Chapter 33A

MAIN SHAFT ASSEMBLY, REASSEMBLING, AND DYNAMIC BALANCING

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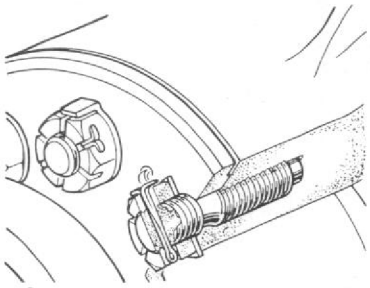
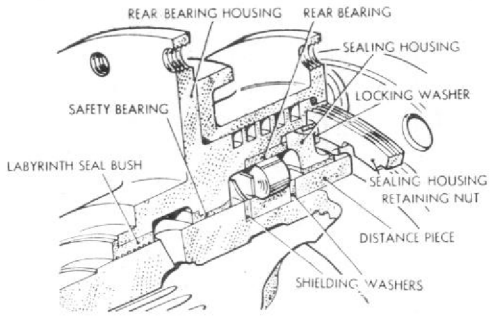


B. PIVOT STUD, TAB WASHER, NUT, AND SPLIT PIN SHOWING CORRECT METHOD OF LOCKING



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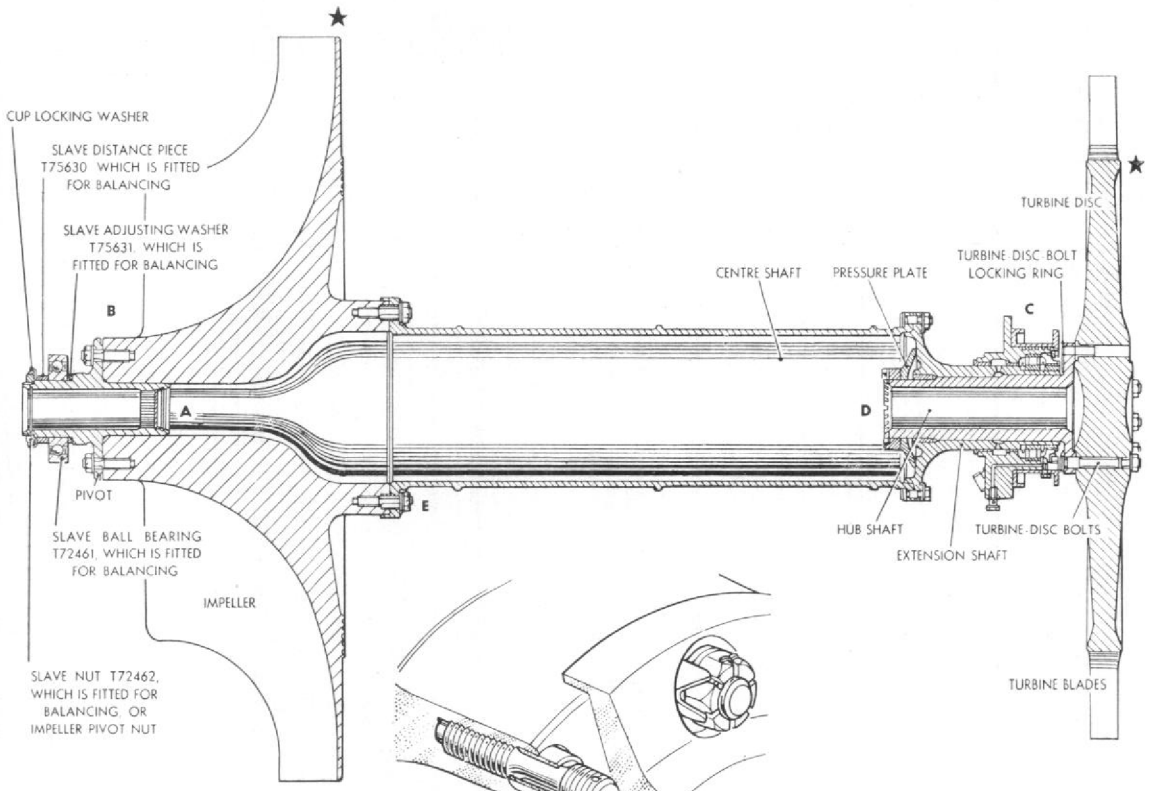

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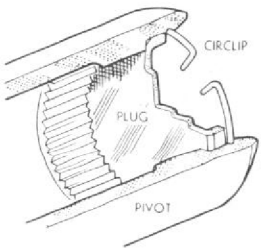
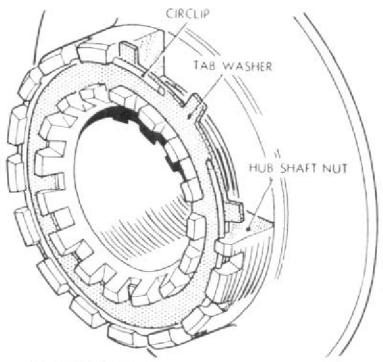


A. ACCESSORY DRIVE SHAFT PLUG AND CIRCLIP IN REAR OF PIVOT



D. METHOD OF LOCKING HUB SHAFT NUT

★ DYNAMIC BALANCE BY REMOVING METAL FROM POSITIONS MARKED

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Fig. 1. Main shaft assembly.

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THIS CHAPTER, which is applicable to both the Ghost 48 Mk. 1 and the Ghost 48 Mk. 2, describes the reassembly and dynamic balancing of the main shaft assembly, Fig. 1. The information is given under two main headings: reassembling, and dynamic balancing. Instructions for reconditioning and repair and the processes essential to such repair, are contained in chapter 28.

Essential renewals, required to replace parts automatically discarded during dismantling, are listed at the end of the chapter. Tools are referred to in the text as they are used.

Prior to reassembly, any inspection report must be read carefully and all work carried out as directed therein. Minor rectification, which may not be entered on the inspection report, includes renewing damaged or loose studs, cleaning up steel components with fine emery cloth or on a buff, stoning splines and polishing out scratches. After any work has been carried out, the part affected must be re-submitted for inspection. Immediately prior to assembly, the rear roller bearing should be washed in white spirit. After draining off the surplus spirit, dry the bearing with a jet of clean dry compressed air, and immediately lubricate it with clean approved engine oil to prevent corrosion.

All parts must be handled with extreme care. To ensure correct assembly, and to maintain, as far as possible, the original condition of balance, all parts must be carefully examined for alignment and correlation marks, and reassembled with punctilious regard to these marks; these precautions must be observed also when assembling the adapters and couplings used when preparing components for balancing. To assemble bolts and nuts in their correct relationships, identify number one correlation mark on the components and assemble the numbered bolts and nuts, starting with number one, in the correct sequence in a clockwise direction as viewed from the turbine end of the assembly. Bolt threads, and the threads at the free end of studs, should be treated with Ragosine L.M. paste, which is best applied by means of a small, good quality brush. All spigots and static bearing surfaces, and the fast ends of studs, should be treated with acid-free tallow; acid-free tallow should, also, be applied to certain ring nut threads, as mentioned in the text.

Throughout this chapter, the phrase "within the limits" implies that, to ascertain the limits applicable, the operator must refer to the Table of Fits and Clearances which forms chapter 38 of this handbook.

REASSEMBLING

IMPELLER

If the impeller has been re-anodised, and lacquered with Rockhard, great care must be exercised, throughout the following operations, to ensure that these protective finishes are not damaged in any way. The removal of even minute portions of these finishes, exposes the impeller to the risk of corrosion, and even slight traces of surface corrosion can quickly initiate inter-crystalline corrosion. This is most serious as, due to the stress to which the impeller is subjected during operation, cracks may easily develop from such corrosion; such cracks being difficult to detect particularly under "in the field" conditions. It is recommended, therefore, that, wherever possible, all renewals should be completed before the impeller is re-anodised and re-lacquered; an exception must be made in respect of any metal removed from the periphery of the impeller backplate during dynamic balancing. Although this area of the impeller is not so critical as the vanes, after removing the required balancing material, the bared surface of the metal must immediately be protected by applying cold-setting lacquer in accordance with T.R.396.

The surface finish of the pivot, where it contacts the oil seal in the air-intakes, is extremely critical and, therefore, at all times the greatest care must be taken to ensure that this surface is protected so that it is neither scratched nor marked in any way. The centre shaft dowel holes in the rear face of the impeller are reamed to finished size after assembly of the impeller to the centre shaft. If, therefore, it is necessary to renew either the impeller or the centre shaft, it will be necessary to fit oversize centre shaft dowels in accordance with T.R.111.

When fitting new studs, whether standard size or oversize, advantage should be taken of the manufacturing tolerances to select a stud which will be the best possible fit in the hole in the impeller. The fast end of each stud should be smeared with a thin film of acid-free tallow. If a stud is loose, or if the threaded hole in the impeller is damaged, rectification may be carried out in accordance with T.R.253 or 254 as appropriate. Where the threaded hole is damaged beyond the scope of rectification by T.R.253 or 254, the $\frac{1}{2}$ in. B.S.F. hole may be opened out to $\frac{9}{16}$ in. B.S.F. in accordance with T.R.133 or 134 but neither of these can be applied if T.R.253 or 254 has been applied already. Screwed ring gauges T.76794 ($\frac{1}{2}$ in. B.S.F.) and T.78447 ($\frac{9}{16}$ in. B.S.F.) should be used in conjunction with a John Bull Intercheck small bore gauge fitted with the appropriate B.S.F. mandrel, to check the effective diameter of the threaded holes. Any stud hole, or any number of stud holes, may be rectified as necessary. Where T.R.134 has been applied, it should be noted that the oversize stepped pivot studs must be fitted before the pivot, as the enlarged ($\frac{9}{16}$ in. B.S.F. fast end) portion of these studs will not pass through the holes in the pivot flange. Where T.R.134 has been applied to the offset hole or the hole diametrically opposite, in the front face of the impeller, a special oversize stud, having an integral extension to guide the pivot inserting tool, must be fitted in these holes, and one, or both, of the standard solid plungers must be removed from the inserting tool and a special hollow plunger substituted. In this instance, after the pivot has been fitted, the exension must be cut off the special stud.

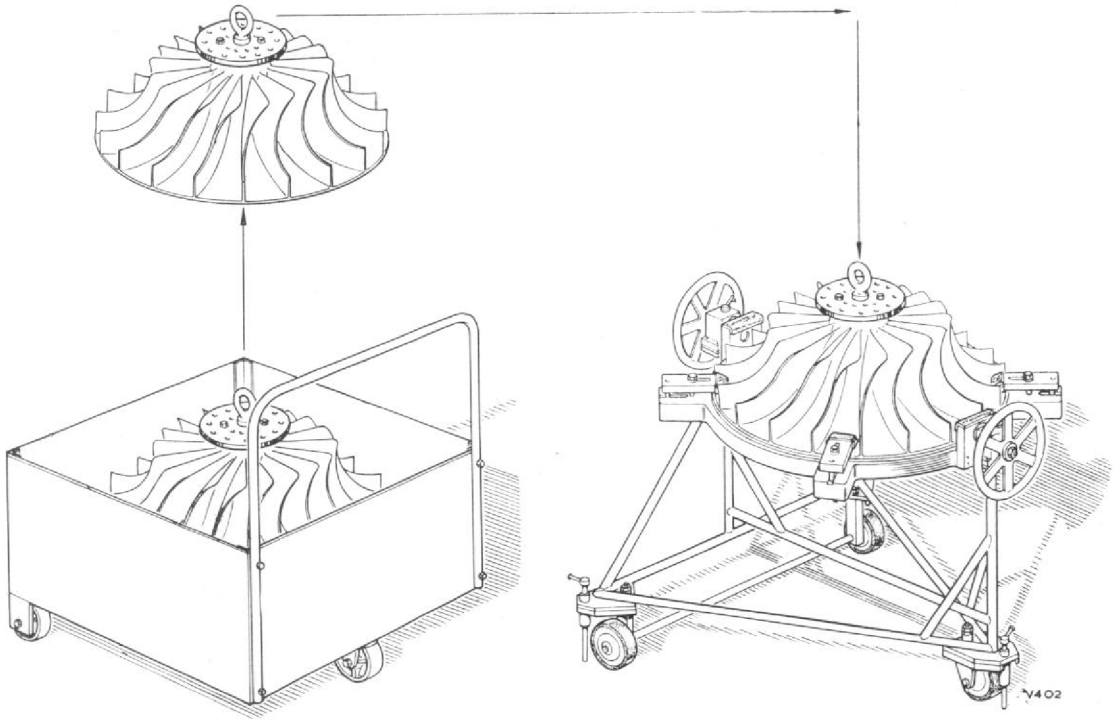


Fig. 1a. Using lifting plate T.72420 to transfer impeller from box trolley T.77555 to cradle trolley T.76578.

