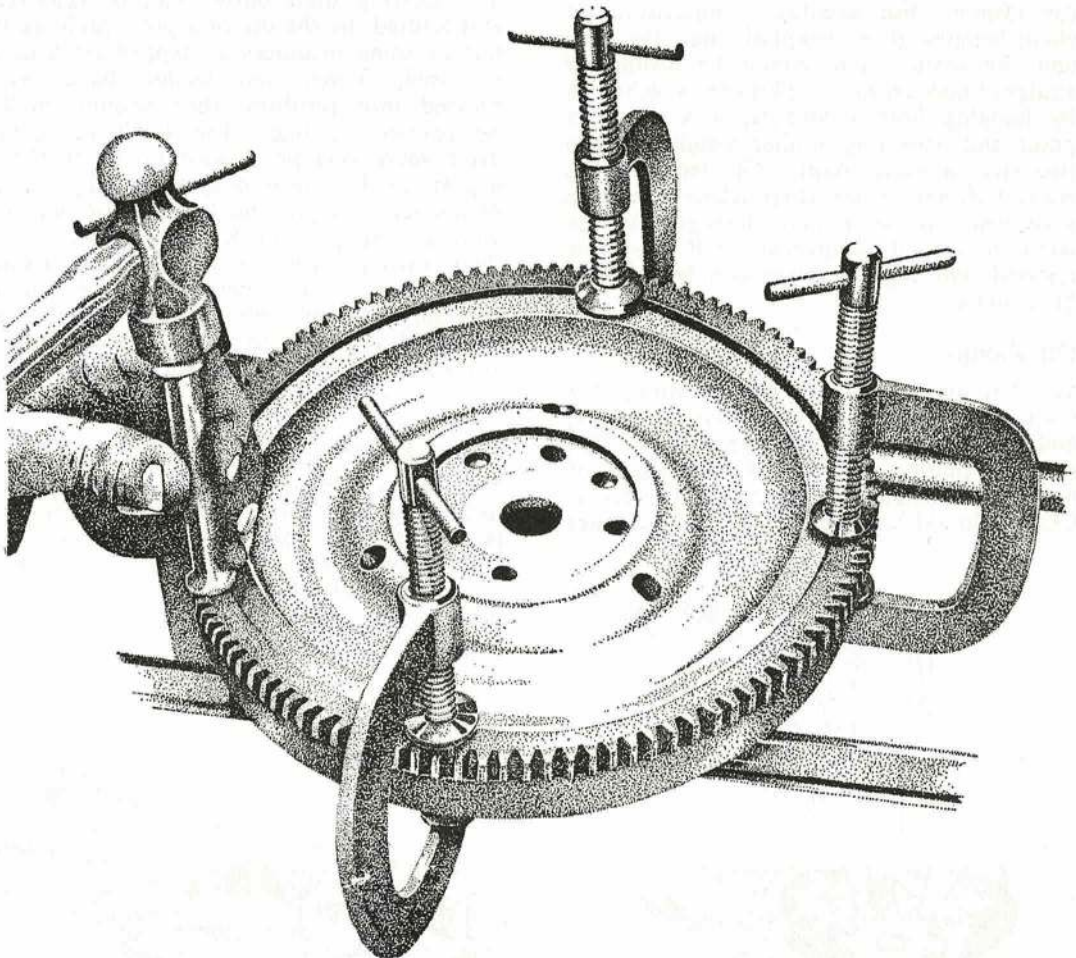


Fig. 28. FITTING STARTER RING

Camshaft and Bearings

54. Examine the camshaft for scoring and wear on the cam lobes and bearing surfaces;

slight scoring can be rectified by careful stoning. Check the journals and bearings for wear. The usual method of removing

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and replacing bearings is by gently tapping them with a suitable drift. If necessary, the bearings are reamed in line after fitting. Support the shaft on "V" blocks mounted on a surface table and use a dial indicator to check the shaft for bow. Slight bowing can be rectified by using a press. Examine the teeth of any drive gears and, if necessary, rectify by careful stoning. Fit new keys where required.

Timing Gear

55. A timing chain should be inspected for condition and checked beside a new chain for stretch. For accurate comparisons of chain lengths it is essential that the new and the worn chain should be absolutely straight under tension. This can be achieved by hanging both chains from a common point and attaching similar weights to the free end of each chain. The teeth of the crankshaft and camshaft sprockets should be examined for wear and damage. If the teeth are hooked the sprockets will have to be rejected, but slight damage can be rectified by stoning.

Oil Pumps

56. Oil pumps should be examined for wear which will affect delivery capacity, and such wear will vary according to the type of pump. Gears and the inside of pump bores should be examined for scores. Checks should be made of the fit of the gears

in the pump body, backlash between the gears and end float. Fit and backlash can be checked with feeler gauges (Fig. 29), and end float with a straightedge and feeler gauges. If oil pump gears are to be renewed they must be replaced in pairs. End float is frequently rectified by rubbing down the end face of the pump body. Plungers of plunger type pumps should be a good working fit in the body of the pump. In vane type pumps, the vanes should be a good fit both in the pump body and the driving slots.

57. Driving shaft bushes can be removed and refitted, by the use of a press preferably, but in some instances a stepped drift may be used. When new bushes have been pressed into position, they should finally be reamed in line. The teeth of spiral drive gears may be cleaned up by stoning; a gear can be removed by filing off the end of the securing pin and tapping the pin out with a small pin punch. Relief valves and their seatings should be inspected for pitting and scoring, parts being renewed where necessary. Relief valve springs should be inspected and checked, and if the valves are adjustable they should be set to "blow off" at the correct pressure.

Water Pumps

58. When dismantling water pumps it will frequently be found that an extractor is required for removal of the impeller (Fig. 30). Do not try driving the spindle, and do not replace the impeller by any means other than a press, or damage is likely to result. Inspection of water pumps will vary accord-

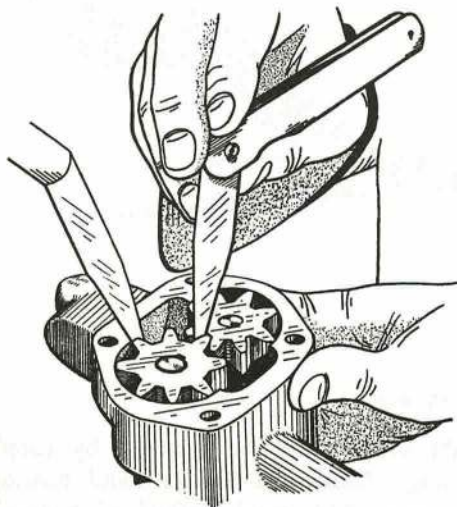


Fig. 29. CHECKING THE OIL PUMP

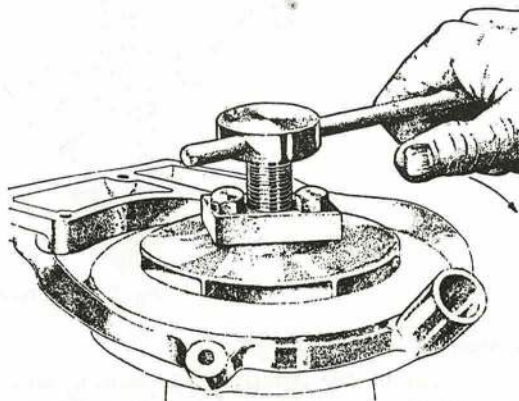


Fig. 30. IMPELLER EXTRACTOR

ing to design details, although main components are usually similar in all pumps.

59. Examine the driving shaft for wear, corrosion, and damage such as scoring or a bent shaft. The shaft should be rejected if defects cause the impeller vanes to foul the pump casing, or water to leak past the gland seal. Examine the pump casing for damage, corrosion and cracks; if a casing is cracked, or its thickness greatly reduced by corrosion, it should be rejected. Ball bearings should be examined and checked as described in Section 2, Chapter 4. Bushes should be examined for scoring and checked for wear, and seals examined for scoring, damage and wear; deep scores and excessive wear will entail rejection of the seal.

60. Examine the impeller for corrosion and damage. Slight corrosion may be removed with a smooth file, but the impeller must be rejected if corrosion is severe. The end float of the impeller should be checked and rectified as applicable. The carbon gland ring should be examined for cracks, scores and wear. This ring should have a smooth flat face, a small amount of wear being permissible, but if the ring is scored it should be renewed. Some pumps have the carbon ring secured in the pump casing and, if necessary, the ring should only be removed by heating the body of the pump until the old ring comes out easily. After the recess has been cleaned, the pump body should be heated and the new gland pushed into position.

Thermostats

61. If a thermostat valve is found to be open when the component is removed from the engine, it can be assumed that the thermostat is defective and must be rejected. A thermostat can be tested by suspending it in a vessel containing water and a thermometer. Heat the water slowly and note the temperature at which the valve begins to open. The results should be checked with the relevant Air Publication and, if outside the limits, the thermostat should be rejected.

62. The bellows should be examined for solid deposits, removal of which may be effected by rubbing with a coarse cloth. On no account may the bellows be scraped with a tool, as they are fragile and easily punctured.

Carburettors

63. The components should be stripped and cleaned using trichlorethylene and suitable brushes. Examination should be made for cracks and damage. Joint faces should be checked for flatness, and any necessary rectification should be done by rubbing down on emery cloth on a surface plate. Fuel passages, jets and needle valve seats should be blown through with compressed air. Do not attempt to grind-in a needle valve to its seating; if the damage to a seating is slight a new seating can be formed by gently tapping the needle on to its seating, at the same time rotating the needle. In bad cases the needle valve and seating must be rejected. Check any pistons, springs, pump leathers and ball valves for condition.

64. Examine floats for condition and test for punctures by immersing the float in boiling water; punctures will be disclosed by the emergence of bubbles. A punctured float should be rejected, because a repair by soldering will unbalance and overweight the float. Valve plates should be examined for excessive scoring on their seating faces, and also for condition of location slots. Check the piston of a S.U. carburettor for sticking in the suction chamber. Any high spots on the inside of the chamber can be removed by careful use of a half-round scraper. When checking Carter carburettors (Rolls Royce), the operator will need certain gauges which can be made up locally as per the instructions in the relevant Air Publication. Filters should be examined for damage to the gauze, and cleaned with compressed air. All new gaskets should be used on reassembly of the carburettor.

Fuel Pumps

65. The parts of mechanical fuel pumps should be cleaned in kerosine or trichlorethylene. Examine the domed cover for any defects that may prevent an airtight joint being made. Deformation of the cover will normally entail rejection, but if the end portion is slightly concave as the result of overtightening the setscrew, the cover should be inverted on a flat steel plate and be tapped carefully back to its original shape with a light hammer. The two halves of the pump body should be examined for cracks, and their diaphragm flanges tested

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on a surface plate. A crack or a badly warped flange will necessitate rejection of the faulty part. Any slight unevenness on the surface of the flange should be removed by careful use of a smooth file or by rubbing down. The pump mounting flange should also be checked and trued up, if necessary, in a similar manner to the diaphragm flanges.

66. Valve discs should be rejected if they are warped or defaced, and likewise the valve springs if they are weak or deformed. Diaphragms should be rejected after the completion of 500 hours running time, and also if the fabric shows any signs of cracking or tearing. Gaskets should be rejected and new ones fitted during assembly. The rocker arm and pivot pin should be examined for wear, and rejected if the rocker arm holes are worn oval or if the pivot pin is ridged. The push rod (if fitted) should be examined for wear and checked to see that it is not bent.

67. **Assembly.** Besides the normal assembly precautions, the following procedure should be strictly adhered to. When the upper half of the pump body is placed in the correct position relative to the lower half, the flange screws should be entered loosely in the threaded holes. The rocker arm should then be forced upward in order to pull the diaphragm into its correct working position, against the pressure of the diaphragm spring. Holding the rocker arm in this position, the screws should be tightened gradually and evenly around the flange until all are fully tight.

68. **Testing.** After a pump has been reconditioned it should be tested on a rig similar to that shown at Fig. 31. Where the bench rig is not available, a pump can be tested on an engine as described in para. 70 of the following test procedure.