To protect the impeller vanes from accidental damage during the insertion of the pivot and its studs, etc., a thick felt pad, in which there is a central hole about the diameter of the boss on the impeller, should be placed over the pivot on to the impeller vanes before working on these parts.

INSERTING PIVOT

1. *If the impeller is received in box trolley T.77555,* use four slave bolts T.75003 to secure lifting plate T.72420 to the pivot face on the impeller. Using a suitable hoist, transfer the impeller from the box trolley to cradle trolley T.76578. Securely clamp the impeller to the cradle trolley, Fig. 1a. Unscrew the four slave bolts and remove the lifting plate.

2. Lightly blend burrs and score marks from the impeller bore and pivot face, and, using the appropriate pair of the blueing gauges, which are listed in the next column, check the pivot face on the impeller, and the mating face on the pivot flange, for flatness as described in chapter 27B.

3. *If TR.134 has been applied,* fit the oversize stepped studs ($\frac{9}{16}$ in. B.S.F. on fast end); these stepped studs cannot be fitted once the pivot is in position—see page 3a.

T.74993	Blueing ring, standard	for checking mating faces of impeller and pivot flange
T.74994	Blueing ring, 0·010 in. oversize	
T.74995	Blueing ring, 0·020 in. oversize	
T.74996	Blueing ring, 0·030 in. oversize	
T.74988	Blueing ring, standard	
T.74990	Blueing ring, 0·010 in. oversize	
T.74991	Blueing ring, 0·020 in. oversize	
T.74992	Blueing ring, 0·030 in. oversize	

4. Swing the cradle through 90 degrees, so that the impeller is vertical, and lock the cradle in position.

5. Using two slave bolts, secure adapter plate T.74997 to the rear face of the impeller. Pass lifting rod T.78045 through the impeller bore and screw it into the adapter plate.

6. Swing the cradle through 90 degrees so that the eye of the lifting rod is uppermost, and lock the cradle in position. Using a suitable

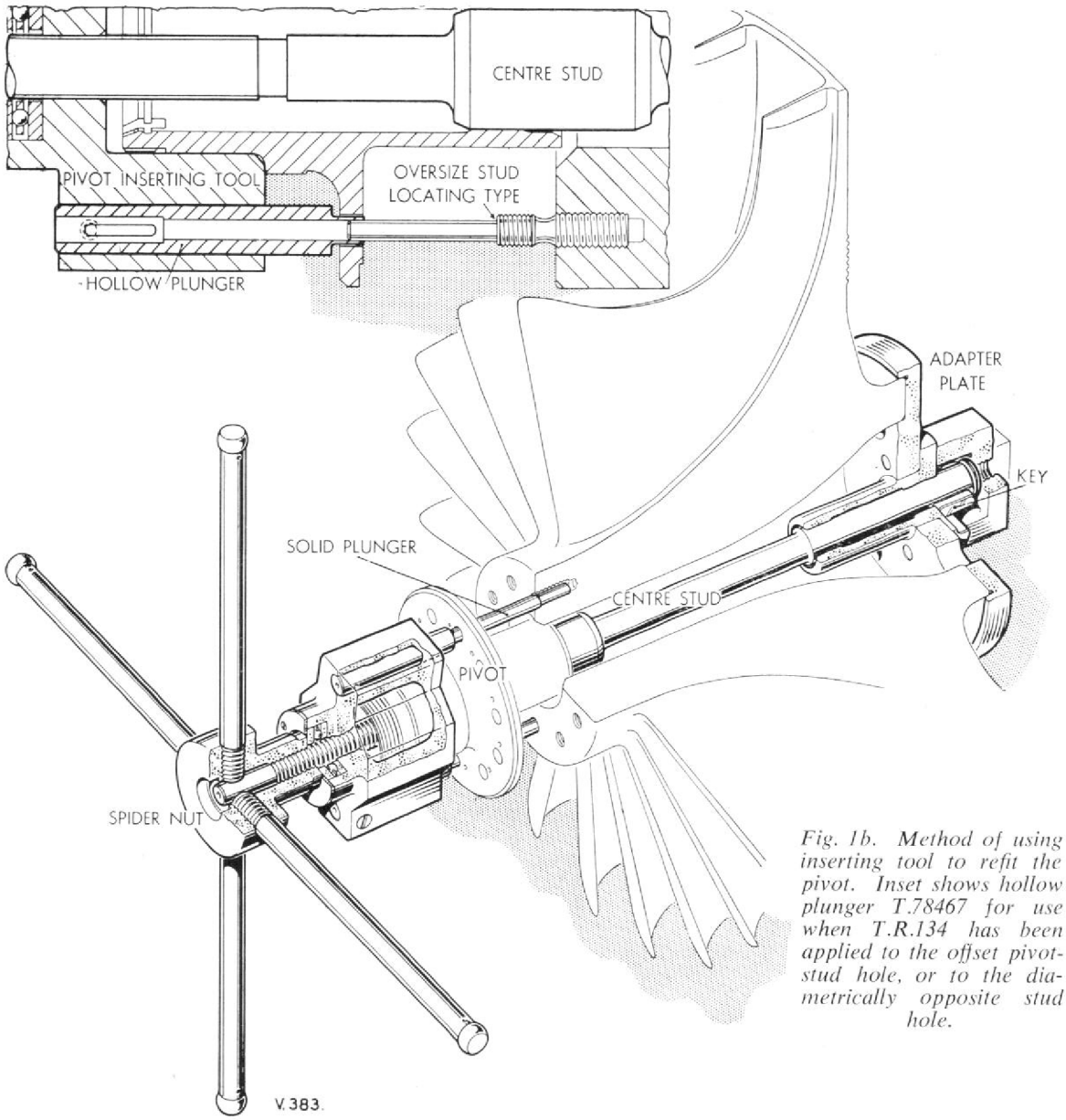


Fig. 1b. Method of using inserting tool to refit the pivot. Inset shows hollow plunger T.78467 for use when T.R.134 has been applied to the offset pivot-stud hole, or to the diametrically opposite stud hole.

hoist, just take the weight of the impeller, release the clamps securing it to the cradle, and transfer it to a hot oil bath.

The temperature of the hot oil bath should be maintained at approximately 80 deg. C. In practice, it will often be found convenient to use the crack detection hot oil and kerosene bath for this purpose.

To avoid excessive cooling of the impeller, before assembly is completed, the preparatory operations—Op. 1 and 2—should be completed before the impeller is removed from the hot oil bath, and operation 3 to 8 must be completed with as little delay as possible. Where T.R.134 has been applied to the offset pivot-stud hole, or to the diametrically opposite stud hole, one, or both, of the standard solid plungers must be removed from the pivot inserting tool and hollow plunger T.78467 substituted, see Fig. 1b. Two operators will be necessary when using the pivot inserting tool, one to insert the key through the adapter on the rear face of the impeller and the slot in the centre stud, whilst the second handles the inserting tool and turns the spider nut.

1. Ensure that the correct plungers are fitted to pivot inserting tool T.74999, and that the plungers are fully extended; spring-loaded balls in the inserting tool will hold the plungers in this position. Ensure that spider nut T.75002 and centre stud T.75000 are in position. Pass the pivot over the centre stud and enter its threaded end into the inserting tool, positioning the pivot so that the plungers pass through the offset hole, and the hole diametrically opposite, in the pivot flange.

Under tropical conditions it will be found advantageous if the pivot is cooled by being placed in an ice box or a refrigerator to ensure the maximum temperature, and therefore dimensional, difference between the pivot and the heated impeller.

2. Unscrew the spider nut on the centre stud so that the slot in the latter, for key T.75001, will be exposed at the opening in the adapter plate, when the inserting tool and pivot are positioned on the impeller.

3. After about 30 minutes, that is when the impeller has attained the temperature of the oil, remove the impeller from the oil bath, drain and wipe off the surplus oil, lower the impeller on to the cradle trolley, and ensure that it is securely clamped to the cradle.

4. Unscrew and remove the lifting rod.

5. *First operator.* Position the pivot inserting tool, complete with pivot, centre stud, and spider nut, so that the plungers enter the offset pivot-stud hole and the diametrically opposite stud hole, in the impeller, and the pivot enters the impeller bore.

If T.R.134 has been applied, the hollow plungers must be located over the extensions on the special oversize studs in the offset and diametrically opposite positions.

6. *First operator.* Simultaneously with operation 5, the centre stud must be guided into the centre of the adapter plate, which is secured to the back of the impeller, and turned until the slot in the stud aligns with the groove in the adapter plate.

7. *Second operator.* Whilst the first operator is carrying out operations 5 and 6, assist the first operator to align the slot in the centre stud, and, immediately the slot is in line with the groove in the adapter plate, insert key T.75001 to lock the centre stud to the adapter plate.

8. *First operator.* Turn the spider nut, in a clockwise direction, until the pivot is pressed into position in the impeller. The pivot must be pressed into position smoothly and progressively without stopping. If the pivot shows any signs of "picking-up" during this operation, no attempt must be made to force it in; remove it immediately, whilst the impeller is still hot, as described in chapter 24. Before proceeding, the cause of the "picking-up" must be ascertained and rectified. If the impeller bore has been damaged, it will be necessary to fit an oversize pivot by applying T.R.222. When the necessary rectification has been effected, fit the pivot as described in these operations.

9. Ensure that the pivot is fully home in the impeller by attempting to insert a 0·0015 in. feeler between the pivot flange and the impeller (Fig. 1c); this feeler must not enter the joint at any point. The outer portion of the rear face of the pivot flange is cut back so that, when the pivot is fully home in the impeller, there is a recess slightly more than $\frac{3}{64}$ in. wide and $\frac{3}{4}$ in. deep between the edge of the flange and the impeller. The joint referred to is at the bottom of this recess.

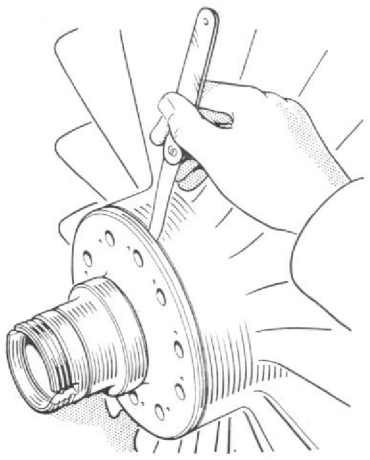


Fig. 1c. Checking that the pivot is fully pressed into the impeller, by attempting to insert a 0·0015 inch feeler.

10. Remove the key, and withdraw the spider nut, inserting tool, and centre stud. Secure the pivot to the impeller by fitting two slave set-screws T.75003. Unscrew the slave bolts and remove the adapter plate from the back of the impeller.

11. *If T.R.134 has been applied,* cut the plain extensions off the special studs, fitted in the offset and diametrically opposite holes.

12. Use a jet of compressed air to clean out all stud and dowel holes.

13. Allow the impeller to cool for a period of at least three hours.

14. Inspect the impeller for damage.

15. Screw lifting eye T.72476 on to the pivot, and, using a suitable hoist, transfer the impeller from the cradle trolley to concentricity fixture T.70438. Remove the lifting eye.

16. Attach a dial test indicator to D.T.I. standard T.74448 and, with its stylus touching the pivot, check that the pivot is concentric within the limits, Fig. 1d.

17. Using the lifting eye and a suitable hoist, return the impeller to the cradle trolley and securely clamp it to the cradle.

18. Remove the two slave set-screws.

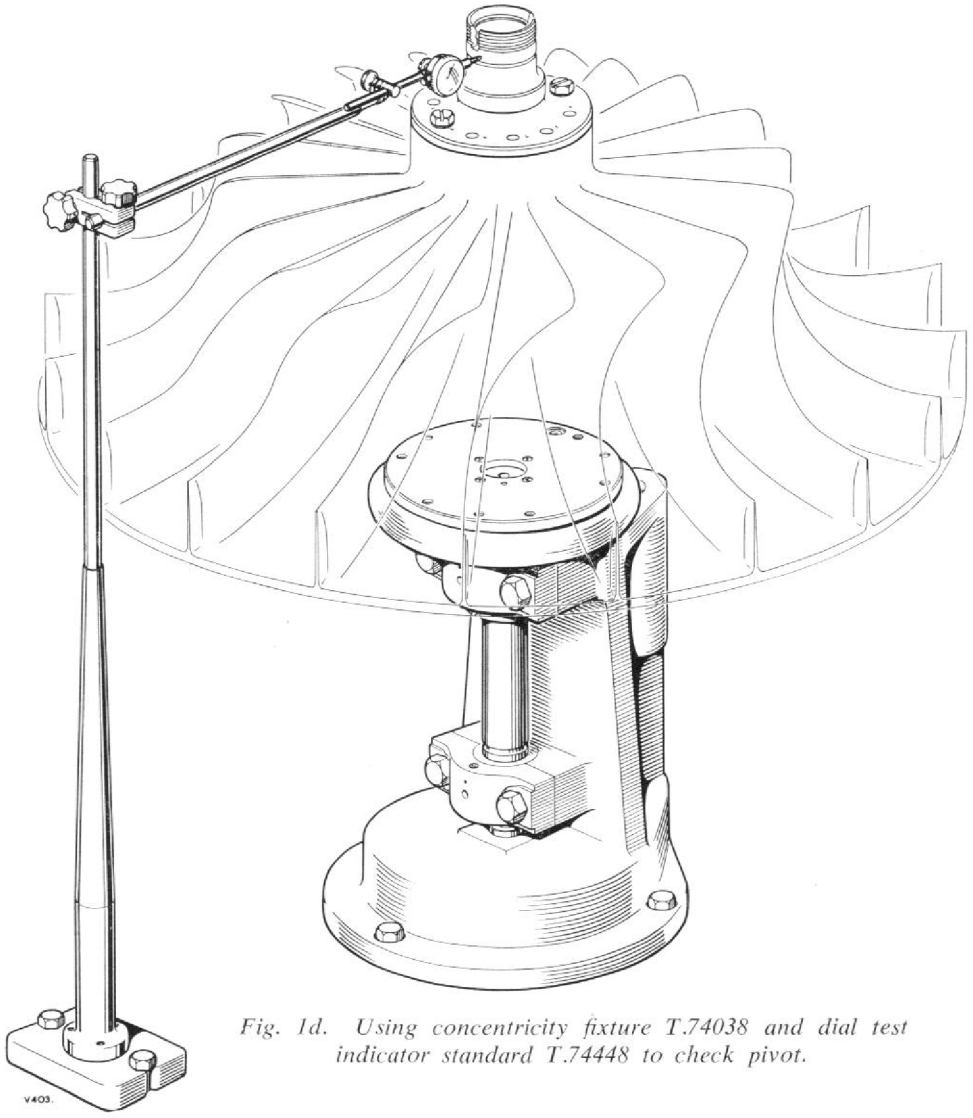


Fig. 1d. Using concentricity fixture T.74038 and dial test indicator standard T.74448 to check pivot.

FITTING PIVOT STUDS (EXCEPT WHERE T.R.134 HAS BEEN APPLIED), TAB WASHERS, NUTS, AND SPLIT PINS.

Before commencing to fit the pivot studs, reference should be made to page 3a. Where T.R.134 has been applied, the oversize stepped studs will have been fitted before the pivot. The pivot studs are numbered in an anti-clockwise direction, when the impeller is viewed from the front, commencing with '1' on the first stud past No. 1 vane. If the studs are not numbered already, they should be marked by etching on the end of the assembled studs, commencing with '1' on the first stud past No. 1 vane in an anti-clockwise direction, and continuing '2', '3', etc., in an anti-clockwise direction around the pivot.

1. Ensure that the stud hole threads are clear, using an appropriate tap if necessary. Smear the fast end of each stud with acid-free tallow. Use $\frac{1}{2}$ in. B.S.F. stud box T.75005 to insert the selected studs.

2. Using ten new tab washers, Part No. N.4491 pre-mod. 254, or N.4504 mod. 254, screw on the ten slotted nuts. Use a suitable torquometer wrench in conjunction with a standard $\frac{1}{2}$ in. B.S.F. socket, to tighten these nuts to the torque loading specified in chapter 22.

3. Check the stud numbering, and re-number as necessary.

4. Lock the nuts by fitting ten new split pins, Part No. SP.9.E.8, paying careful attention to the instructions contained in chapter 22. Lock the ten tab washers in the approved manner.

FITTING CENTRE SHAFT DOWELS

The centre shaft dowels should be an interference fit in the rear face of the impeller. Dam-

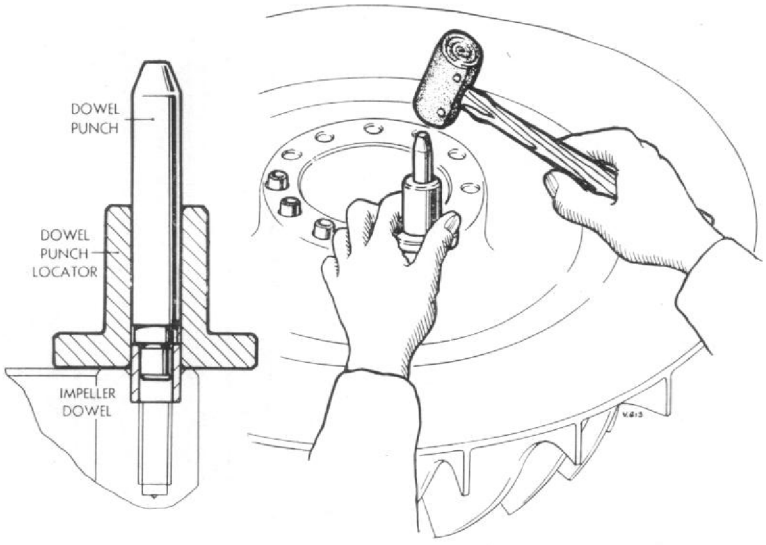


Fig. 1e. Using dowel punch T.76796, guide T.76797, and a hide-faced hammer to drive the centre shaft dowels into the impeller.

aged dowel holes may be rectified in accordance with T.R.111.

1. Swing the cradle through 180 degrees, so that the back of the impeller is uppermost, and lock the cradle in position.

2. Use setting ring T.73136 and a $\frac{1}{2}$ inch to $\frac{7}{8}$ inch John Bull Intercheck small bore gauge to check the diameter of the dowel hole.

3. Select a dowel which will give between 0·001 inch and 0·002 inch interference in the hole ; if necessary apply T.R.111.

4. Use dowel punch T.76796, dowel punch guide T.76797, and a hide-faced hammer, to drive in the selected dowel, Fig. 1e.

5. Repeat the foregoing sequence for each dowel.

FITTING CENTRE SHAFT STUDS

Before commencing to fit the centre shaft studs, reference should be made to page 3a.

1. Ensure that the stud hole threads are clear, using an appropriate tap if necessary. Smear the fast end of each stud with acid-free tallow. Use $\frac{1}{2}$ inch B.S.F. stud box T.75005 to insert the selected studs.

2. Check the stud numbering, and re-number as necessary.

ACCESSORY DRIVE SHAFT PLUG (Fig. 1)

It is most important to ensure that the accessory drive shaft plug and its circlip are correctly fitted. If these parts move out of position whilst the engine is being flown, the accessory drive shaft can slide rearwards and cause a catastrophic failure of the engine ; because the accessory drive shaft transmits the power from the main shaft to drive both the essential engine accessories—fuel pumps, etc.—and the engine-driven aircraft accessories.

1. *If the impeller is received in box trolley T.77555.* Ensure that, at least, two washers and nuts are securely tightened on the studs which secure the pivot. Screw lifting eye T.72476 on to the pivot. Using a suitable hoist, transfer the impeller from the box trolley to cradle trolley T.76578. Securely clamp the impeller to the cradle trolley.

2. Check the fitting and locking of the ten nuts which secure the pivot to the impeller. If necessary, using ten new tab washers Part No. N.4491 pre-mod. 254, or N.4504 mod. 254, screw on the ten slotted nuts. Use a suitable torque wrench in conjunction with a standard $\frac{1}{2}$ in. B.S.F. socket, to tighten these nuts to the torque loading specified in the table in chapter 22. Lock these nuts by fitting ten new split pins Part No. SP.9.E.8, paying careful attention to the instructions contained in chapter 22 ; lock the ten tab washers correctly.

3. Swing the cradle through 180 degrees, so that the back of the impeller is uppermost ; ensure that the cradle is securely locked in this position.

4. Ensure that the counterbore, and the circlip groove, in the after end of the pivot bore are perfectly clean and that there are no burrs or other damage which might prevent the accessory drive shaft plug or the circlip entering their locations correctly.

5. Ensure that the accessory drive shaft plug is perfectly clean, smear it with a thin film of acid-free tallow, position it in the after end of the pivot, hollow side uppermost (to the rear),

and use plug punch T.76762 and a hammer to drive the plug to the bottom of the counterbore.

6. Ensure that the circlip groove is fully exposed beyond the plug, and that this groove is perfectly clean and undamaged.

7. Ensure that a new circlip Part No. N.4172 pre-mod. 258, or N.4250 mod. 258, is perfectly clean, and spring it into the circlip groove in the pivot.

8. Swing the cradle through 180 degrees so that the pivot is uppermost; ensure that the cradle is securely locked in this position.

9. Place one of the two rubber washers, which form part of blanking tool T.78822, over the pivot, followed by the light-alloy distance piece complete with its Schraeder valve adapter, and the second rubber washer; screw the lifting eye tightly on to the pivot to make an air-tight joint. Blanking tool T.78822 consists of lifting eye T.72476 modified to make it air-tight, a pair of rubber washers, and a distance piece fitted with a Schrader valve.

10. Swing the cradle through 180 degrees; ensure that the cradle is securely locked in this position.

11. Pour sufficient kerosene into the bore of the impeller to cover the drive shaft plug.

12. Attach a compressed air line to the Schraeder valve, apply an air pressure of 10 lb. per sq. in. and examine for air leaks which will be disclosed by the appearance of air bubbles in the kerosene; no leakage is permitted.

13. Remove the kerosene and blow out the residue with a jet of compressed air; wipe away any remaining traces of kerosene with a clean rag.

14. Swing the cradle through 180 degrees; ensure that the cradle is securely locked in this position.

15. Release the air pressure in the pivot bore, unscrew the lifting eye and remove the remaining parts of the blanking tool.

REAR BEARING

Temporary assembly of dummy bearing for diffuser casing alignment checks

Dummy rear bearing T.72400 must be temporarily assembled in the rear bearing housing in order that the diffuser casing alignment checks may be carried out as described in chapter 33G.

1. Mount vice block T.76557 in a vice, and clamp the rear bearing housing to the vice block, Fig. 2.

2. Insert dummy bearing T.72400, followed by the sealing housing, into the rear bearing housing; the $\frac{1}{4}$ in. drilling in the periphery of the sealing housing must align with the locking bolt hole in the rear bearing housing, Fig. 3.