69. **Bench Test.** The layout of the equipment required is shown at Fig. 31. The bottom tank should be filled with kerosine and the pump operated by hand. After sufficient kerosine has been pumped into the top tank to submerge the end of the delivery pipe, the pump should deliver kerosine free from air bubbles at each stroke. The presence of air bubbles indicates an air leak in the pipe line or at the pump cover gaskets which must be rectified.

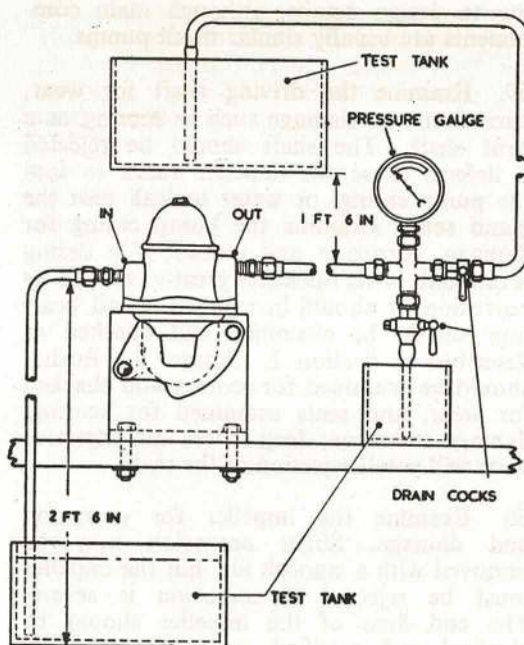


Fig. 31. FUEL PUMP TEST RIG

The delivery valve should be closed and the pump again operated, when the pressure gauge should show a reading in accordance with the pressure given in para. 71. A low reading would indicate faulty valves, and a high reading may be the result of an incorrectly fitted diaphragm or the fitting of a diaphragm return spring which is too strong.

70. **Engine Test.** The pump should be fitted to the engine and a test rig (similar to Fig. 31) fitted in place of the normal pipeline. The carburettor should be fitted with a temporary gravity-fed fuel supply. The engine should be started and allowed to run at idling speed, the pressure on the gauge being checked as in para. 69. The drain cock should then be turned on and the fuel should flow from the pipe-end free from air bubbles. Faults can be diagnosed as stated in para. 69. If a previous bench test had proved satisfactory, air leaks or obstructions on the inlet side of the pump may be the cause of lack of pressure. The fuel pressure can be varied by the use of gaskets of different thicknesses, fitted between the pump mounting flange and the engine; a thicker gasket reduces pressure and a thinner one increases pressure. A guide as to the efficiency of the pump can be got

by fitting a temporary gravity-fed fuel supply, and arranging that the fuel delivery pipe feeds into a one pint vessel, fitted on the same level as the base of the float chamber. The time taken to pump one pint can then be compared with the time given in para. 71.

71. Fuel delivery pressures and times for A.C. fuel pump tests:—

Horse Power R.A.C. rating	Max. pressure lb./sq. in.	Delivery time 1 pint, secs.
7-9	1 $\frac{3}{4}$	90
9-12	2 $\frac{1}{4}$	90
12-16	2 $\frac{3}{4}$	60
16-25	3 $\frac{1}{4}$	60
25-30	3 $\frac{3}{4}$	45

Note.—The test pressure values given may require to be varied slightly in instances where the needle valve of the carburettor is either exceptionally light or heavy. For high speed engines the fuel pressures required will generally be less for the same horse power than that indicated.

C.I. ENGINES

Introduction

72. The repair and reconditioning of compression ignition engines is generally very similar to the procedure applied to gasoline engines. The main difference between the two types is the injection equipment. All working parts of this equipment are finished to high precision limits. Working tolerances are not normally specified for mating parts, the serviceability of components being assessed by visual examination or by the results of calibration tests. Consequently, the necessity for **SCRUPULOUS CLEANLINESS** during the repair and testing of injection equipment cannot be over-emphasized.

C.A.V. Fuel Feed Pumps

73. After dismantling, wash all parts thoroughly in kerosine or fuel oil, but do not use rag or such like material either for cleaning or drying the parts. Inspect all parts for scoring and corrosion. Defective valves or springs may be replaced by new ones, providing the seats are in good condition. A faulty plunger or spindle will necessitate rejection of the pump, as these

components are mated to the body by selective assembly. If all parts are satisfactory, the pump should be reassembled, ensuring that the outlet valve plug, fuel priming device and plunger chamber cap are all securely tightened.

74. **Priming Device.** To dismantle this component it is only necessary to unscrew the cap-nut and withdraw the plunger. Parts should be cleaned and inspected in the same manner as those of the feed pump. The plunger is mated with the body by selective assembly, so that if either component is defective the priming device must be rejected.

Testing C.A.V. Fuel Feed Pumps

75. Provision is made on the Hartridge injection pump test bench to enable the feed pump to be tested during the general test of the injection pump. For the tests, the pump is connected up as shown in Fig. 32. The suction pipe from the supply tank is connected to the pump inlet connection, and the delivery pipe from the pump outlet to the calibrating unit. Some pumps have two pipes leading to the inlet connection, and in this case, the nut and nipple connection should be blanked off.

76. **Priming Test.** The priming device should lift fuel a distance of 3 ft. within 20 strokes of the plunger. The outlet connection should be slackened off and the priming device operated. After approximately 20 strokes, fuel should appear at the outlet connection.

77. **Delivery Capacity Test.** With the injection pump running at 600 r.p.m., a feed pump should deliver 960 c.c. of fuel per minute. To carry out the test proceed as follows:—

(a) Ensure that there is sufficient fuel in the supply tank.

(b) Open the drain cock of the calibrating unit, and also the air vent screw at the top of the unit.

(c) Start the test bench and adjust the speed to 600 r.p.m.

(d) Close the drain cock of the calibrating unit and at the same time set a stop watch in motion.

(e) After a period of 15 seconds switch off

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the test bench motor and check the amount of fuel delivered.

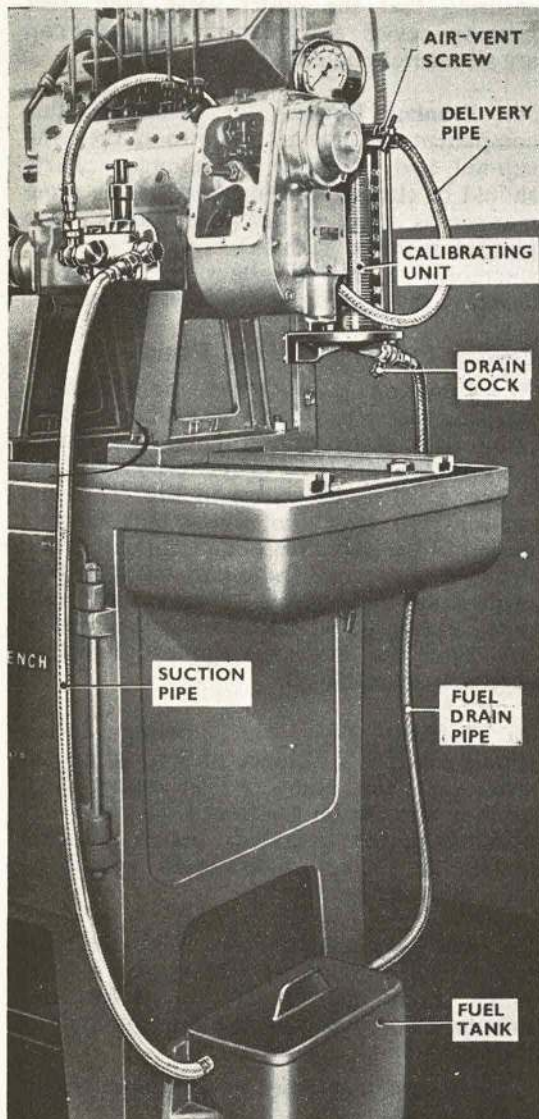


Fig. 32. FUEL FEED PUMP ON TEST

78. **Leakage Test.** This test is to prove the ability of the pump to deliver fuel against pressure and is applied as follows:—

- (a) Close the air vent screw at the top of the calibrating unit.
- (b) Start up the test bench and when the calibrating unit gauge registers 2 atmospheres (29.4 lb. per sq. in.), switch off the test bench motor and observe the gauge.

(c) The rate of drop in pressure as shown by the gauge, should not be more than 1 lb. per sq. in. in 5 seconds.

C.A.V. Fuel Injection Pumps

79. Thoroughly clean all parts, using kerosine and a soft brush; the parts should then be placed in trays to drain. It is again emphasized that all mated parts (pump plungers and barrels, delivery valves and seats) must be kept together, as it is during the cleaning operations that an interchange of parts is most likely to occur. No attempt must be made to degrease or clean in any way the diaphragm assemblies of pneumatic governors. The parts should be inspected according to the information in the following paragraphs.

80. **Camshaft.** This component should be examined for wear and corrosion, particularly on the cam lobes. Worn lobes will cause erratic readings when the pump is calibrated and it will be found impossible to adjust the pump to give constant readings within the permissible limits. A camshaft with obviously worn lobes must be rejected. Surface corrosion is liable to affect the working faces of all cam lobes, especially that of the lift-pump cam. Slight corrosion may be removed by light stoning, but the camshaft must be rejected when the corrosion is more than slight. The cone seating for the governor sleeve and the coupling end must be examined for picking-up, which, if only slight, may be removed by stoning.

81. **Tappets.** These should be examined for corrosion, especially on the working faces of the rollers. Each roller should be perfectly free on its pin, but without any appreciable wear, and without any signs of flats on the circumference. An eye-glass should be used to examine the rollers for cracks. The adjusting screw and nut should be examined for serviceability.

82. **Pump Elements.** Each pump element should be inspected for scoring on any part of the working surfaces. The part of the plunger which operates in the vicinity of the two ports in the barrel should be carefully examined for signs of wear. Normal wear will be seen as minute scoring in these areas, especially on the helix side of the plunger. Fig. 33 shows a magnified view of a worn plunger and it can be seen that the affected

area extends from the top edge of the plunger to the helix edge, and to a width which is approximately the circular movement of the plunger between idling and maximum speeds. When it is not possible to assess accurately the serviceability of an element by visual examination, the final assessment must be made from the readings taken on the calibration test. Plunger springs should be inspected and judged by comparison with a new spring.

83. Delivery Valves. These components should be inspected for obvious defects, but no attempt should be made to recondition a valve or valve seat. Use an eye-glass to examine the anti-dribble device for abrasions, and the contact face of the valve seat for radial abrasions which would indicate an interference leakage. The valve's efficiency can only be finally assessed from the test bench results. A valve spring should be tested by comparison with a new one.

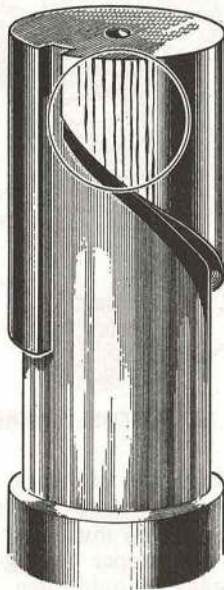


Fig. 33. A WORN PLUNGER

84. Bearings. These should be examined for wear and damage and tested for smooth running. Defective bearing inner and outer races can be removed (Fig. 34) and new ones fitted with the aid of special tools. Oil seals should be examined and rejected if unserviceable or if they are at all doubtful.

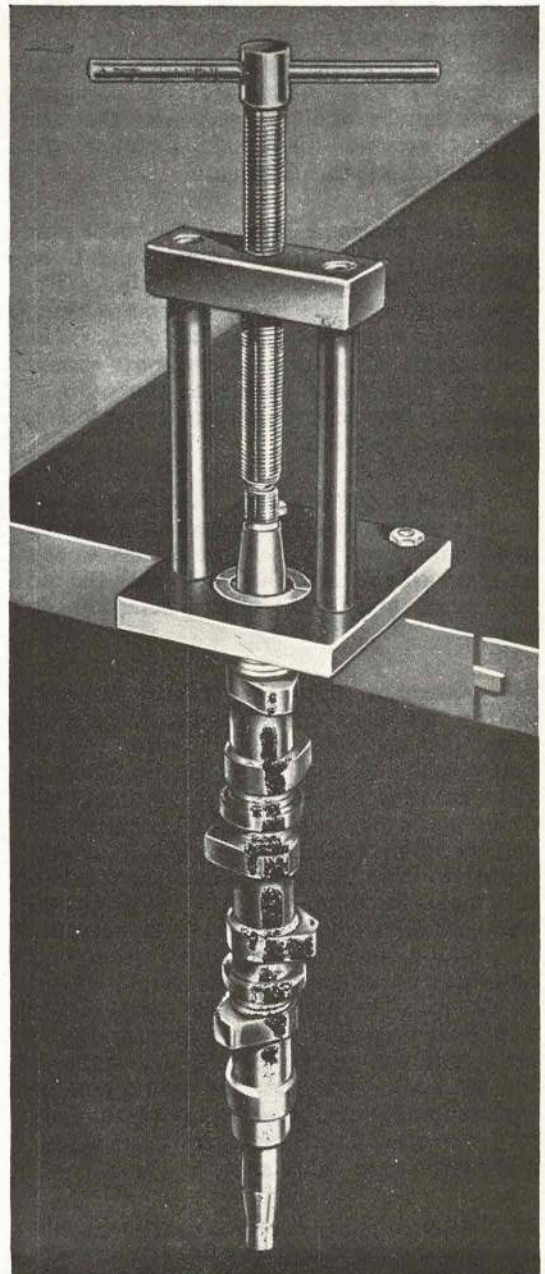


Fig. 34. REMOVING BEARING INNER RACE

85. Control Rod and Quadrants. The teeth on the control rod and regulating quadrants should be carefully inspected for damage. The control rod should be tested for straightness and the bearing portions at each end

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examined for wear and damage. The quadrants should be examined for distortion, which is often caused by overtightening of the clamping screws. Check that the clamping screws can be easily turned, and that the threads are not damaged. Examine the quadrant slots for damage.

86. Governor and Linkage. The pivot pins used with these components should be inspected for general serviceability. The pins should fit quite freely in their working positions, but must not be slack. The diaphragms of pneumatic governors should be very pliable and free from any signs of cracking; any defects in these respects will necessitate rejection.

87. Control Rod Bearings. The control rod bearing bushes should be inspected for scoring and undue wear. Unserviceable bushes can be removed and new ones fitted with the aid of special tools, the bushes being finally reamed.

88. Assembly. The assembly sequence is, in general, a reversal of the dismantling operations, plus the observance of several important points. Components must be rinsed in clean kerosine, allowed to drip, smeared with clean lubricating oil, and finally assembled entirely without the use of any kind of drying material. The camshaft should be fitted to the pump housing with the bearings, oil seals, adjusting shims and end plates correctly in position, and the end float tested and adjusted if necessary by the shims to 0.005 in. -0.007 in. The omission of gaskets, if they were fitted originally, between the bearing end plates and the pump housing will decrease the end float. The camshaft should then be removed and placed in a clean position ready for reassembly after the elements and tappet assemblies have been fitted.

89. After fitting the control rod, check that it is a good but perfectly free fit in its bearings and that it is positioned with the stop arrow pointing towards the governor housing. Ensure that each element barrel locking screw is fitted with a sealing washer, fit each barrel so that the end of the locking screw will enter the slot, and securely tighten the locking screw. The barrel should then be free to be moved up and down. Fit a new sealing washer between the delivery valve seating and the valve holder. When fitting the regulating

sleeves and quadrants, the control rod must first be clamped in its central position. The quadrants must be clamped in position on the sleeves with the timing marks coincident (Fig. 35), and the upper spring-plates fitted to the sleeves. The quadrant should be engaged with the control rod, with the clamping jaws centrally towards the operator. The control rod and quadrants should be tested for freedom of movement by turning the pump end-for-end several times and noting that the control rod falls freely under its own weight at each turn.

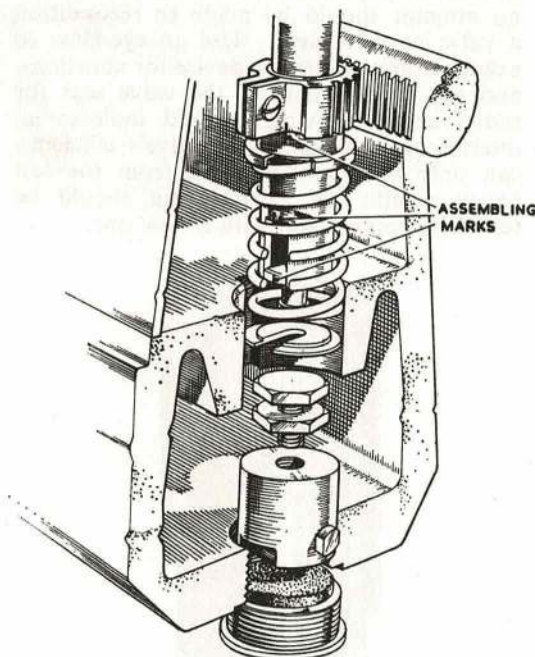


Fig. 35. ASSEMBLING MARKS

90. When fitting the plungers, springs and tappets, the pump should be positioned on its side. Each spring must first be fitted to bear against the upper spring-plate. The lower spring-plate should then be fitted to the end of the plunger and the plunger end gripped in the special tool (Fig. 36). With the marked lug of the plunger uppermost, the plunger should be carefully inserted in the barrel, the plunger lug engaged in the slot of the regulating sleeve, and the tool removed. The tappet assembly should be held in the special tool, fitted in position, and then pushed in against the spring pressure until a tappet holder can be inserted under the tappet head.

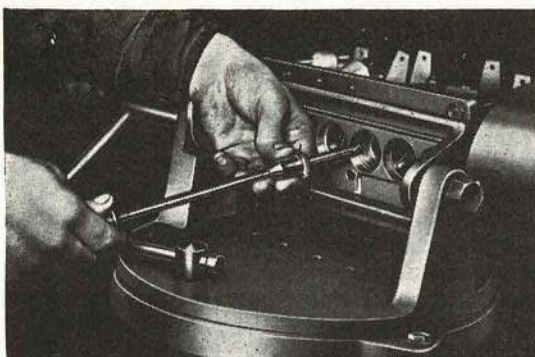


Fig. 36. FITTING A PLUNGER

91. When a pneumatic governor is being assembled, the diaphragm assembly must be fitted so that the small semi-circular tab on the diaphragm frame fits into the recess in the housing. In this position, and with the diaphragm assembly connected to the control rod, there must be no twist in the diaphragm itself. If there is twist, the diaphragm must be replaced by a new one.

Principles of Phasing

92. **General.** Phasing a fuel injection pump is the means adopted to ensure that fuel injection to the various cylinders occurs at

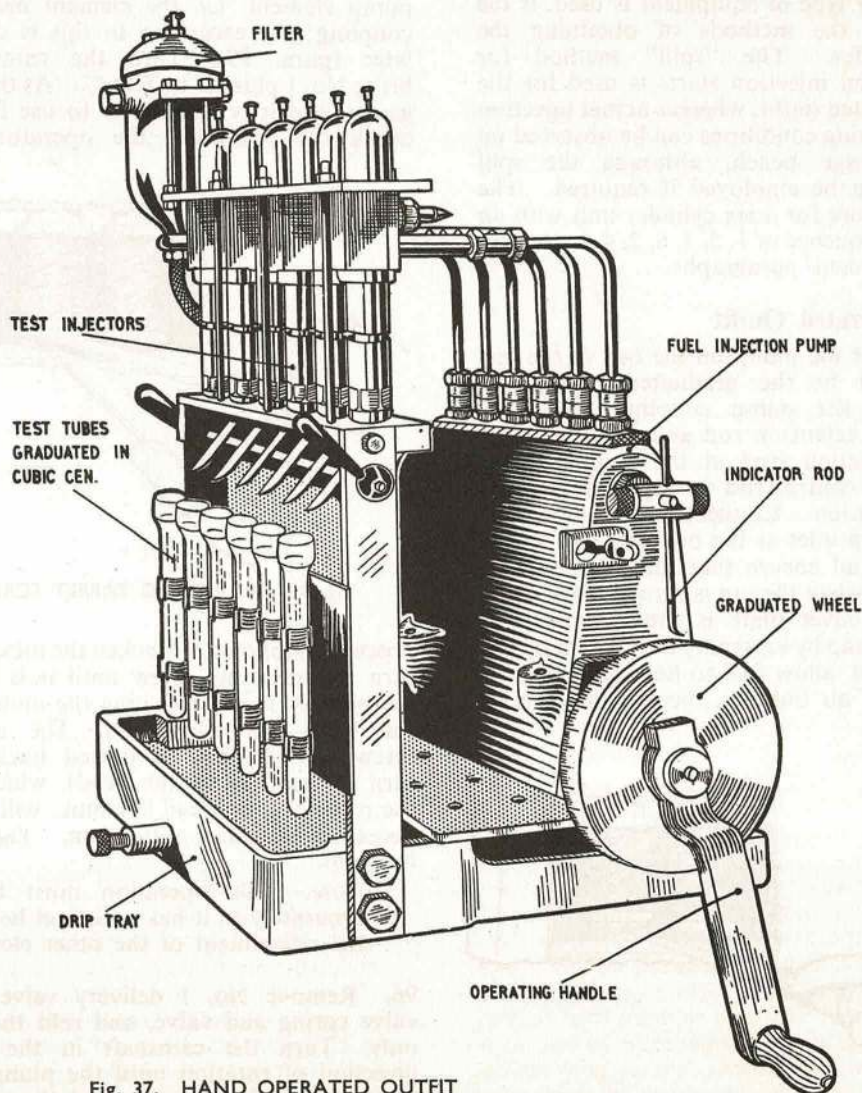


Fig. 37. HAND OPERATED OUTFIT

equi-angular intervals. Adjustment is by altering the length of the tappet, thus raising or lowering the plunger in its barrel and so advancing or retarding the commencement of injection as required. Some pumps can be phased in the workshop whilst others have to be done on the engine, unless a slave camshaft is available. A hand operated test outfit or a Hartridge test bench is used for the phasing operations. The Hartridge bench is the more elaborate, but better method, because it enables the performance of the injection pump to be noted at any speed within its working range. The principle, when either type of equipment is used, is the same, but the methods of obtaining the results differ. The "spill" method for finding when injection starts is used for the hand operated outfit, whereas actual injection under working conditions can be observed on the Hartridge bench, although the spill method can be employed if required. The test procedure for a six cylinder unit with an injection sequence of 1, 5, 3, 6, 2, 4, is given in the subsequent paragraphs.

Hand Operated Outfit

93. Mount the pump on the bed of the test outfit, and fit the graduated wheel and handle to the pump coupling (Fig. 37). Secure the extension rod and pointer to the inlet connection stud at the coupling end. Clamp the control rod in approximately its central position. Connect the fuel feed pipe to the pump inlet at the opposite end to the coupling, and ensure that the filter bowl is full of fuel when the tap is turned off. If the inspection cover plate is fitted, remove it. Vent the pump by loosening the air vent screw, turn on fuel, allow fuel to flow until there is no trace of air bubbles, then tighten the air vent screw.

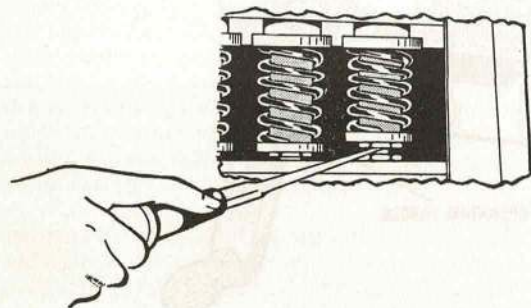


Fig. 38. TESTING PLUNGER END CLEARANCE

94. Check that none of the element plungers touches the underside of its delivery valve seat when the camshaft is turned, as this would cause considerable damage. Turn the camshaft carefully, and as each plunger in turn comes to T.D.C., insert a screwdriver under the head of the tappet screw (Fig. 38). Gently lever up the plunger assembly which should lift approximately 0.5 mm. (0.020 in.), any adjustment required need not be too accurate as a further adjustment will probably be needed whilst phasing.