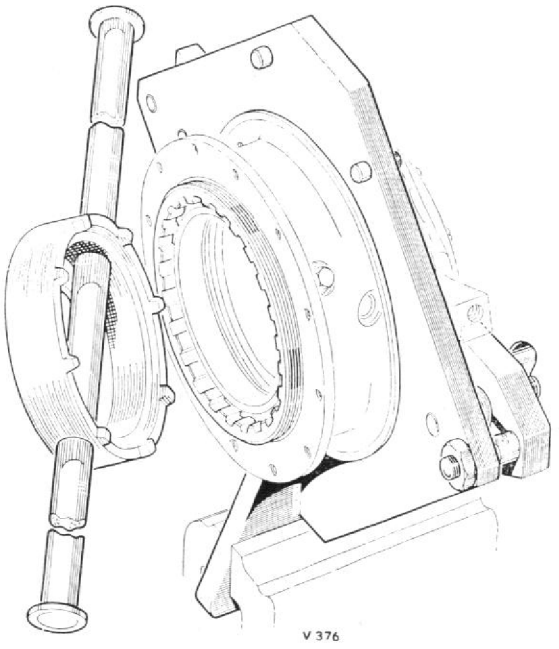


Fig. 2. Spanner T.76556 and vice block T.76557.

3. Using a slave tab washer, Part No. 601424, screw in the sealing housing locking bolt; do not lock this bolt at this stage.

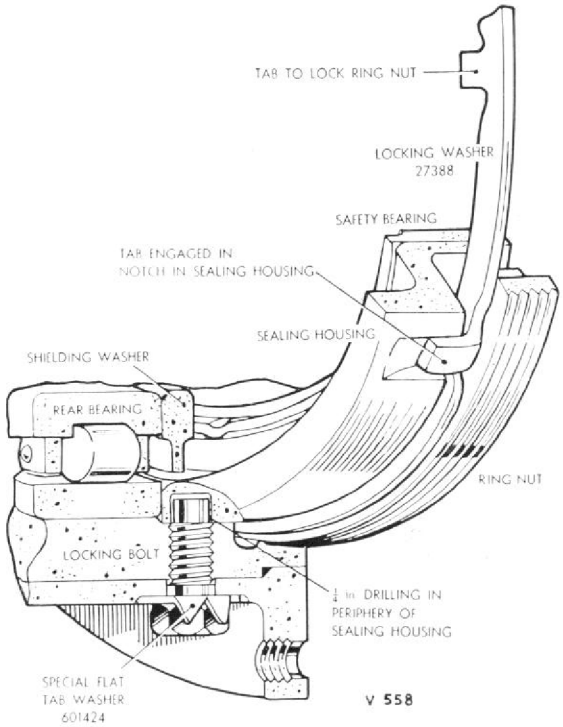


Fig. 3. Sealing housing locking.

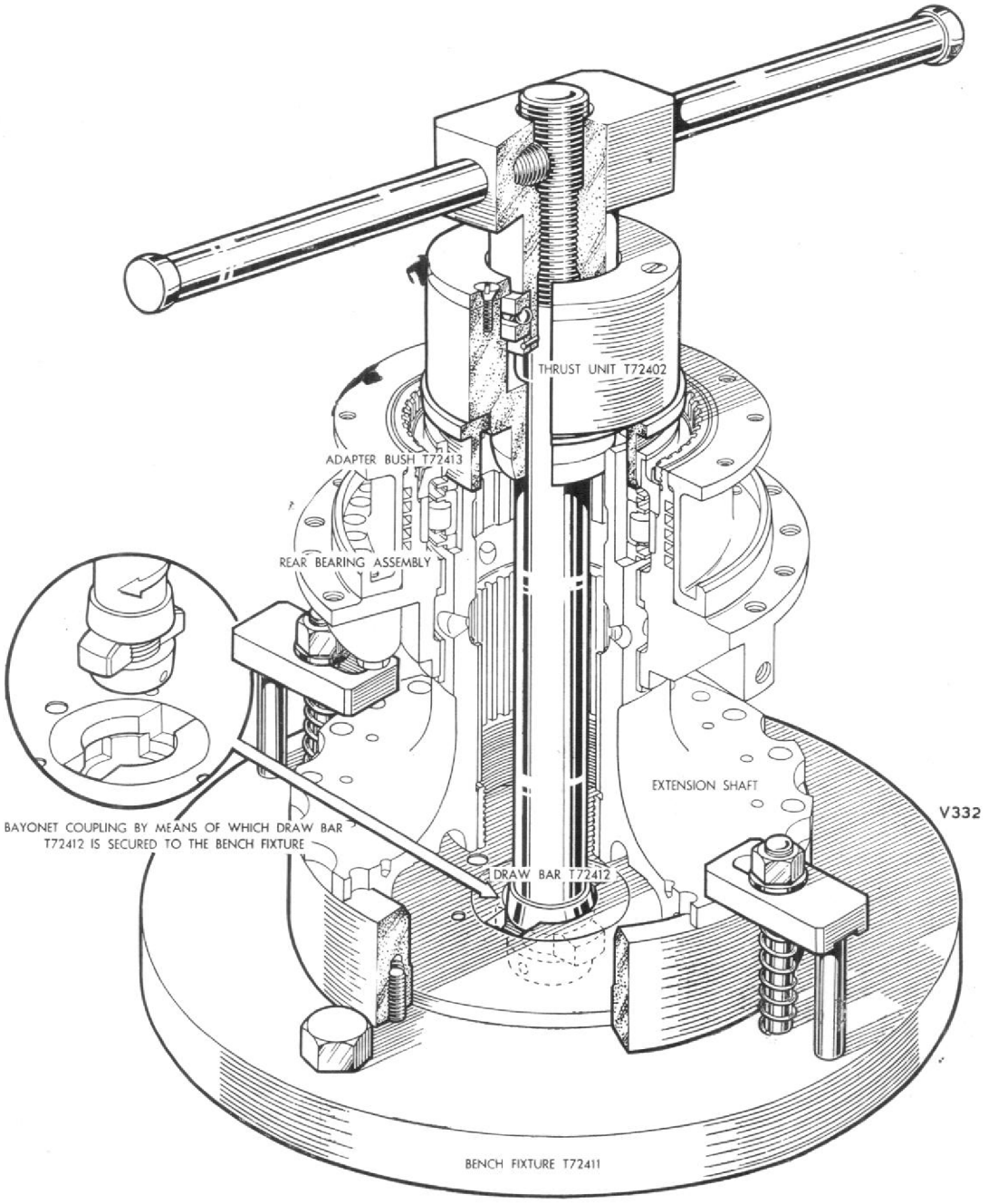


Fig. 4. Pressing rear bearing on to extension shaft.

4. Using a slave locking washer Part No. 27388, screw the ring nut (which is threaded externally) into the rear bearing housing, and use spanner T.76556 to tighten the nut; do not lock the nut at this stage. The tab which projects outwards from the locking washer must engage in the notch cut in the periphery of the sealing housing.

5. Remove the partially assembled sub-assembly from the vice block, and pass it to the operator who checks the diffuser casing alignment.

Final assembly of rear bearing

When the rear bearing housing has been returned after completion of the diffuser casing alignment checks, the dummy rear bearing must be removed and the sub-assembly reassembled with the flight rear bearing.

1. Clamp the rear bearing housing in vice block T.76557, and remove the sealing housing locking bolt and its tab washer. Use spanner T.76556 to unscrew the ring nut. Remove the

locking washer, the sealing housing, and the dummy rear bearing.

2. Position the following parts in the rear bearing housing (refer to Fig. 1 and 3):—

   (a) One of the two shielding washers.

   (b) The complete roller bearing.

   (c) The second shielding washer.

   (d) The sealing housing ; with larger diameter towards the roller bearing, and aligning the $\frac{1}{4}$ in. drilling in the periphery of the sealing housing with the locking bolt hole in the rear bearing housing.

   (e) A new locking washer Part No. 27388 ; the tab which projects outwards must engage in the notch in the sealing housing.

   (f) The ring nut ; having smeared the threads with acid-free tallow, screw in by hand only.

3. Using a new special flat copper tab washer Part No. 601424, screw in the sealing housing locking bolt. Tighten and lock this bolt, Fig. 3. This copper tab washer also acts as an oil seal and, therefore, a new one should be fitted as if the surface of the one used for the temporary assembly is in any way damaged an oil leak could occur.

4. Use spanner T.76556 to tighten the ring nut ; lock this nut.

5. Using new joint washers Part No. AGS.1138D, fit the two cooling oil pipe unions ; lock these unions with 22 S.W.G. (0·028 in. diameter) stainless steel wire.

6. Using new joint washers Part No. N.1493, secure the oil drain and feed banjo connections to the bearing housing with the banjo bolts.

7. *If it has been removed,* secure the cooling air block to the housing with two new tab washers Part No. AGS.518E, and the two bolts ; lock these bolts.

8. Remove the sub-assembly from the vice block.

REAR BEARING AND EXTENSION SHAFT
(Fig. 4 and 5)

1. Place the extension shaft, flange downwards, on bench fixture T.72411, and clamp it to the fixture.

2. Place the rear bearing assembly over the extension shaft, large flange downwards, followed by adapter bush T.72413, positioned so that it bears on the shielding washer and thus on the inner race of the roller bearing.

3. Pass draw bar T.72412 down through the extension shaft, and secure it to the bench fixture by means of the bayonet coupling, inset on Fig. 4.

4. Screw thrust unit T.72402 on to the upper end of the draw bar, and press the rear bearing into position on the extension shaft.

5. Remove the thrust unit, and the adapter bush.

6. Place the distance piece, castellated end uppermost, over the extension shaft ; if necessary, use the thrust unit and the draw bar to press this distance piece home, Fig. 5. Remove the thrust unit, if it has been used, but leave the draw bar in position for the operations which follow.

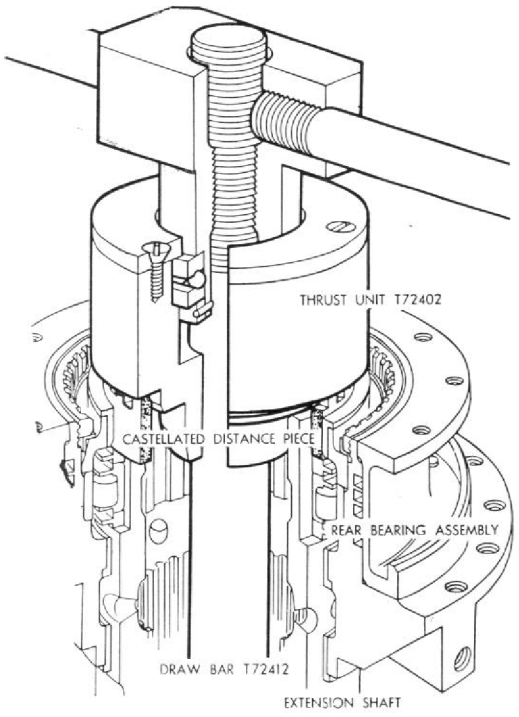


Fig. 5. Pressing distance piece on to extension shaft.

HUB SHAFT AND EXTENSION SHAFT
(Fig. 6)

1. Pass the turbine disc bolt locking ring over the hub shaft until it rests against the front face of the hub shaft flange. When mod. 910 has been embodied, a modified, machined, locking ring replaces the earlier pressed type, and the turbine disc bolts are modified to suit ; ensure that the correct parts are fitted.

2. Insert the eight bolts numbered 2, 3, 4, 5, 7, 8, 9, and 10, through the locking ring and the appropriately numbered holes in the hub shaft flange. The flat which is machined on each

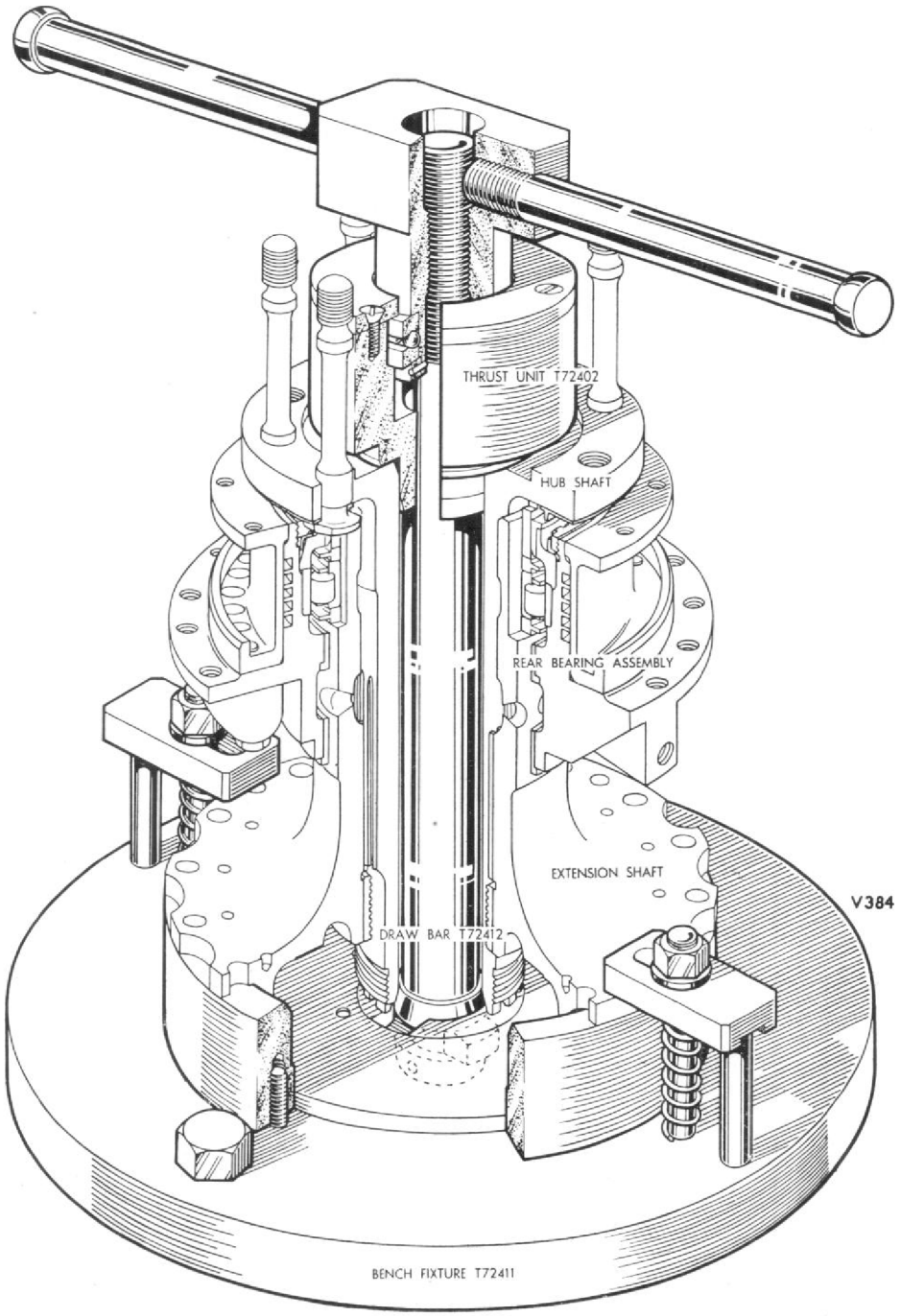


Fig. 6. Pressing hub shaft into extension shaft.

bolt head must bed against the locking ring to prevent the bolt turning when, at a later stage, the nut is fitted and tightened. Temporarily secure these eight bolts with adhesive tape to prevent them dropping out of position when the hub shaft is inverted. Numbers 1 and 6 bolt positions, which are threaded, are for the two bolts which are fitted through the extractor holes in the turbine disc ; these bolts are not fitted at this stage.

3. Enter the hub shaft into the extension shaft, and use draw bar T.72412 and thrust unit T.72402 to press it fully home, Fig. 6.

4. Remove the thrust unit and the draw bar. Release the clamps, and lift the partially assembled sub-assembly off the fixture.

5. Invert the sub-assembly ; place the pressure plate, dished face downwards, over the threaded

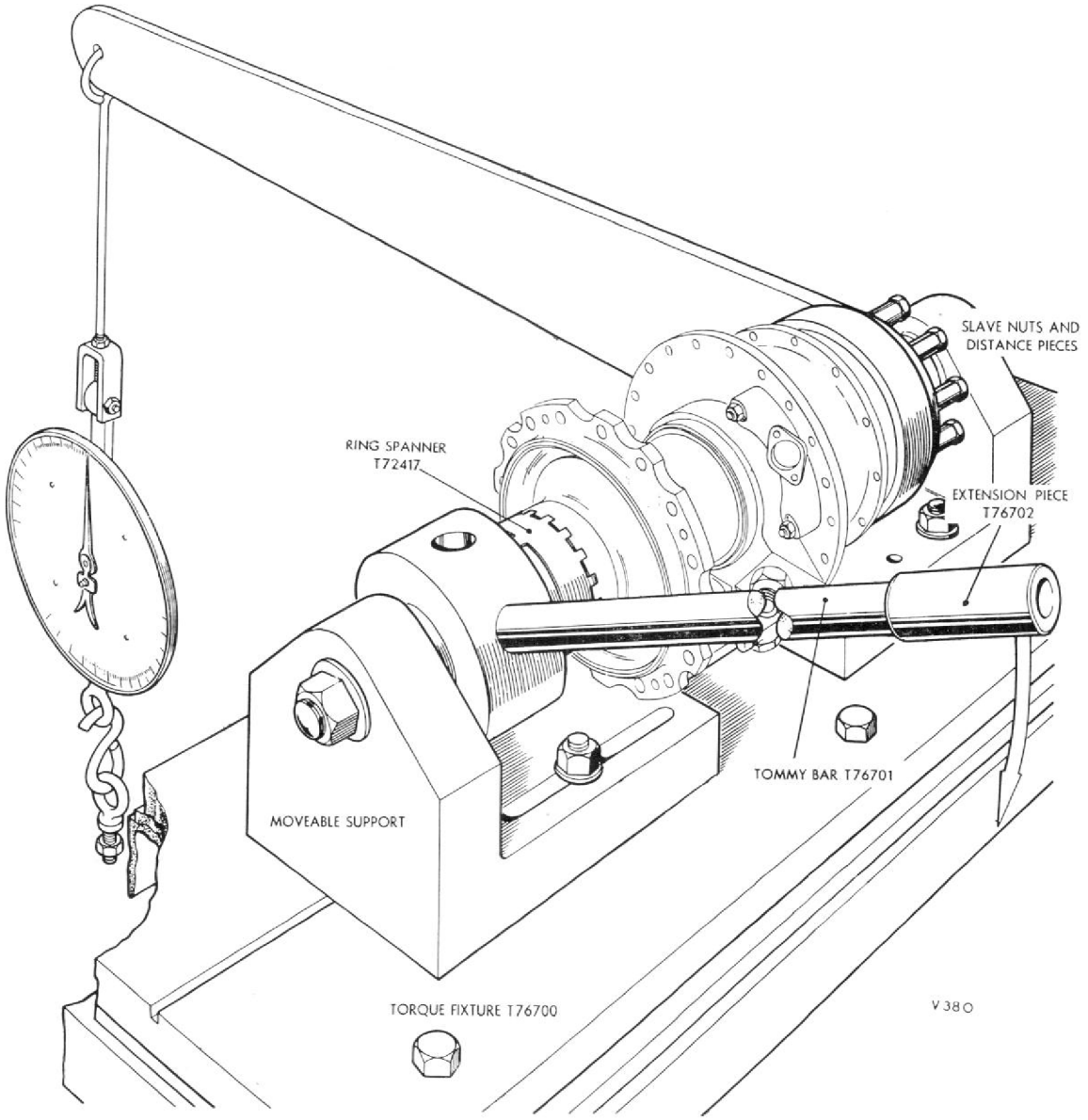


Fig. 7. Tightening hub shaft nut.

end of the hub shaft ; smear the threads of the hub shaft nut with acid-free tallow, and screw it on to the hub shaft, by hand.

6. Transfer the sub-assembly to torque fixture T.76700, which should be mounted on torque fixture stand T.74466 fastened to the floor ; ensure that one of the two location spigots T.72416 is assembled at the spring balance end of the fixture. Slacken the two nuts and slide the moveable support away from the fixed support to permit the sub-assembly to enter the fixture. Pass the turbine bolts through the holes in the flange at the spring balance end of the fixture and secure the assembly to the fixture by means of the eight slave $\frac{17}{32}$ in. distance pieces and $\frac{9}{16}$ in. B.S.F. nuts.

7. Ensure that ring spanner T.72417, and the second location spigot T.72416 are fitted to the moveable end of the fixture and slide this end inwards until the castellations on the ring spanner are firmly engaged with those in the hub shaft nut. Tighten the nuts which secure the moveable end.

8. Use tommy bar T.76701 and extension piece T.76702 to tighten the hub shaft nut to the torque loading specified in chapter 22, Fig. 7. The table in chapter 22 quotes the actual design torque loading. Due to the geometry of the fixture, a reading of 275 $\pm$ 8 lb. on the spring balance is equivalent to the correct torque loading. Although the use of the extension piece increases the effective length of the tommy bar, it will, usually, be found

necessary for two men to operate the tommy bar and extension piece to attain the required torque loading.

9. Slacken the two nuts which secure the moveable end of the torque fixture and slide this end clear of the sub-assembly.

10. Remove the sub-assembly from the torque fixture.

11. Assemble the tab washer by so selecting slots in the hub shaft and the hub shaft nut that the tab washer will drop into place and lock the nut. Spring a new circlip Part No. 21304, into the groove in the nut to retain the tab washer, Fig. 1. As the hub shaft nut locking tab washer is not bent to lock this nut, this tab washer may be re-used indefinitely so long as it is undamaged.

EXTENSION SHAFT AND CENTRE SHAFT

1. Clamp the impeller flange of the centre shaft to floor fixture T.72403.

2. Mount the sub-assembly of the rear bearing, hub shaft, and extension shaft, on the centre shaft. *If necessary,* use centre stud T.72401 and thrust unit T.72402 to press the spigot on the extension shaft into the centre shaft. Ensure that these parts have been assembled correctly and that the mating flanges are in contact at all points around the circumference.

3. Insert the sixteen bolts so that their heads face towards the impeller end of the centre shaft, and the flat on each bolt head beds against the centre shaft. Using sixteen new tab washers Part No. N.3717, fit the sixteen $\frac{3}{8}$ in. B.S.F. plain nuts. Use a suitable torque wrench in conjunction with a $\frac{3}{8}$ in. B.S.F. socket, to tighten these nuts to the torque loading specified in chapter 22. Lock these nuts. When a new extension shaft is to be assembled to the engine's original centre shaft, it will be necessary to fit oversize bolts in accordance with T.R.221 as described in chapter 28.

4. Secure lifting fixture T.74809 to the hub shaft, ensure that the cradle in transport stand T.72419 is in position to receive the centre shaft when vertical and that the clamps have been released, use a suitable hoist, attached to the lifting fixture, to transfer the centre shaft to the stand; this lifting fixture and stand are illustrated in chapter 24. If the centre shaft is to be assembled to the impeller immediately, the latter part of this operation, the whole of the next operation, and operation 2 of the next sequence of operations should be omitted.

5. Clamp the centre shaft to the stand, and remove the lifting fixture.

6. *If the centre shaft has been renewed,* dynamically balance this assembly, as described on page 29.

CENTRE SHAFT AND IMPELLER

Before commencing to assemble the centre shaft to the impeller, make a check to ensure that the pivot-stud tab washers, nuts, and split pins have been fitted in accordance with the instructions given on page 3, Op. 2.

1. *If necessary,* swing the impeller, in the cradle of cradle trolley T.76578, until it is rear face uppermost, secure lifting plate T.72420 to the rear face of the impeller by means of three or four slave nuts on the centre shaft studs, and, using a suitable hoist, transfer the impeller, pivot downwards, to low table T.75876.

2. Swing the centre shaft, in the cradle of transport stand T.72419, until the hub shaft is uppermost. Secure lifting fixture T.74809 to the hub shaft, and hoist the centre shaft out of the stand.

3. Gently lower the centre shaft into position on the impeller.

4. With twelve new tab washers Part No. N.3765, followed by the plain washers Part No. 601714 which were introduced by mod. 1035, secure the centre shaft to the impeller with the twelve nuts. Use a suitable torque wrench in conjunction with a $\frac{1}{2}$ in. B.S.F. socket, to tighten these nuts to the torque loading specified in chapter 22.