95. Phasing is normally started at No. 1 pump element, *i.e.* the element nearest the coupling; the exception to this is described later (para. 99). Turn the camshaft to bring No. 1 plunger to T.D.C. As there is no gauge, and it is impossible to use feelers to check the clearance, the operator should

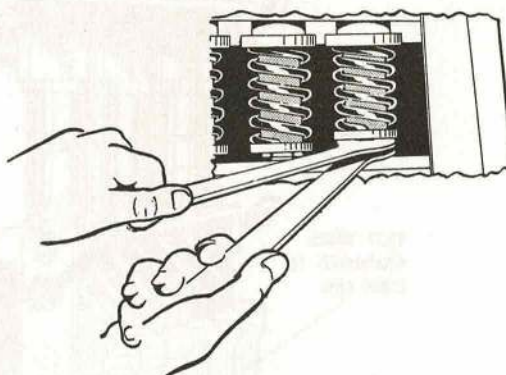


Fig. 39. ADJUSTING TAPPET SCREW

proceed as follows. Slacken the lock-nut and turn the adjusting screw until it is felt that the plunger is just touching the underside of the valve seat (Fig. 39). The adjusting screw should then be turned back a half turn (three flats of the head), which, since the pitch of the thread is 1 mm., will give the necessary clearance of 0.5 mm. Tighten the lock-nut.

Note.—This operation must be done accurately as it has a distinct bearing on the adjustment of the other elements.

96. Remove No. 1 delivery valve holder, valve spring and valve, and refit the holder only. Turn the camshaft in the normal direction of rotation until the plunger is at the bottom of its stroke, and then turn on the fuel. Fuel will flow through the pump

suction chamber, through the open ports in the barrel, and spill from the delivery valve holder. The other delivery valves are in position so there will not be any flow from these. Turn the camshaft slowly in the normal direction of rotation until the fuel flow is reduced to a trickle. Continue to turn the camshaft by gently tapping it, and at each tap the fuel should be flicked from the delivery valve holder (Fig. 40). Continue until there is no change in the surface of the

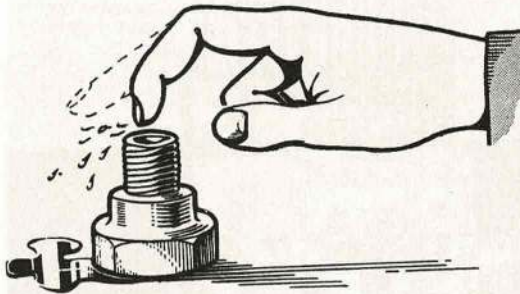


Fig. 40. DETERMINING SPILL CUT-OFF

fuel in the holder, which means that the barrel ports are closed and the theoretical point of "commencement of injection" has been reached. This point when the fuel flow finishes will be shown more definitely if a swan neck pipe is fitted to the delivery valve holder (Fig. 41). Take particular care that the plunger is rising at this point.

97. Slacken the handle securing nut and carefully set the wheel so that the pointer indicates 0° . Check that the camshaft was not moved during the wheel adjustment by repeating para. 96. When satisfactory turn off the fuel, remove No. 1 delivery valve holder, wash this, the valve and its spring in clean fuel or kerosine and refit these parts.

98. Each of the pump elements is now adjusted in turn to commence injection exactly 60° after the preceding element in the injection sequence. Remove No. 5 delivery valve holder, valve spring and valve, and refit the holder only. Turn on the fuel, and when it is flowing freely from the holder, turn the camshaft in the normal direction of rotation through nearly 60° , and check the point when fuel flow ceases, as in para. 96. The reading on the graduated wheel must be exactly 60° . If there is an error of more



Fig. 41. SWAN NECK PIPE

than $\frac{1}{2}^\circ$, the tappet must be lowered when the reading is less than 60° , and raised if the reading is more. Careful adjustment is necessary, $\frac{1}{8}$ of a turn (one flat on head) of the adjusting screw will give 1° difference in the pointer reading. After locking the tappet, the point when fuel flow ceases should again be checked.

99. When the phasing of No. 5 element is satisfactory, a check should be made as in para. 94 that the 0.5 mm. clearance exists. Should there be less than the minimum permissible clearance, the tappet must be adjusted to the minimum permissible clearance, i.e. 0.3 mm. (0.012 in.), and the complete phasing of the pump recommenced. The sequence would now be 5, 3, 6, 2, 4, 1, and if at a later stage any of the elements are found with less than the minimum permissible clearance, the element in question would be the starting point for complete re-phasing.

100. Assuming the phasing of No. 5 element to have been satisfactory, the remaining elements should be tested in the same

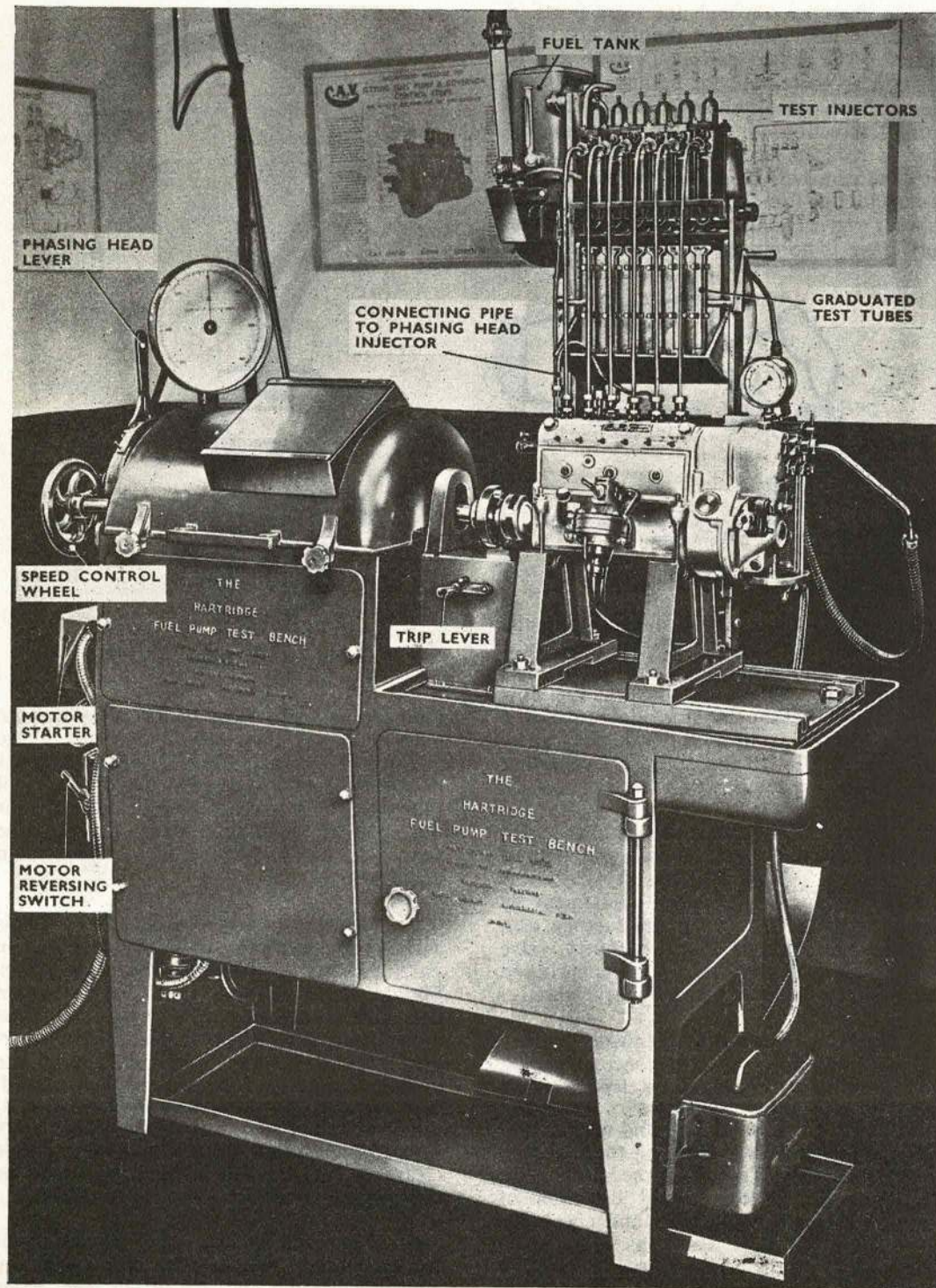


Fig. 42. PUMP MOUNTED ON HARTRIDGE TEST BENCH

manner in injection sequence. A final test should be made of No. 1 element, or, exceptionally, the element used as the starting point, checking that the pointer reads 0° . Any discrepancy here will indicate that the pointer or wheel has moved, and the phasing will have to be checked again throughout.

Hartridge Test Bench

101. Injection pumps can be phased on a Hartridge bench by watching the actual injection from each pump element under working conditions, or by the spill method. In the following description the first method will be termed injection phasing and the second spill phasing. Before either method of phasing is commenced, check that there is clearance on all plungers (para. 94). For either method the pump is mounted on the bench (Fig. 42), and this procedure is described in the following paragraph.

102. **Mounting the Pump.** Assuming the pump to be a six-cylinder unit with an injection sequence of 1, 5, 3, 6, 2, 4, and anti-clockwise rotation, proceed as follows:—

(a) Fit the appropriate pair of brackets to the bed of the test bench as shown in Fig. 42, this allows the left-hand bracket to be as close as possible to the trip mechanism case.

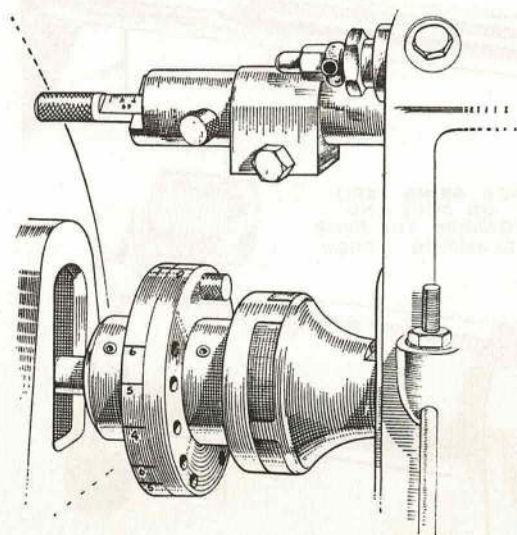


Fig. 43. COUPLING CORRECTLY ENGAGED

(b) Fit clamping bolts to the pump and engage the bolt heads in the bracket channels.

(c) Turn the pump coupling in direction of rotation until No. 1 plunger is at commencement of injection, shown by the markings.

(d) Turn the test bed shaft until the knurled-head locking pin is approximately at T.D.C.

(e) Slacken the Allen locking screws in each half of the test bench coupling and disengage the locking pin from the left-hand half coupling.

(f) Turn the test bench shaft until the lines marked "1" and "0" are in line (Fig. 43). Re-engage the locking pin in the left-hand half coupling.

(g) Slide the pump towards the test bench coupling until the delivery valve holders are approximately in line with the delivery pipes to the test injectors. Slight movement of the bench coupling on its shaft may be necessary to ensure correct engagement of the dogs (Fig. 43), but ensure that the pump elements are kept approximately in line with the delivery pipes.

(h) Ensure that the locking screw in each half coupling is securely tightened.

(j) Keep the pump in perfect alignment whilst securing it. Any incorrect alignment will be evident if the test bench driving shaft is turned by hand as the pump is being tightened.

(k) Connect the delivery pipes to their respective holders on the pump, and the feed pipe to the normal fuel inlet.

103. Fitting Control Rod Setting Device.

During the phasing operations it is necessary to control the setting of the rack in accurately defined positions. This is done by fitting a rack setting device to the pump as described in Fig. 44. The locating pin should then be removed and the graduated rod pulled out until it measures 12 mm., which is the recommended position for phasing.

104. **Injection Phasing.** Proceed with the phasing of the pump in the following sequence:—

(a) Disconnect No. 1 element delivery pipe at the holder, and in its place connect the

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delivery pipe leading to the phasing head injector.

(b) Adjust the T.D.C. clearance of No. 1 element plunger to 0.5 mm. (para. 95).