5. Fit twelve new split pins Part No. SP.9-E.8, in accordance with the instructions given in chapter 22, and lock the tab washers correctly.

6. Attach the hoist to the lifting fixture on the hub shaft, and return the partially assembled main shaft to transport stand T.72419. Ensure that this assembly is securely clamped to the cradle of the stand, and that the cradle is locked, before disconnecting the hoist.

TURBINE DISC AND HUB SHAFT

1. Remove lifting fixture T.74809 from the hub shaft. Ensure that the turbine disc bolt and nut threads are perfectly clean and that each nut will screw on to the appropriate bolt freely, by hand, for the full length of the thread. Smear the bolt threads with Ragosine L.M. paste. It is essential to make this check before attempting to fit the turbine disc as, when the disc is in position, the bolt heads are inaccessible and a tight nut might cause the bolt to turn and damage the bolt head locking ring, which will necessitate extensive dismantling to renew the locking ring. This is less likely to occur where mod. 910, which introduced a solid machined locking ring, has been embodied.

2. Ensure that the turbine disc is rear face uppermost. *If not already done,* secure combined extractor and lifting fixture T.74810 to the turbine disc, as follows. Position the extractor and lifting fixture on the turbine disc so that

the extractor bolts enter the eccentric nut holes in the disc. Swing the large "C" latches into engagement with the outer extractor bolts, and, using a suitable spanner on the lower, larger, hexagon, screw these bolts into the eccentric nuts until the "C" latches are nipped. *No attempt must be made to use this lifting fixture if the turbine disc is front face uppermost, as in this attitude, the load can pull the eccentric nuts out of the disc, which, if it occurred during the moment of lift, would result in major damage to the disc.*

3. Couple the hoist to the lifting fixture, and hoist the turbine disc out of the felt-lined transport box.

4. Ensuring that the disc will be correctly located relative to the hub shaft, carefully lower the disc into position, Fig. 8 ; take care to ensure that neither the turbine disc bolts, nor the honed holes in the disc, are damaged during this operation.

5. Ensure that the disc is fully home on the hub shaft flange and remove the lifting fixture.

6. Referring to Fig. 9, place two new triple tab washers Part No. 600542 pre-mod. 279 or Part No. 98986 mod. 279, over the turbine disc bolts so that one is centrally located on one of the pair of unoccupied bolt holes, and the second is diametrically opposite. Similarly, place two new double tab washers Part No. 98987, over the remaining bolts, between the two triple tab washers.

7. Having coated their threads with Ragosine L.M. paste, screw on the eight nuts, but do not screw the remaining two turbine disc bolts through the unoccupied holes into the threaded holes in the hub shaft flange, as the driving coupling, which is used to couple the main shaft to the balancing machine drive, is secured by two bolts through these holes. Use a suitable torque wrench in conjunction with a $\frac{1}{2}$ in. B.S.F. socket, to tighten the eight nuts to the torque loading specified in chapter 22 ; tighten these nuts evenly and progressively to ensure that the turbine disc is pulled squarely on to the hub shaft. Do not lock the tab washers as the turbine disc must be removed, after balancing the main shaft, before the main

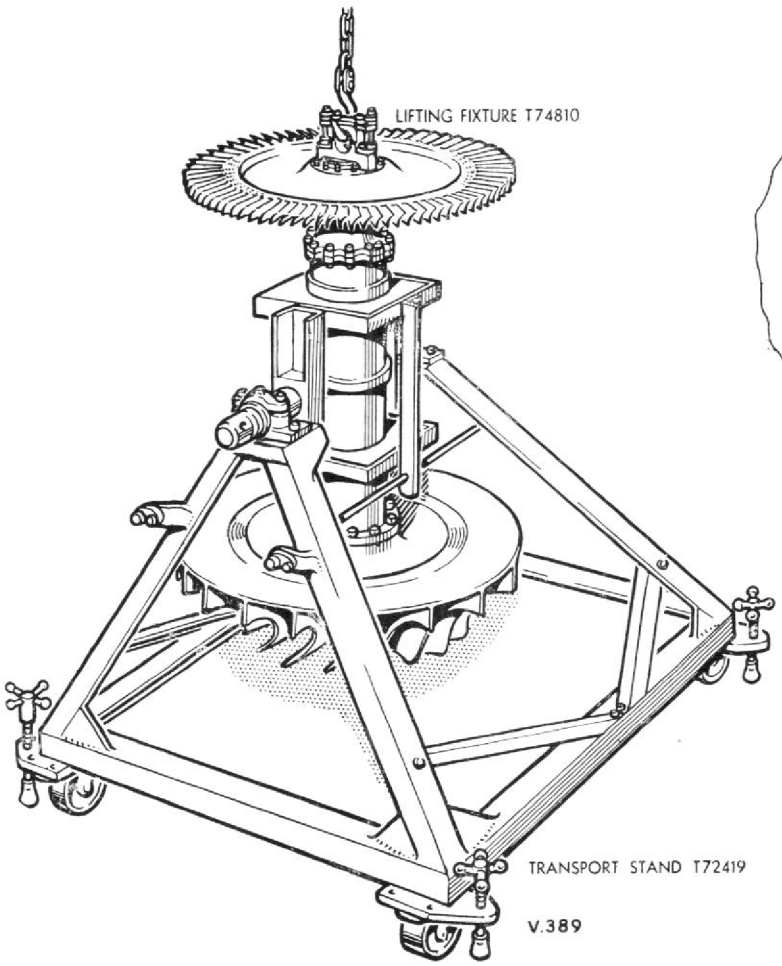


Fig. 8 (left). Lowering turbine disc on to hub shaft.

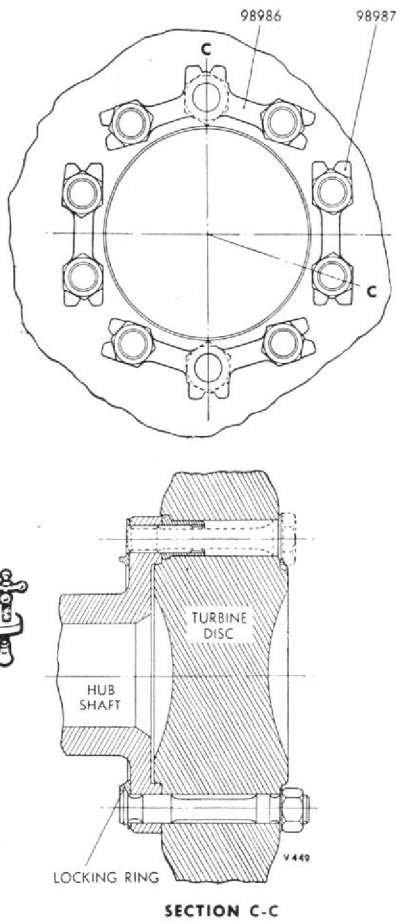


Fig. 9 (right). Arrangement of bolts which secure turbine disc to hub shaft, showing location of locking devices.

shaft can be assembled into the complete engine.

8. Dynamically balance the main shaft assembly as described on pages 11 to 18.

REMOVING TURBINE DISC FROM MAIN SHAFT AFTER DYNAMIC BALANCING

1. Swing the main shaft assembly, in the cradle of transport stand T.72419, through 90 degrees so that the main shaft is vertical, with the turbine disc uppermost.

2. Use combined extractor and lifting fixture T.74810, to remove the turbine disc as described in chapter 23, and place the turbine disc in felt-lined transport box T.72575.

3. Temporarily assemble the tab washers and nuts to the turbine disc bolts; apply adhesive tape to prevent the bolts falling out of position in the hub shaft flange and screw the two remaining turbine disc bolts into the threaded holes in the flange. Blank off the hub shaft with blanking plate T.72422.

DYNAMIC BALANCING

Various types of dynamic balancing machines can be used; for example the British Avery, the American Gisholt, or the German Schenk. This chapter contains instructions for dynamically balancing the main shaft assembly and its components, using the Avery type 7208, 20-2000 lb., electro-dynamic balancing machine, and alternative instructions for using the Gisholt 3 U.J.P. dynetric balancing machine.

The Avery type 7208 balancing machine is suitable, also, for check balancing the complete main shaft assembly without removing that assembly from the engine. Such in situ check balancing is invaluable when investigating certain types of running defects and is essential at the conclusion of a Combined Endurance/Final Bench Test of an overhauled engine; instructions for this check balancing are contained in chapter 36C.

In addition to the Gisholt 3 U.J.P. machine, the Gisholt $4\frac{1}{2}$ U. will accommodate the Ghost main shaft assembly, but the Gisholt 3 U. is only large enough to accommodate the Ghost centre shaft assembly; to obtain the 36-inch swing required for the Ghost impeller, the driving head of the 3 U. must be raised and lengthened auxiliary supports must be fitted. Operators who wish to use balancing machines other than the Avery type 7208 or the Gisholt 3 U.J.P., should ask the Service Department of the de Havilland Engine Company for details of any special equipment required and for advice regarding the changes which must be made to the technique described in this chapter, to suit the different machine.

Balancing main shaft assembly using Avery type 7208, 20-2000 lb., electro-dynamic balancing machine.

Provided that only the original components have been reassembled, and that due attention has been paid to the correlation and alignment marks during assembly, very little rebalancing of the main shaft assembly will be necessary and the following operations will, in practice, be a check of the balance only. If, however, any of the major components have been renewed appreciable amounts of metal may have to be removed to dynamically balance the assembly. Metal may only be removed, for balancing purposes, from the periphery of the impeller backplate and from the balancing rims on the turbine disc; if there is insufficient material available on the rear rim of the turbine disc, due to previous corrections, it may be necessary to remove metal from the rim on the front face of the disc. In certain circumstances, it may be necessary to balance the impeller and pivot as a unit; or the centre shaft complete with extension shaft, rear bearing, and hub shaft; or both. These circumstances are detailed on pages 17, 21, and 29.

Throughout these instructions, the terms "left" and "right" are used on the assumption that the operator is facing the balancing machine with the driving head of the machine on his left; i.e., as the balancing machine is depicted in the illustrations.

SETTING UP MACHINE (Fig. 10)

1. Place one bearing pedestal T.75400 on each vertical support and bolt the pedestals to the supports through the four $\frac{3}{8}$ in. elongated holes which are provided in the base of each pedestal. If the machine is being set up for the first time, great care must be taken to align the bearing pedestals so that they are square to the centre line (working axis) of the balancing machine and concentric with that centre line. When they have been aligned correctly, it is advisable to dowel the pedestals in position, and to mark them so that for each subsequent occasion they can be fitted correctly without difficulty.

2. Engage the dovetail slide of one of the removable adjusters T.75405 into each of the three dovetail slots in the left-hand face of the left pedestal, and similarly, fit three removable adjusters T.75618 in its right-hand face; each 2 B.A. adjusting screw must be fitted so that its head is on the narrower side of the dovetail slide. Unscrew each adjusting screw until its hardened tip is flush with the surface of the slide.

3. Engage the dovetail slide of one of the removable adjusters T.75405 into each of the six dovetail slots in the right pedestal; set the 2 B.A. adjusting screws as described in Op. 2.

4. Place one spherical half bearing shell T.75420 in the pedestal on the right support. Loosely retain it by securing combined lock plate and dial test indicator stand T.75637 to the operator's side of the pedestal, and by securing a keep plate T.75403 to the remote side, by means of the $\frac{5}{16}$ in. B.S.F. socket-headed screws provided; tighten these screws finger-tight only.