(c) Switch on the phasing light, open the fuel tank cock, start the motor (in correct

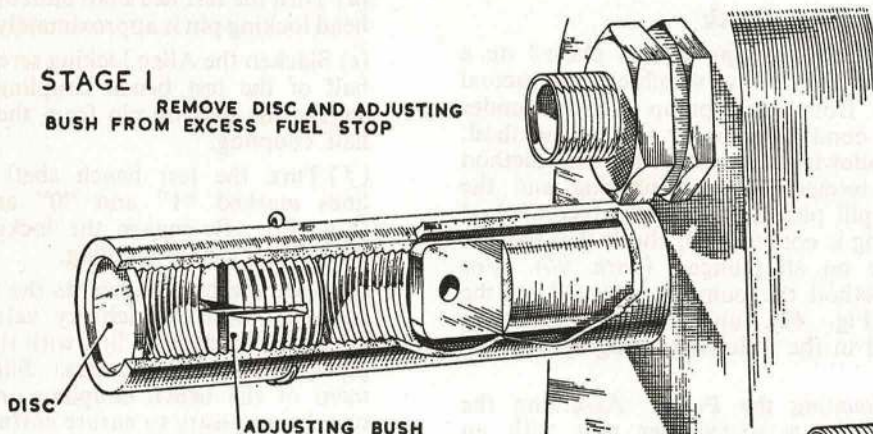
direction of rotation) and adjust the speed of the bench shaft as shown on the tachometer to approximately 500 r.p.m.

(d) Open the pump air-vent cock until the fuel flows freely.

(e) Turn the phasing injector carrier

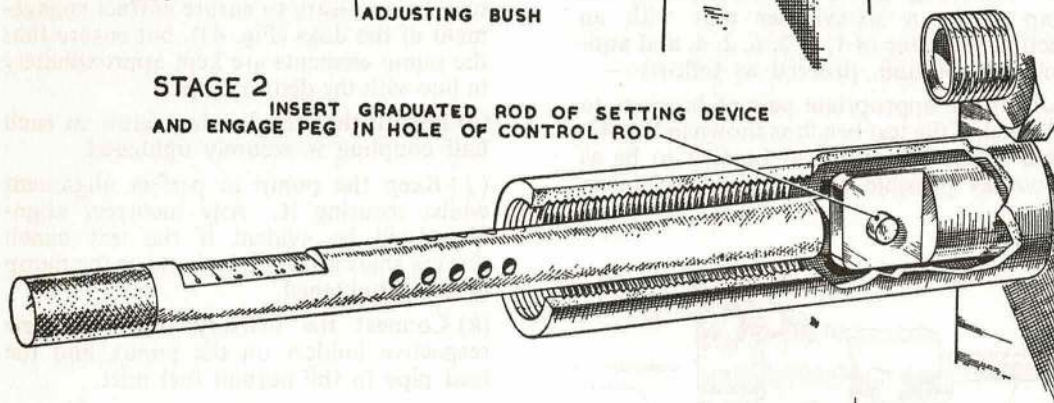
STAGE 1

REMOVE DISC AND ADJUSTING BUSH FROM EXCESS FUEL STOP



STAGE 2

INSERT GRADUATED ROD OF SETTING DEVICE AND ENGAGE PEG IN HOLE OF CONTROL ROD



STAGE 3

FIT BODY OF SETTING DEVICE, BRING ZERO MARK ON ROD COINCIDENT WITH LINE ON BODY AND INSERT PIN. PUSH THE ASSEMBLY TOWARDS THE PUMP AS FAR AS POSSIBLE AND TIGHTEN CLAMPING SCREW

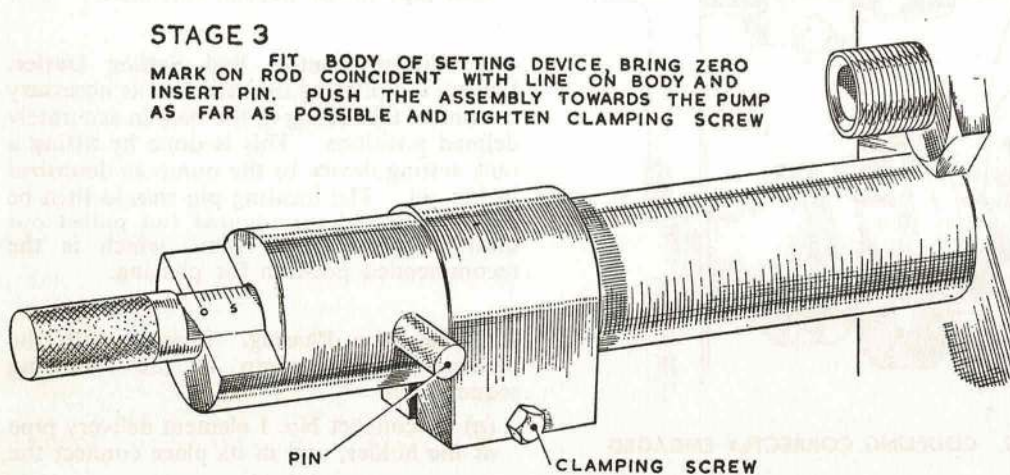


Fig. 44. FITTING CONTROL ROD SETTING DEVICE

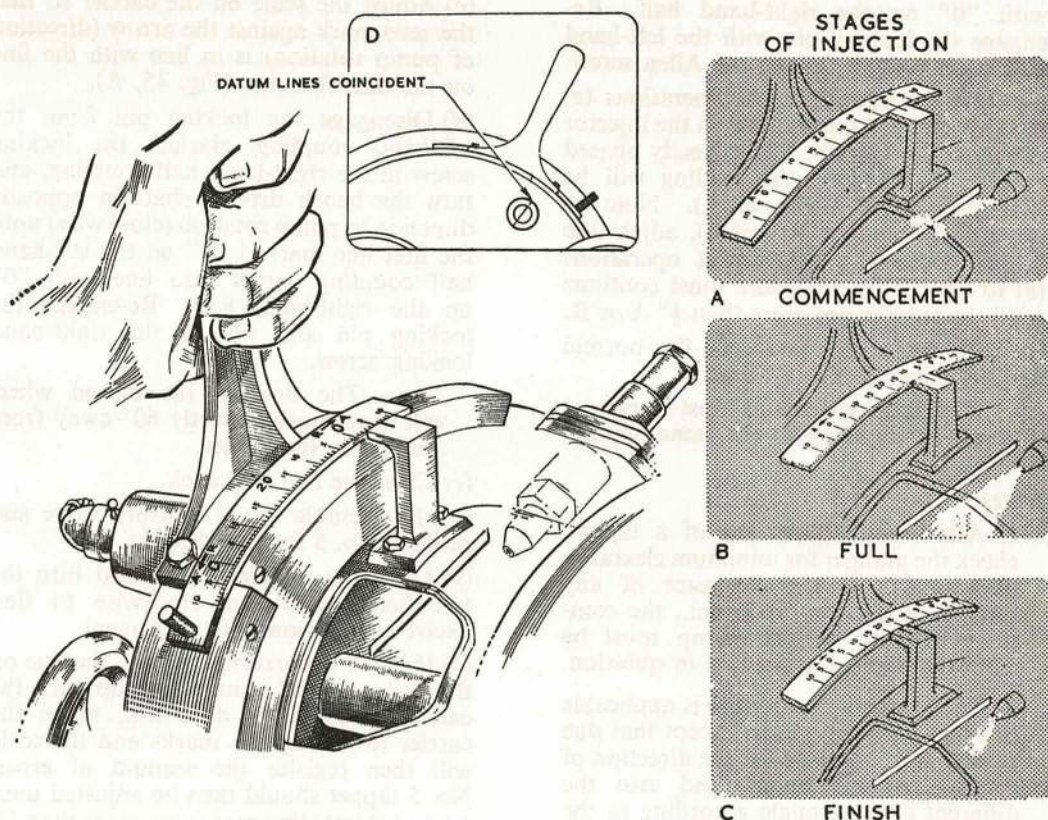


Fig. 45. USING THE PHASING HEAD

towards the front of the bench until it is in approximately the position shown in Fig. 45.

(f) Move the carrier slowly in the opposite direction (direction of pump rotation) until a full spray is observed through the viewing aperture (Fig. 45, B).

(g) Move the carrier very slowly towards the front of the bench until the spray stops, and then slightly in the opposite direction to the point where the spray just appears. This is the actual start of injection (Fig. 45, A).

(h) Adjust the scale attached to the injector carrier so that the zero mark against the arrow (direction of pump rotation) is in line with the line on the fixed bracket (Fig. 45, A).

Note.—This setting must be accurate and only altered when the procedure

described in Note 1 to this para. is necessary.

(j) Repeat operations (e) to (g) and check that the scale is correctly set. Stop the driving motor.

(k) Disconnect the phasing delivery pipe from No. 1 element and re-connect the normal delivery pipe. Disconnect the normal delivery pipe from No. 5 element and connect the phasing pipe in its place.

(l) Turn the bench driving pulley until the locking pin on the coupling is at T.D.C. (Fig. 43).

(m) Slacken the Allen locking screw in the right-hand half coupling, and disengage the locking pin from the left-hand half coupling.

(n) Turn the bench driving pulley in opposite direction to pump rotation (clockwise) until the first line marked "6" on the left-hand half coupling comes into line

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with "0" on the right-hand half. Re-engage the locking pin with the left-hand half coupling and tighten the Allen screw.

(o) Start the motor, repeat operations (e) to (g) and check the reading on the injector carrier scale. If No. 5 is correctly phased at 60° after No. 1, the reading will be exactly as for No. 1 (Fig. 45, A). Note the error (Advanced or Retarded), adjust the tappet (para. 98), and repeat operations (e) to (g). This procedure must continue until the error is not more than $\frac{1}{2}^\circ$ A or R.

(p) Stop the motor and refit the normal delivery pipe to No. 5 element.

(q) The remaining elements must be phased in injection sequence in the same manner as No. 5.

Notes:—

1. After each adjustment of a tappet, check the plunger for minimum clearance (0.3 mm.). If the clearance of any plunger is less than 0.3 mm., the complete phasing of the pump must be re-started from the element in question.

2. The foregoing procedure is applicable to other types of pumps except that due regard must be made for the direction of rotation of the pump, and also the different phasing angle according to the number of pump elements (normally the phase angle is $360^\circ \div \text{No. of elements}$).

3. Pressure waves, always present in delivery pipes, may influence the start of injection and cause fluctuation in phase readings. A slight alteration of the pump speed will overcome this.

105. Spill Phasing. This is similar to the method used on the hand-operated outfit. The start of injection is found in the same manner, but the test bench coupling and phasing head are used instead of the graduated wheel and pointer for finding the exact angular distance between injections. The pump is mounted on the test bench as described in para. 102, but it is not necessary to connect the elements to the test delivery pipes. The procedure is as follows:—

(a) Set No. 1 element to "start of injection" (paras. 94 to 96).

(b) Rotate the phasing head injector carrier until the line on the inner dished wheel is in line with the lines on the carrier (Fig. 45, D).

(c) Adjust the scale on the carrier so that the zero mark against the arrow (direction of pump rotation) is in line with the line on the fixed bracket (Fig. 45, A).

(d) Disengage the locking pin from the left-hand coupling, slacken the locking screw in the right-hand half coupling, and turn the bench driving shaft in opposite direction to pump rotation (clockwise) until the first line marked "6" on the left-hand half coupling comes into line with "0" on the right-hand half. Re-engage the locking pin and tighten the right-hand locking screw.

Note.—The line on the dished wheel will have moved exactly 60° away from the line on the carrier.

(e) Close the fuel feed cock.

(f) Reassemble No. 1 delivery valve and prepare No. 5 for the spill test.

(g) Open the fuel feed cock and turn the test bench shaft anti-clockwise to find "start of injection" No. 5 element.

(h) If No. 5 is correctly phased, the line on the dished wheel should line up with the carrier lines. If it does not, move the carrier to line up the marks and the scale will then register the amount of error. No. 5 tappet should then be adjusted until on repeat tests the error is not more than $\frac{1}{2}^\circ$.

(j) Test each element in injection sequence and finally re-check No. 1 element to ensure there has been no accidental movement of the phasing head scale.

Note.—The plunger clearance test must be applied to each element in turn, total phasing having to be re-started if any element is found to have less clearance than the specified minimum of 0.3 mm.