5. Place one half bearing T.75606 in the spherical shell, ensuring that the $1\frac{7}{16}$ in. groove in its periphery locates on the spherical shell. Loosely retain it in the shell by securing two keep

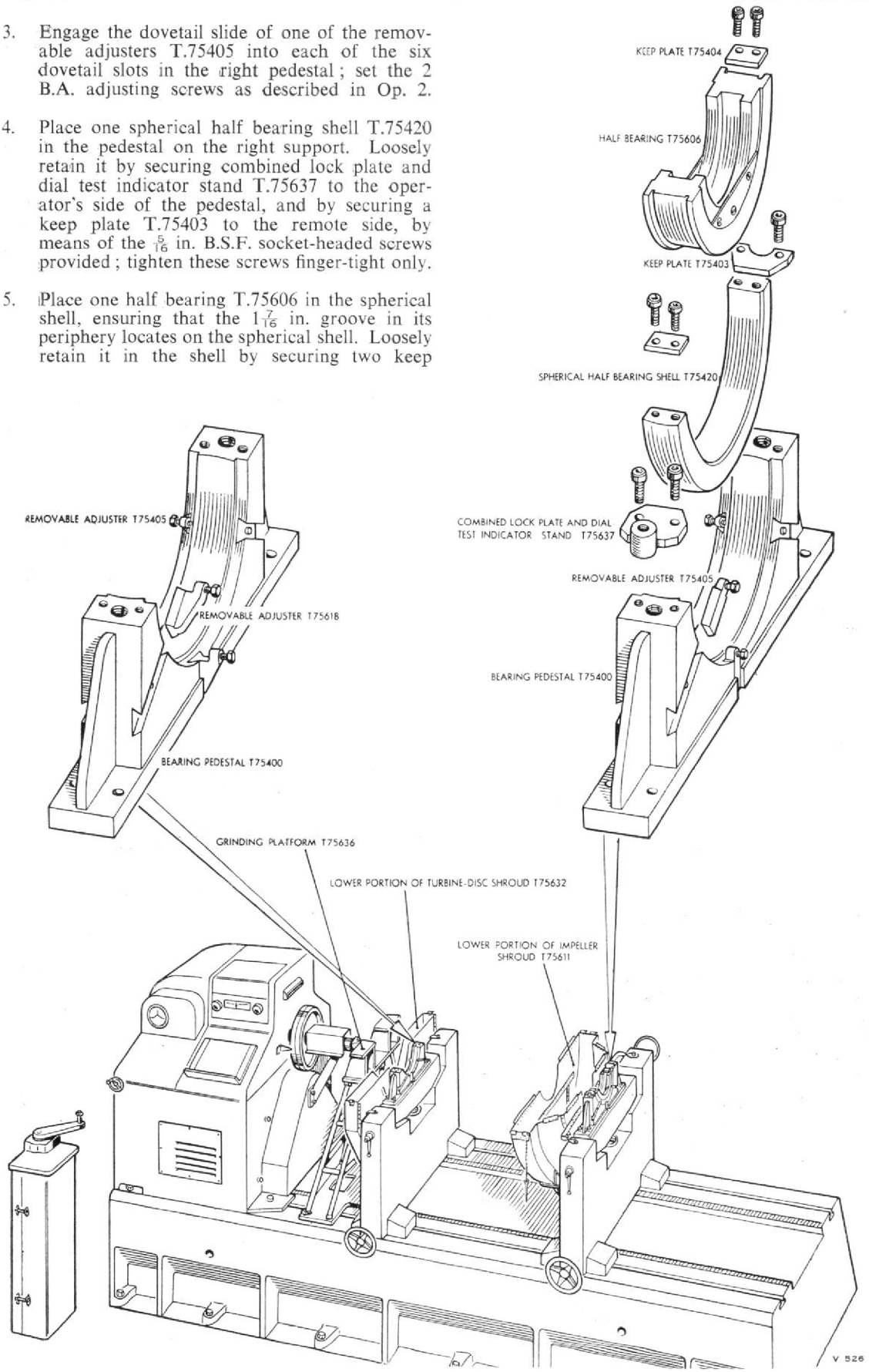


Fig. 10. Setting up Avery type 7208 balancing machine for main shaft assembly.

plates T.75404 to the shell with four $\frac{5}{8}$ in. by $\frac{5}{16}$ in. Whitworth set-screws; tighten these screws finger-tight only. If the half bearing is new and has not been used before, the diameter may have sprung in slightly when it was parted from the rest of the complete ring. This can cause it to nip the outer race of the ball bearing and so cause ovality of the outer race and loss of end float in the bearing; this will seriously affect the accuracy of the balancing operation. Therefore, make a check by applying marking blue to the half bearing and checking the marking on the outer race of the slave ball bearing when it is tried in position. Local high spots should be rectified by grinding the half bearing, using a suitable grinding wheel. A high degree of accuracy and finish are not essential, provided that the ball bearing is not nipped in the half bearing.

6. Using the handles provided, traverse the vertical supports until they are approximately 48 inches between centres.

7. Place the lower portion of impeller shroud T.75611 at the left-hand of the right support (between the two vertical supports adjacent to the right support), and the lower portion of turbine disc shroud T.75632 adjacent to the left support between that support and the driving head of the machine. Do not finally tighten the securing bolts.

8. Mount grinding platform T.75636 on the base of the balancing machine, between the turbine disc shroud and the driving head of the machine, and secure it with the bolts and nuts provided.

PREPARING MAIN SHAFT (Fig. 11 overleaf)

1. Assemble drive coupling T.75624 to the rear face of the turbine disc, ensuring that the projections on the face of the coupling flange fit correctly over the spigot on the turbine disc, and aligning the bolt holes in the coupling with the two unoccupied holes in the disc. Secure this coupling to the main shaft assembly by screwing the two special bolts (T.75628 pre-mod. 279, or T.75629 mod. 279) through the holes in the coupling flange and the turbine disc into the threaded holes in the hub shaft flange; the threads of these bolts should be lubricated with a thin film of Ragosine L.M. paste, and great care must be taken to ensure that the honed holes in the turbine disc are neither scratched nor damaged. Tighten these bolts evenly and progressively to not more than the torque loading specified in chapter 22 for the normal turbine disc bolts.

   The two special bolts must form a pair which are **exactly** *the same weight; no difference in the weights is permissible. If the spigot on the turbine is undersize, use:—*

   T.75625 Drive coupling, 0·005 in. undersize
   T.75626 Drive coupling, 0·010 in. undersize
   T.75627 Drive coupling, 0·015 in. undersize

   Ensure that the tab washers do not foul the drive coupling and so prevent it seating squarely on the turbine disc.

2. Position rear half bearing shell T.75616 between the two flanges of the rear bearing housing, on the sector which is clear of the oil connections and the cooling air block, and align the ten threaded holes in the shell with those in the larger flange on the bearing housing.

3. Position clamping strip T.75619 on the front face of the larger rear-bearing-housing flange so that the eight holes in the clamping strip line up with the corresponding holes in the half shell. Secure the clamping strip and the half shell to the rear bearing housing, using four plain washers and set-screws T.75617; these set-screws will pass through the clearance holes in the clamping strip and through the $\frac{5}{16}$ in. B.S.F. holes in the bearing-housing flange to screw into the $\frac{1}{4}$ in. B.S.F. holes in the half shell; fit one set-screw in each end of the strip and shell, and the other two into the 3rd and 6th holes.

4. Swing the main shaft assembly in the cradle of transport stand T.72419, through 90 degrees, so that the main shaft is horizontal and the cradle clamps are uppermost. Lock the stand cradle.

5. Place adjusting washer T.75631, with the chamfered end of its bore towards the impeller, on to the pivot.

6. Place slave ball bearing T.72461 on to the pivot, and use inserting tool T.75657 and a hide-faced hammer to drive the bearing into position gently.

7. Place distance piece T.75630 on to the pivot, and secure these items by fitting a new cup locking washer, Part No. N.2883, and screwing on the impeller pivot nut; use box spanner T.72785 in conjunction with $\frac{1}{4}$ in. square drive wrench T.73936 to tighten this nut.

MOUNTING MAIN SHAFT IN MACHINE (Fig. 12). *Ensure that the bearing pedestals are locked.**

1. Lower lifting tackle T.72942 into position and attach it to the centre shaft, remove the cradle clamps and hoist the main shaft assembly clear of the stand.

2. Transfer the main shaft assembly to the balancing machine and lower it into position, so that the turbine disc will be towards the driving head of the machine.

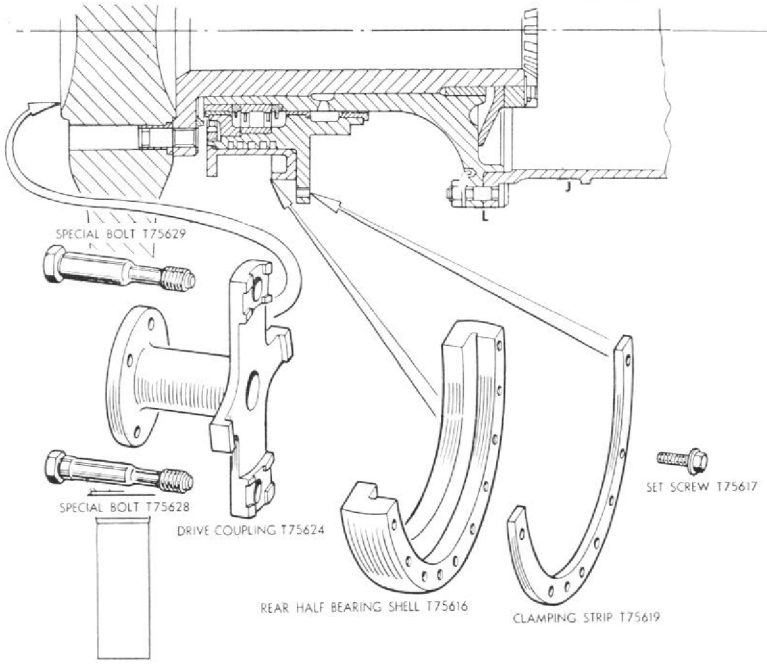
3. As the assembly is lowered into position, guide the slave ball bearing into the half bearing on the right vertical support of the balancing machine, and the rear bearing housing into the

* *When mounting a component in the balancing machine, or when removing it, it is essential to ensure that the balancing machine's bearing pedestals are LOCKED. Failure to do this may result in damage to the machine.*

pedestal on the left support ; making any necessary final adjustments to the positioning of the vertical supports.

4. Loosely secure the rear half bearing shell to the pedestal on the left support by securing combined lock plate and dial test indicator stand T.75637 to the operator's side of the pedestal and by securing a keep plate T.75403 to the remote side, by means of the $\frac{5}{16}$ in. B.S.F. socket-headed screws provided ; tighten these screws finger-tight only.

5. Use feeler gauges to ensure that a clearance is maintained between the safety bearings in the rear bearing housing and the extension shaft—the clearance should be approximately equal all the way round. Use the twelve adjusting screws to finally adjust and align the spherical shells, to ensure that the ball bearing is square with the axis of the shaft, that the safety bearing clearance is maintained, and that the assembly will rotate freely in its bearings. Finally tighten the keep plates. The half bearings should be concentric with the centre line of the balancing machine within 0·002 inch, and the safety bearing clearance should not be less than 0·003 inch. Correct positioning of the main shaft assembly can be checked thus. Release the right support and rock the shaft, using the finger-tip only ; it should be quite free and require very little pressure to push it backwards and forwards between the stops. Lock the right support and repeat this check on the left support.



6. Connect the balancing machine's Cardan shaft to the coupling on the turbine disc by means of the four special bolts and nuts T.75411 ; ensure that the spigot on the Cardan shaft flange fits correctly into the recess in the drive coupling flange, and tighten the nuts evenly. The four bolts and the four nuts must form a set in which all four bolts are the same weight as each other and all four nuts are the same weight as each other, no difference in weights is permissible.

7. Assemble sighting plate T.75641 on the right (impeller) pedestal, and T.75642 on the left (turbine) pedestal.

8. Lubricate both bearings, with clean approved engine oil, and check that the assembly rotates freely, when turned by hand.

9. Screw dial indicator standard base T.72918 into the $\frac{5}{16}$ in. B.S.F. threaded boss on lock plate T.75637 which is fitted to the right support, and, using a dial test indicator supported from this base, check the front face of the pivot flange for swash and the oil seal location on the pivot for eccentricity ; ensure that they are within the limits, and record the readings.