Principles of Calibration

106. The full calibration of a pump ensures that the outputs from all elements are equal throughout the normal range of engine speed; it also ensures that the outputs conform, within reasonable limits, to those specified by the engine manufacturers. The hand-operated outfit is not suitable for full calibration, because its maximum speed is well below that at which the pump normally runs when the engine is idling. Any calibration on this outfit can be regarded only as a check on a pump which is known to be reasonably serviceable, and on which there

have been no major replacements, or, as will be explained later, to decide that the elements are unserviceable.

107. If there have been major replacements, then it is essential that the pump is fully calibrated on a Hartridge test bench. For all calibration tests it is necessary for personnel to know the characteristics of the pump and to be in possession of the necessary data sheets. Calibration usually follows the phasing operations, and, assuming that the pump has been mounted on the test equipment as previously described, the procedure for using both types of equipment is as follows.

Using Hand Operated Outfit

108. Connect each of the test injectors to its respective delivery valve holder. Clamp the control rod in the central position, i.e. 12 mm. travel from the fully closed position. If the pump is fitted with a governor the operating lever must be secured. Turn the test injector delivery scoops away from the measuring glasses and ensure that the glasses are completely empty. Turn on the fuel supply, air-vent the pump, and operate the pump to expel any air from the delivery pipes and injectors.

109. During the test run a speed of at least 120 r.p.m. must be steadily maintained. When this speed has been reached, the delivery scoops should be moved to divert the fuel supply to the measuring glasses, and turning the camshaft continued for a minimum of 100 revolutions. The amount of fuel in each measuring glass should be recorded, the figures compared and the relative efficiency of each element assessed. Suppose that the following figures are recorded:—

No. 1 element	..	9.8 cc.
No. 2 element	..	10.4 cc.
No. 3 element	..	10.1 cc.
No. 4 element	..	10.6 cc.
No. 5 element	..	9.4 cc.
No. 6 element	..	10.5 cc.

These figures show that No. 1, 3, and 5 elements have deteriorated or are out of adjustment, and they should be adjusted to approximately the level of the rest.

110. **Adjustment.** Unclamp the control rod and move it to the fully closed position.

Make a temporary datum mark on the quadrant and sleeve of each element requiring adjustment and slacken the clamping screws. Sleeves and quadrants fitted by the manufacturer are marked (Fig. 35), but if these parts were fitted in a repair shop they may not be marked. To increase the fuel delivery from an element, the sleeve should be turned in the same direction as it turns when the control rod is moved to the open position. There is a hole in the sleeve for a tommy bar by which the sleeve can be turned.

Note.—Only a very small movement is required for normal adjustment, and several test runs may be necessary to obtain the correct setting. Ensure that the quadrant is clamped after each adjustment.

111. When all elements have been balanced, the test runs should be repeated with a control rod setting of 6 mm. opening and the readings recorded. If all elements are reasonably balanced, it can be assumed they are serviceable, but a big difference in outputs would indicate that the elements with the low outputs are worn and need renewing. This is a major replacement requiring full calibration tests on a Hartridge test bench.

Notes:—

1. Table 1 shows minimum and maximum outputs for different sizes of plungers at 6, 9, and 12 mm. control rod opening and should be used in conjunction with tests on the hand-operated outfit when it is known that the camshaft speed can be evenly maintained at 120 r.p.m., and that the test delivery strokes can be accurately recorded to give the necessary 100.

2. After all tests have been completed and the required adjustments made, the pump should be tested with the control rod in the fully closed position to check that there is no delivery of fuel at this position.

Using Hartridge Test Bench

112. Full calibration of a pump is possible on this powered test bench because the pump can be run at a constant speed at any point in its working range, and because the number of deliveries to the test tubes is automatically controlled. Normally, it is sufficient to make

Table 1

Delivery quantities per 100 strokes "B" type pumps—20 mm. pitch helix

Camshaft speed in r.p.m.	Plunger diameter mm.	Delivery in cubic centimetres					
		Control rod opening 6 mm.		Control rod opening 9 mm.		Control rod opening 12 mm.	
		Min.	Max.	Min.	Max.	Min.	Max.
120	10	2.6	3.4	8.4	9.6	14.0	15.6
	9	1.6	2.2	6.4	7.2	11.0	12.6
	8	1.6	2.2	5.2	6.0	9.0	9.8
	7.5	1.6	2.1	5.0	5.7	8.2	9.0
	7	1.4	2.0	4.1	4.8	7.2	7.8
	6.5	1.2	1.8	3.6	4.2	5.8	6.6
	6	0.8	1.4	2.8	3.2	4.7	5.3

test runs at 600 r.p.m. and 200 r.p.m. with control rod settings of 12 mm. and 9 mm. opening at both speeds, but if there is any doubt about the serviceability of an element, further runs with a 6 mm. setting should be made. The principle involved is the same as for the hand operated outfit. The reading obtained should be recorded on a prepared record card (Fig. 46).

113. Assuming that the pump has been installed on the bench, the delivery valve holders connected to the test injectors, and the system, pump and injectors have been air-vented, proceed as follows:—

(a) Set the control rod to 12 mm. opening, and adjust the bench speed to 600 r.p.m.

(b) Ensure that the test tubes are completely empty and then depress the automatic trip lever (Fig. 42).

(c) When the automatic trip has operated to direct the fuel to the front set of glasses, release the lever.

(d) When the automatic trip has again operated to divert the fuel from the glasses, the amount of fuel in each glass should be recorded.

(e) From the readings it can be seen which elements need adjusting in order to balance the outputs. Any necessary adjustments should be done as detailed in para. 110.

Note.—Ensure that the outputs at this control rod setting are within the limits of the specified maximum for the type of pump (Table 2). The permitted tolerance between element outputs is $\pm 2\frac{1}{2}$ per cent. of the mean average of the

outputs which are within the specified tolerances for this particular control rod setting and r.p.m.

(f) When the elements have been satisfactorily balanced and the final figures recorded, the bench speed should be set to 200 r.p.m., a test run made, and the outputs recorded.

(g) Re-set the control rod to 9 mm. opening, make test runs at 600 r.p.m. and 200 r.p.m. and record the outputs.

114. The serviceability of each element can be assessed from a comparison of the recorded figures. As an example, the readings from a test on a BPE pump are shown in Table 3. From these figures it will be seen, that although element No. 3 gives the highest output at the 600 r.p.m. and 12 mm. control setting, it gives the lowest output on the rest of the tests. All the other elements are within the permissible limits; No. 3 element is therefore unserviceable.

Note.—If new elements are fitted the full calibration must be repeated, to permit the new elements to be balanced and to check their serviceability.

Adjustment of Control Stops

115. There are normally four control stops (Fig. 47) which require to be correctly set after a pump has been serviced. The maximum fuel stop, the auxiliary maximum fuel stop and the excess fuel stop can conveniently be set on a Hartridge test bench, but the minimum fuel or idling stop must be set after the pump has been installed on an engine.

MAKE OF PUMP	PUMP NO.	DIRECTION OF ROTATION		DATE OF LAST TEST CARD NO.		DATE PUT IN SERVICE									
		MILES PER GALLON		DATE OF TEST		PERIOD									
MILEAGE	SPEED R.P.M.	M.M. RACK OPENING	NO. 1 PLUNGER	NO. 2 PLUNGER	NO. 3 PLUNGER	NO. 4 PLUNGER	NO. 5 PLUNGER	NO. 6 PLUNGER	NO. 7 PLUNGER	NO. 8 PLUNGER	TESTED BY				
PUMP OUTPUT READINGS (IN C.C.)															
PHASE ANGLE READINGS (IN °)	ERROR BEFORE ADJUSTMENT	No. 1 BEFORE T.D.C.	*	*	*	*	*	*	*	*					
	ERROR AFTER ADJUSTMENT	No. 1 BEFORE T.D.C.	*	*	*	*	*	*	*	*					
GOVERNOR TEST															
MECHANICAL		NUMBER		BEFORE ADJUSTMENT				AFTER ADJUSTMENT							
BEFORE ADJUSTMENT		AFTER ADJUSTMENT		RELIEF VALVES		HIGH		LOW P.S.I.		RELIEF VALVES		HIGH		LOW P.S.I.	
IDLING MAXIMUM R.P.M.		IDLING MINIMUM R.P.M.		IDLING MAXIMUM R.P.M.		IDLING MINIMUM R.P.M.		IDLING MAXIMUM R.P.M.		IDLING MINIMUM R.P.M.		IDLING MAXIMUM R.P.M.		IDLING MINIMUM R.P.M.	
RACK MOVEMENT M.M.		RACK MOVEMENT M.M.		IDLING PRESS P.S.I.		OPENING		CLOSING		IDLING PRESS P.S.I.		OPENING		CLOSING	
CUTTING IN MAXIMUM SPEED R.P.M.		CUTTING IN MAXIMUM SPEED R.P.M.		IDLING FUEL		CU.MM./CYCLE		CLOSING		IDLING FUEL		CU.MM./CYCLE		CLOSING	
COMPLETE CUT OUT R.P.M.		COMPLETE CUT OUT R.P.M.		MAXIMUM FUEL		CU.MM./CYCLE		CLOSING		MAXIMUM FUEL		CU.MM./CYCLE		CLOSING	
RACK MOVEMENT M.M.		RACK MOVEMENT M.M.		EXCESS FUEL TRAVEL		M.M.		CLOSING		EXCESS FUEL TRAVEL		M.M.		CLOSING	
HARTRIDGE TEST INJECTORS ARE NORMALLY SET AT A PRESSURE OF 175 ATMOSPHERES															

Fig. 46. PHASING AND CALIBRATING RECORD CARD

Table 2

Delivery quantities per 200 strokes. "B" type pumps—20 mm. pitch helix.

Camshaft speed in r.p.m.	Plunger diameter mm.	Delivery in cubic centimetres					
		Control rod opening 6 mm.		Control rod opening 9 mm.		Control rod opening 12 mm.	
		Min.	Max.	Min.	Max.	Min.	Max.
200	10	5.6	7.2	17.4	19.8	29.2	32.4
	9	3.6	4.6	13.2	14.8	23.0	25.2
	8	3.4	4.4	10.8	12.4	18.4	20.4
	7.5	3.4	4.6	10.2	11.8	16.8	18.6
	7	3.4	4.6	9.0	10.4	14.6	16.4
	6.5	3.4	4.4	8.2	9.4	13.2	14.6
	6	2.2	2.8	6.4	7.2	10.6	11.8
	5	0.6	1.2	2.8	3.8	6.0	7.0
600	10	8.0	10.4	20.0	23.0	31.6	35.2
	9	5.6	7.2	15.2	17.4	25.0	27.6
	8	4.4	5.6	12.0	13.8	19.6	21.8
	7.5	4.4	5.6	11.0	12.6	17.6	19.6
	7	4.0	5.2	9.8	11.4	15.6	17.6
	6.5	4.0	5.2	9.0	10.4	14.2	15.8
	6	2.4	3.2	6.6	7.8	10.8	12.2
	5	0.8	1.4	3.6	4.4	6.4	7.4

116. The pump must be installed on the test bench and the delivery valve holders connected to the test injectors. The excess fuel stop must be fitted, care being taken not to enter the adjusting bush too far into the body. The blanking disc should not be fitted, and the maximum fuel stop adjusting screw should be set to an approximate working position.

117. **Maximum Fuel Stop.** This stop is set to restrict the pump output to the engine manufacturer's specified permissible maximum. This maximum output should never be exceeded, and consequently the stop is sealed to deter unqualified personnel from making indiscriminate adjustments. The stop should be set in the following manner:—

(a) Air-vent the test bench fuel system,

pump and injectors, and ensure that the test glasses are completely empty.

(b) Start the test bench, set the speed to 600 r.p.m., and make a test run.

(c) Check the output of each element against the engine manufacturer's specification and adjust the stop accordingly. If the output is less than that specified, the stop adjusting screw must be slackened an estimated amount, locked in position and another test run made. Repeat until the output is within the specified limits.

(d) When the result is satisfactory, check that the adjusting screw is locked and fit the cover and seal.

Note.—The sealing cover of this stop must only be removed by qualified personnel.

Table 3

Calibration test figures—"B" type pump—8 mm. dia. plunger

Control rod setting	r.p.m.	Delivery in cubic centimetres					
		No. 1 element	No. 2 element	No. 3 element	No. 4 element	No. 5 element	No. 6 element
12 mm.	600	21.4	21.0	22.0	21.2	21.6	21.2
	200	20.2	19.8	19.0	20.2	20.2	19.8
9 mm.	600	13.4	13.0	12.4	13.0	13.6	13.2
	200	12.0	11.8	10.8	11.6	12.2	11.4

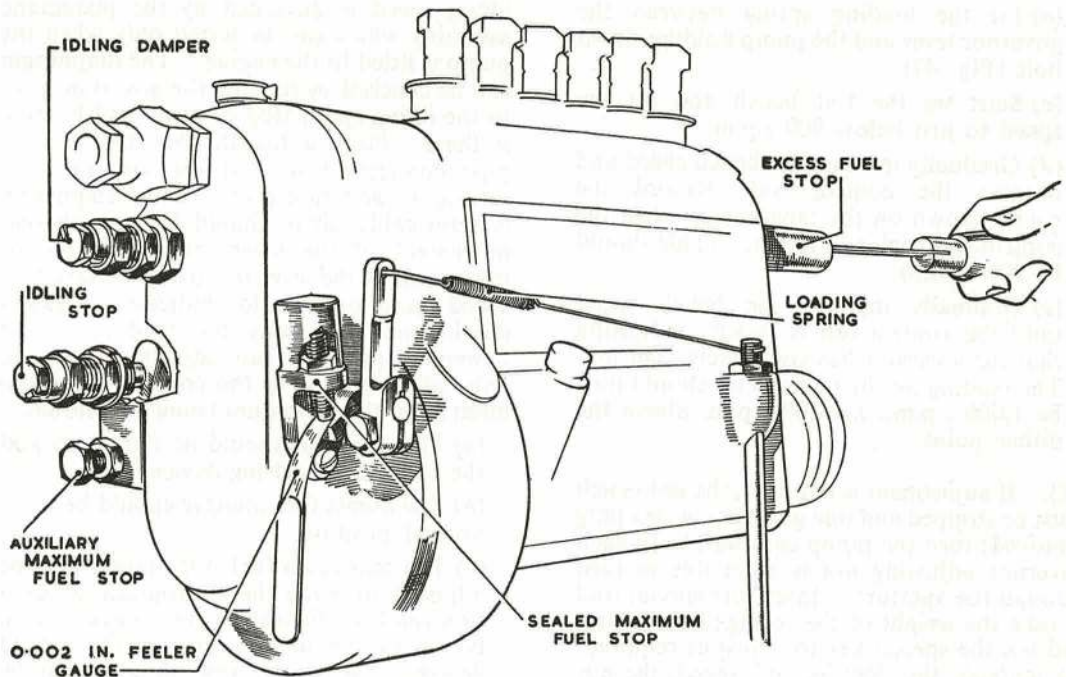


Fig. 47. CONTROL STOPS

118. Excess Fuel Stop. This stop is set to permit the pump to provide fuel in excess of that permitted by the maximum stop during engine starting operations. Set the stop as follows:—

(a) Fit the loading spring between the governor lever and the pump holding-down bolt (Fig. 47).

(b) Insert a 0.002 in. feeler between the lever and the maximum fuel stop and allow to hang (Fig. 47).

(c) The adjusting bush of the excess fuel stop should be screwed in slowly until it bears against the end of the control rod and the feeler gauge falls away. At this point, turn the adjusting bush back $1\frac{1}{2}$ turns, insert the locking pin and fit the blanking disc.

Note.—The $1\frac{1}{2}$ turns quoted is a general setting and the engine manufacturer's specification, which may be slightly different, should be used when available.

119. Auxiliary Maximum Fuel Stop. This stop is set to permit the pump to provide the maximum fuel required on full-load, which, for a serviced pump, is usually less than the

permissible maximum controlled by the maximum fuel stop. Thus, if the efficiency of a pump tends to decline after a period of use, this state can be rectified by careful adjustment of the auxiliary maximum fuel stop up to the overriding maximum fuel stop.

120. Idling Stop. The adjustment of this stop and also the auxiliary idling stop (when fitted) is done after the pump has been fitted to the engine and the engine is running.

Testing and Adjusting the Governor

121. A flyweight governor can be conveniently tested on a Hartridge test bench, but the testing of a pneumatic governor requires the pump to be installed on its engine. When a flyweight governor requires adjustment, an equal adjustment must be made to both weights.

122. Assuming the governor under test to be a BR/900 BF 60, which has a maximum control speed of 900 r.p.m. and a minimum of 200 r.p.m. The procedure is as follows:—

(a) The control rod setting device must be fitted and the locking pin removed.

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(b) Fit the loading spring between the governor lever and the pump holding-down bolt (Fig. 47).

(c) Start up the test bench and set the speed to just below 900 r.p.m.

(d) Gradually increase the bench speed and observe the control rod. Record the r.p.m. shown on the tachometer when the control rod begins to dither. (This should be 900 r.p.m.).

(e) Gradually increase the bench speed until the control rod is steady, indicating that the governor has completely "cut-in". The reading on the tachometer should now be 1,000 r.p.m., i.e. 100 r.p.m. above the dither point.

123. If adjustment is required, the test bench must be stopped and one governor access plug removed; turn the pump camshaft until each governor adjusting nut is accessible in turn through the aperture. Insert the special tool to take the weight of the springs off the nut, and use the special key to adjust as required. To increase the "cutting-in" speed, the nut must be turned clockwise. When turning anti-clockwise to reduce the "cutting-in" speed, ensure that the nut is not turned past the point where its face is 0.5 mm. beyond the end of the bolt.

Note.—The adjusting nut is self-locking at each half-turn. Adjustment should therefore be a number of complete half-turns (the same for each weight). One complete turn of each nut makes a combined difference of 25 r.p.m.

124. This adjustment affects the loading on all three springs of each governor weight, there being no separate adjustment for the outer spring which controls the idling speed.

125. When the governor has been satisfactorily adjusted at 900 r.p.m., a check test should be made at 200 r.p.m. Reduce the test bench speed to a little above 200 r.p.m., and then gradually reduce the speed whilst observing the control rod as before for the "cutting-in" point, which should be within reasonable limits of 200 r.p.m. A large discrepancy would indicate that the governor outer springs need to be renewed.

126. **BEP/LB Governor.** Very little adjustment of this governor can be done on the test bench, because only the maximum speed is governed by the flyweight assembly. The

idling speed is governed by the pneumatic assembly which can be tested only when the pump is fitted to the engine. The diaphragm can be checked by moving the governor lever to the idling speed stop position and holding it there. Place a thumb over the vacuum pipe connection to seal the aperture and release the governor lever. If the diaphragm is serviceable, there should be no apparent movement of the lever, but a continuous movement of the lever towards the maximum speed position would indicate a faulty diaphragm. Normally the loading of the flyweight springs is not adjustable and the only adjustment is to the control rod maximum stop, the procedure being as follows:—

(a) The governor should be stationary and the control rod setting device fitted.

(b) The excess fuel plunger should be in its normal position.

(c) The maximum fuel stop should then be adjusted to bring the appropriate graduation (maker's figure) on the control rod in line with the datum line on the setting device. The stop screw should then be adjusted to give a clearance of 1 mm. between its end and the forked lever.

127. **BEP/MZ Governor.** The testing of this governor must be done on the engine, but the diaphragm can be tested for serviceability. This is done by moving the control lever to the fully closed position, holding the thumb over the venturi inlet, and watching for movement of the quadrants when the control lever is released. Any appreciable movement will indicate that the diaphragm is leaking.

Storage and Transit Precautions

128. After all workshop attention to a pump has been completed, all open ports on the pump should be effectively and securely sealed to prevent the ingress of dirt and moisture during storage and transit periods. The requisite amount of the specified lubricating oil should be put into the pump and governor housings.

Servicing C.A.V. Fuel Injectors

129. Nozzles should be removed from the engine for routine servicing at periods specified in the relevant Servicing Schedules. They may also be removed, if thought to be defective, when one or more of the following symptoms develops:—

- (a) One or more cylinders knock.
- (b) Engine overheats.
- (c) Engine loses power.
- (d) Exhaust contains black smoke.
- (e) Fuel consumption increases.

Table 4 gives a summary of possible faults and remedies.

130. A faulty nozzle can often be located by slackening each nozzle feed pipe union nut in turn, thus cutting out that particular nozzle. When a faulty nozzle is cut out there will be no noticeable difference in the running of the engine. To check a suspected nozzle on the engine, remove the injector and re-connect it to the fuel supply so that the nozzle points outwards. Slacken the unions of all the other injector feed pipes, turn the engine and observe the spray from the suspected nozzle. If the spray is unduly "wet" (*i.e.* not finely atomized), or if it is streaky, emerges to one side, or the nozzle dribbles, then the injector should be replaced by a serviceable one and the unserviceable injector returned for workshop attention.

Warning

Personnel must keep their hands from contact with the spray.

131. All servicing work on injectors must be done in conditions of scrupulous cleanliness and under no circumstances must cotton waste or rags be used. A special nozzle cleaning kit is provided (Fig. 48), and when these tools are not in use they must be placed in the hold-all and kept in a dust-proof drawer or cupboard.

132. A slotted plate fixed to and overhanging the bench (Fig. 49) will facilitate the handling of the injector during servicing operations. Before a nozzle is removed from the holder, the spring pressure on the nozzle valve must be released by slackening the pressure adjusting screw. To remove a nozzle, position the injector in the slotted plate (Fig. 49) and remove the nozzle cap-nut with the special spanner. The nozzle cap-nut must never be gripped in a vice.

Table 4
Faults and Remedies

Fault	Possible Cause	Remedy
Nozzle does not buzz during injection	1. Nozzle valve too tight, binding, or valve seating leaky 2. Nozzle cap-nut distorted	1. Clean nozzle 2. Examine nut. If necessary fit serviceable nozzle
Excessive leak-off	1. Nozzle valve slack 2. Nozzle cap-nut not tight 3. Foreign matter between contact faces of nozzle and nozzle holder	1. Replace nozzle 2. Tighten nut 3. Remove nozzle, and clean faces
Nozzle blueing	Faulty fitting or engine cooling	Fit new nozzle and check engine cooling system
Nozzle opening pressure incorrect	1. Adjusting screw improperly set 2. Valve corroded and seized up 3. Valve dirty and sluggish in movement 4. Sprayholes clogged with dirt and carbon 5. Pressure spring broken	1. Adjust for prescribed pressure 2. Fit new nozzle 3. Clean nozzle 4. Clean nozzle 5. Fit new spring and set to prescribed pressure
Nozzle drips	Nozzle leak owing to carbon deposit Valve sticking	Clean nozzle. If fault is not remedied fit new nozzle
Distorted spray	1. Excessive carbon deposit on nozzle tip 2. Spray holes partially choked 3. Valve damaged	1. Clean nozzle 2. Clean nozzle 3. Fit new nozzle

1. CLEANING TOOLS FOR USE WITH PINTLE HOLE CLEANER.
2. DOME CAVITY CLEANER (1.8 MM DOME), LONG STEM.
3. ANGULAR CAVITY CLEANER.
4. NOZZLE BODY PIN CLEANER.
5. DOME CAVITY CLEANER (1.2 MM DOME).
6. NOZZLE BODY SEAT SCRAPER (LONG STEM).
7. NOZZLE BODY SEAT SCRAPER.
8. PINTLE HOLE CLEANER.
9. PROBING TOOL.
10. NOZZLE BODY GROOVE SCRAPER.
11. BRASS WIRE BRUSH.

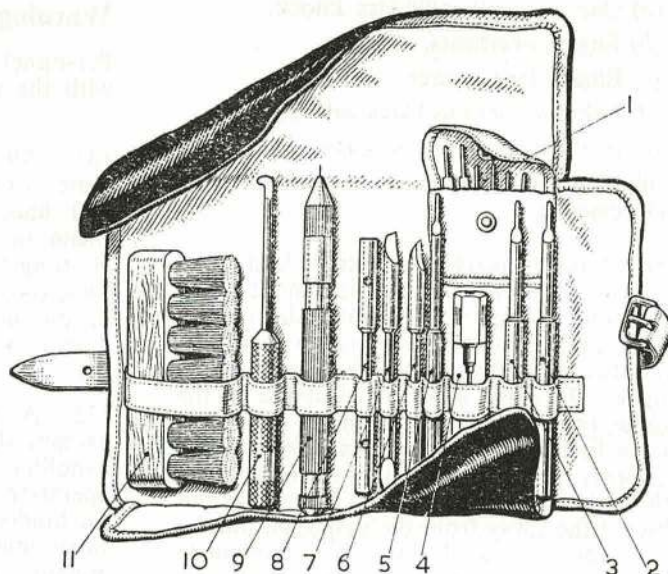


Fig. 48. NOZZLE CLEANING KIT

133. **Cleaning Nozzles.** The procedure for cleaning nozzles is as follows:—

- (a) Remove the valve from the nozzle body and place it in a bath of kerosine or fuel oil.
- (b) Brush off all the carbon from the outside of the nozzle body and place the body in the kerosine or fuel oil.
- (c) When the parts have soaked sufficiently to soften the carbon, clean out the fuel feed passages in the body with a drill or a piece of wire of 1.70 mm. dia.

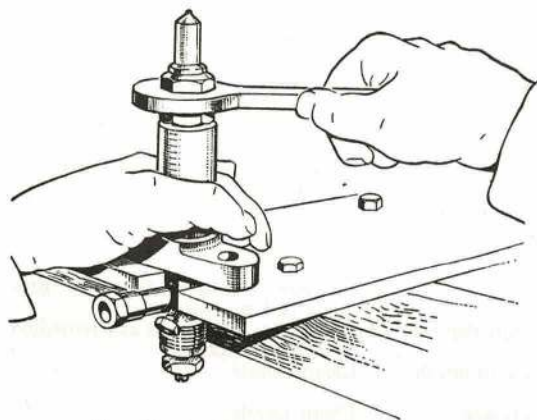


Fig. 49. REMOVING A NOZZLE

- (d) Insert the tool (10 in Fig. 48) in the nozzle body until the nose locates in the

gallery, and, with considerable pressure against the gallery wall, rotate the tool to dislodge all deposit.

- (e) Using a dome cavity cleaner appropriate to the type of nozzle, remove the carbon deposit from the dome cavity.

(f) Clean any carbon deposit from the valve seat by pressing the appropriate seat scraper on to the seat and rotating it.

- (g) Use the probing tool (9 in Fig. 48) with the appropriate sized wire to clear the spray holes of carbon. The wire should protrude for about $\frac{1}{2}$ mm., at first, being progressively lengthened as the carbon is cleared. Rotate the probe gently with light pressure to prevent breaking the wire. Tap the nozzle body gently on a soft pad to dislodge the loosened carbon. Fit the nozzle to the flushing adaptor on the testing outfit, if available, and flush; otherwise, thoroughly wash and then blow out with compressed air. Always blow out or flush in the opposite direction to normal fuel flow.

(h) Carefully clean the nozzle valve using the brass wire brush (11 in Fig. 48). The nozzle must be rejected if there are any scores or other defects on the working surface of the valve.

- (j) Fit the nozzle body and the valve together whilst immersed in clean fuel oil.

(k) Thoroughly wash the nozzle holder, spring and cap nut in clean kerosine or fuel oil, and after inspecting these components for damage or corrosion, reassemble them. Great care must be taken to avoid damaging the lapped pressure face of the holder.

(l) Ensure that the lapped joint faces of the holders and nozzle body are perfectly clean, and that there is no tension on the spring. Place the holder, joint face uppermost, in the slotted plate, and place the nozzle in position, taking care to locate the holder dowels (if fitted) in the holes in the nozzle (Fig. 50).

(m) Fit the nozzle cap-nut and tighten it with the correct spanner. This nut must be reasonably tight, but distortion, causing a seized valve, may result if it is overtightened. The injector is now ready for testing.

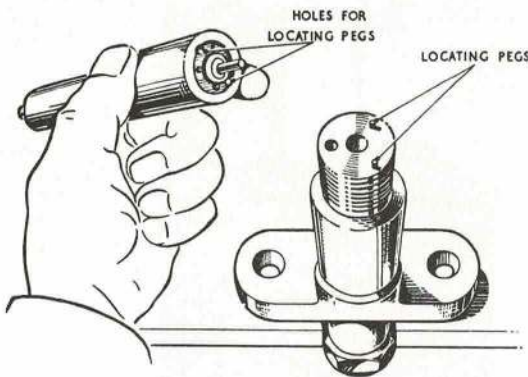


Fig. 50. FITTING A NOZZLE

134. Power-operated equipment which can simulate actual working conditions is necessary for the complete testing of an injector, but the general performance and estimation of the leakage rate can be made on equipment which is hand-operated.

Testing on the Hand Operated Outfit

135. **Leakage Test.** This outfit with an injector fitted for checking is shown in Fig. 51. A receptacle should be provided for the fuel delivered from the nozzle. Remove the air vent screw until the fuel flows freely at this point. Slightly slacken the delivery pump union nut at the injector, and operate the pump until fuel flows freely from the joint. Re-tighten the union nut. The test procedure is as follows:—

(a) Ensure that the check valve is closed (to protect the pressure gauge) and operate the hand lever smartly several times to expel any air remaining in the system.

(b) Open the check valve, operate the pump, and set the opening pressure of the nozzle valve to 160–170 atmospheres. Turn the adjusting screw clockwise to increase pressure and anti-clockwise to decrease it. Watch the gauge needle carefully, the maximum pressure indicated before the needle flicks, is the valve opening pressure.

(c) Operate the pump until the gauge registers about 10 atmospheres less than the opening pressure then stop pumping. Check the time taken for the pressure to drop from 150 to 100 atmospheres, and if this is less than 6 seconds the leakage rate is excessive.

136. An excessive leakage rate may be caused by one or more of the following:—

(a) Faulty joint faces between nozzle body and holder, giving either an internal or external leak.

(b) Excessive leakage between nozzle valve and nozzle body.

(c) Faulty valve seating.

(d) A sticking valve (probably caused by scoring of, or small spots of rust on, the lapped portion).

(e) A cracked nozzle.

137. The internal leak at (a) would be shown by fuel appearing at the top of the nozzle cap-nut. In this case, the cap-nut should be checked for tightness but no attempt should be made to overtighten in an effort to stop the leak. If the cap-nut is found to be correct and the leakage persists, the nozzle should be dismantled, the joint faces inspected for faults, and the leakage test repeated if necessary.

Note.—Always close the check valve, when pressure exists in the system, before attempting to remove an injector from a test outfit. This will protect the gauge from the sudden drop in pressure which would occur when the union nut is slackened.

138. All internal leaks will be shown by an excessive amount of fuel appearing at the leak-off connection. Should this condition

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persist, after careful inspection of the nozzle components and repeated tests, the nozzle should be replaced by a serviceable one. A faulty valve seating will be shown by the appearance of fuel at the nozzle tip. At the test pressure (para. 135 (c)), the nozzle tip or the flat bottom face of single-hole and pintle type nozzles should remain practically dry, a little dampness can be ignored, but there should be no tendency for fuel to collect or drip.

139. If, after examination and further test, the nozzle is still unsatisfactory, it should be replaced by a serviceable one. Under no circumstances should the nozzle valve be reseated by lapping it in the nozzle body. Although it may be possible to cure a leaking valve by this method, the lapping process would result in an alteration to the amount of valve lift which would cause a variation in the spray characteristics.

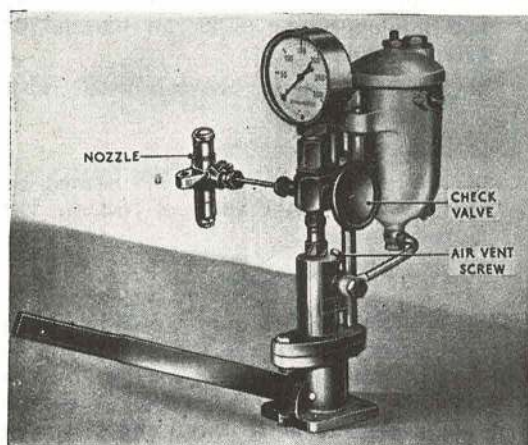


Fig. 51. HAND OPERATED TEST OUTFIT

140. **Spray Check.** Because the normal working speed of the nozzle cannot be produced on the hand-operated outfit, an atomization test is not completely satisfactory. However, a reasonable idea of the working of the nozzle can be obtained by watching the spray produced when the hand-lever is operated at 80 to 100 strokes per minute, with the check valve closed. Normal types of hole and pintle nozzles should deliver an atomized spray which is free from irregular wet streaks if the nozzle is to be classed as satisfactory. This check cannot be applied to any of the delay type nozzles.

Testing on the Hartridge Nozzle Tester

141. The efficiency of a nozzle under test on this tester can be accurately assessed because fuel can be supplied to the nozzle under the same conditions as when the nozzle is fitted to the engine. The outfit is shown in Fig. 52. When testing central single-hole types of nozzles, the adjustable arm should be positioned above the centre of the funnel at a height of approximately 1 ft. from the table, but multi-hole nozzles, and those with a single hole drilled at an angle, should be positioned so that the tip of the nozzle is below the top edge of the exhaustor funnel rim. The pressure gauge valve must never be open when the accumulator valve is closed and the motor running. Pressure must never exceed 300 atmospheres.

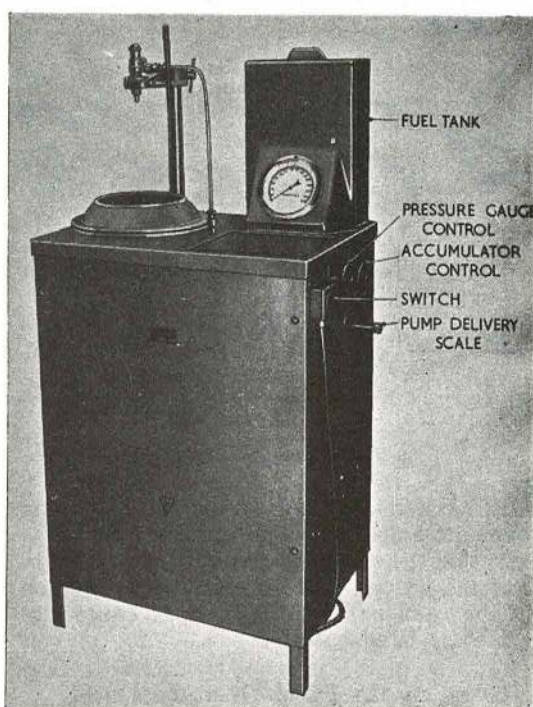


Fig. 52. HARTRIDGE NOZZLE TESTER

142. **Leakage Test.** To operate the tester proceed as follows:—

- (a) Fully open the pressure accumulator control and the pressure gauge control valves.
- (b) Set the pump delivery scale to 25 mm.
- (c) Switch on the motor.
- (d) By adjustment of the pressure adjusting

screw set the nozzle valve to lift at 160–170 atmospheres.

(e) Allow the pressure to build up to approximately 10 atmospheres below the valve lifting pressure, then quickly move the pump delivery scale to zero and close the pressure accumulator control valve.

(f) Check the time taken for the pressure to drop from 150 to 100 atmospheres. If the time is less than 6 seconds, the leakage rate is too high and the procedure outlined in paras. 136–139 should be applied.

143. Pressure-Setting Test. After a nozzle has passed the leakage test it should be set to spray at the pressure specified by the engine manufacturer, which should be obtained by reference to the relevant publication. Proceed as follows:—

(a) Fully open the accumulator control valve and the pressure gauge control valve.

(b) Set the pump delivery scale to 25 mm.

(c) Start the motor and alter the pressure adjusting screw until the pressure recorded immediately before the gauge needle flicks is that specified. When satisfactory, lock the adjusting screw.

144. Spray Formation Test. With the motor running, close down the pressure gauge control and watch the spray formation. This should be a very fine mist with no sign of wet streaks; it should not be to one side of the spray hole, and on multi-hole nozzles all sprays should be alike and of the same length.

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