10. Mount dial test indicator standard T.75640 on the bed of the machine between the two supports and, using the dial test indicator supported on this standard, check the impeller and the impeller-end of the centre shaft for swash and eccentricity at the stations specified in the Table of Fits and Clearances ; ensure that they are within the limits, and record the readings. Similarly, check the turbine-end of the centre shaft for eccentricity. These stations are indicated by the letters A to J, and L and N on Fig. 11.

11. Transfer the dial indicator standard base, and the dial test indicator to the lock plate on the left support, and, similarly, check the turbine disc for eccentricity over the tips of the blades and for swash ; ensure that they are within the limits, and record the readings.

12. Place the upper portion of shroud T.75611 over the impeller so that it mates up with the lower portion which has been fitted already (page 13, Op. 7). Rotate the main shaft by hand, through at least one complete revolution, to ensure that the impeller is clear of the shroud at all points ; if necessary, adjust the position of the shroud until the required clearance is obtained. The clearance should not be more than about $\frac{1}{2}$ in. and must be, as nearly as possible, equal at all points—the shroud being concentric with the impeller, and fitting closely around the impeller boss. When

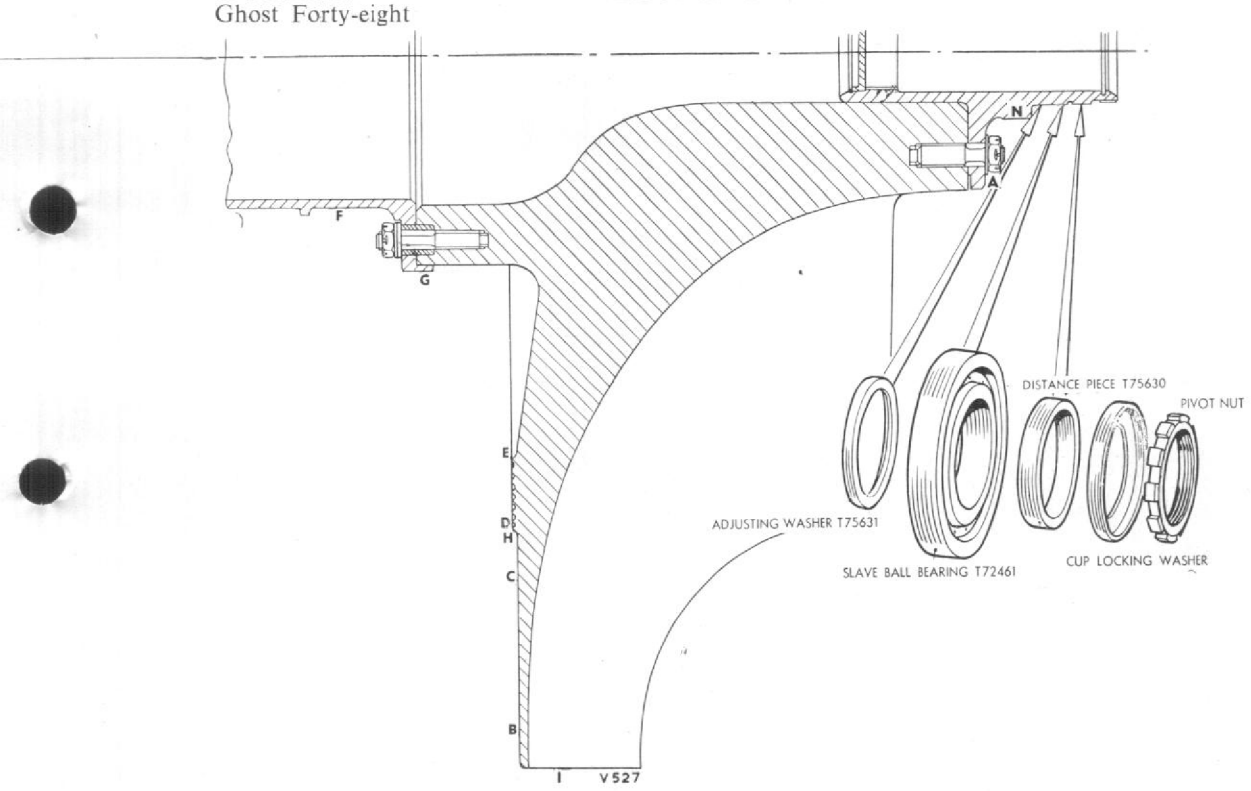


Fig. 11. Preparing main shaft assembly for balancing in Avery type 7208 machine.

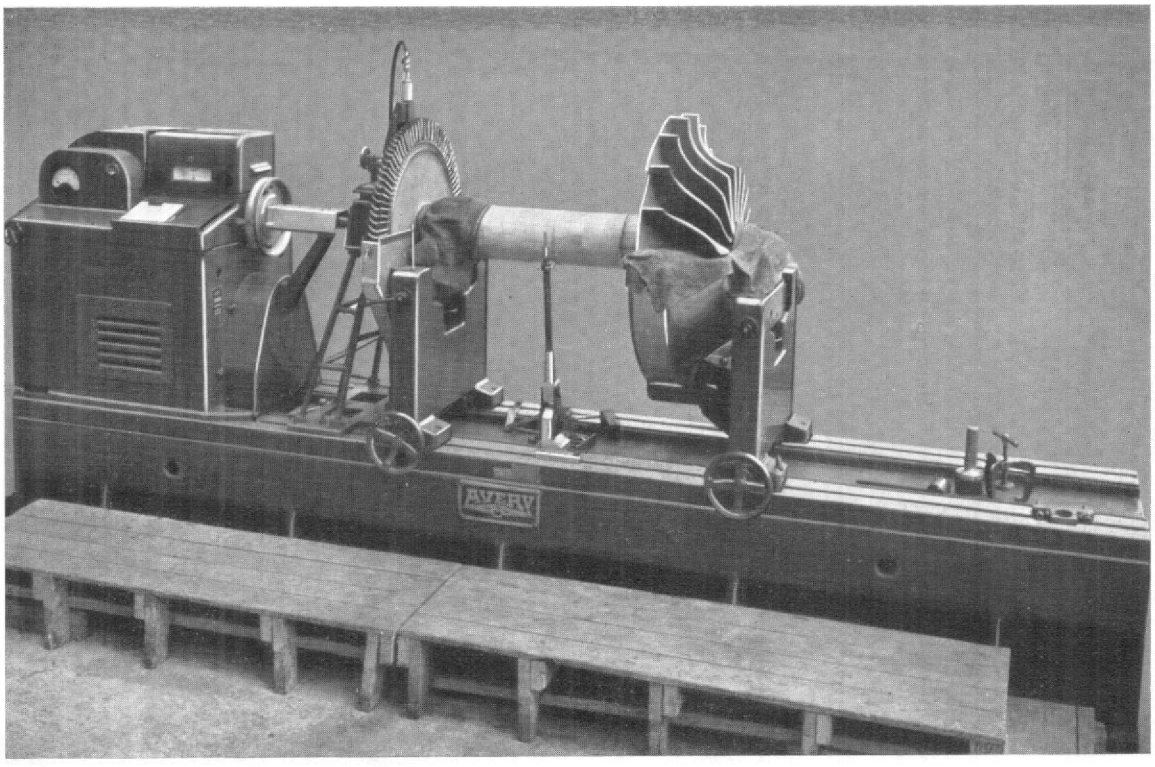


Fig. 12. Main shaft assembly mounted in Avery type 7208 balancing machine.

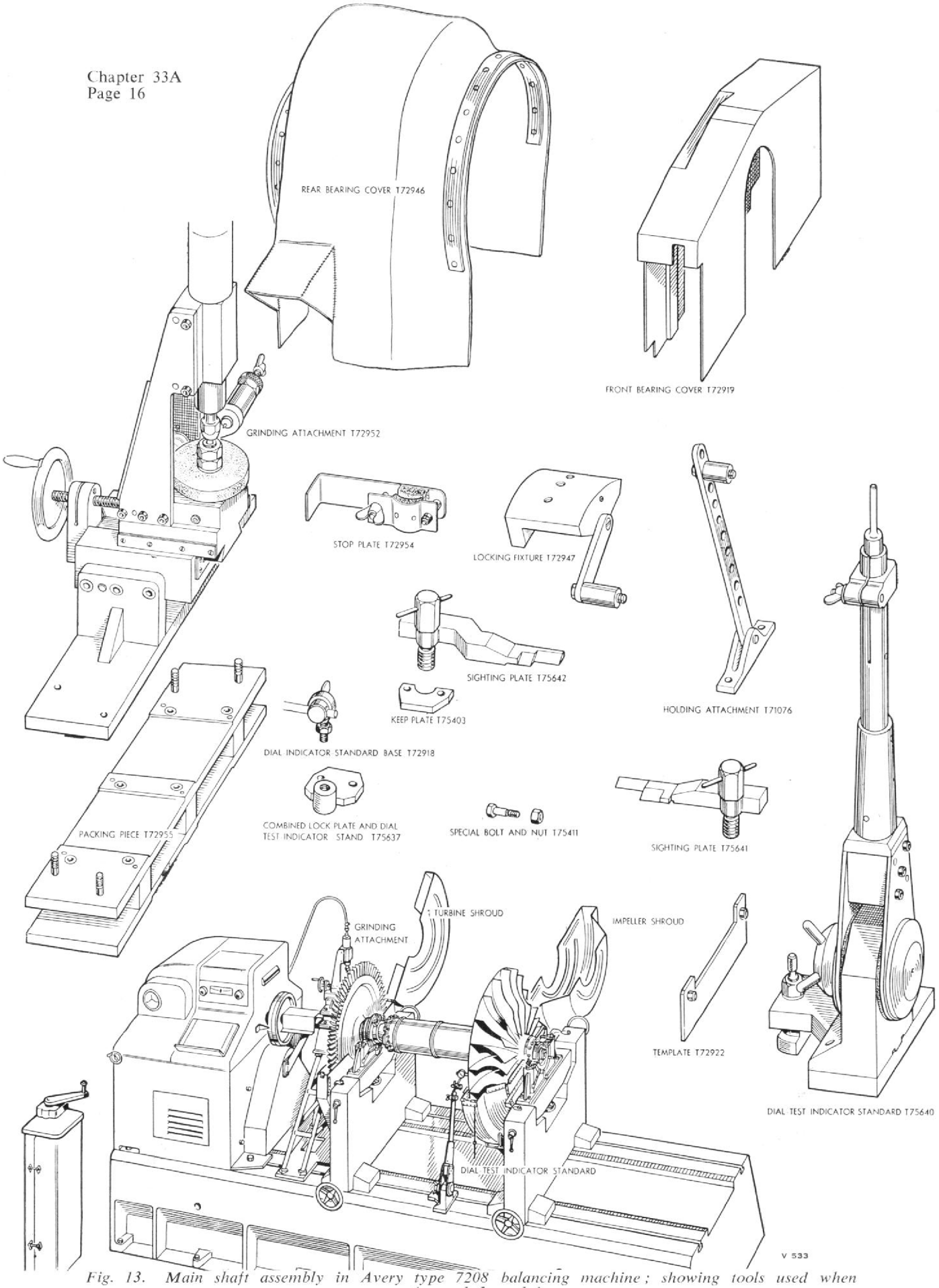


Fig. 13. Main shaft assembly in Avery type 7208 balancing machine; showing tools used when correcting unbalanced forces.

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everything is satisfactory, tighten the bolts and clamps which secure the shroud.

13. Similarly, fit the upper portion of turbine disc shroud T.75632 over the turbine disc.

CORRECTING UNBALANCED FORCES (Fig. 13)

It is assumed that the operator is fully conversant with the operating and setting of the balancing machine, and with the technique of balancing; and that reference will be made, as necessary, to standard text books and to the instructions published by the makers of the balancing machine being used. The unbalanced forces in the main shaft assembly are corrected by removing metal from the periphery of the impeller backplate and from the balancing rim on the rear of the turbine disc; if necessary the rim on the front of the disc may be used. The assembly should be dynamically balanced to within 0·5 gramme at the periphery of the impeller and at the radius of the turbine disc balancing rim. Having ascertained the amount and direction of the unbalanced forces, remove the upper portion of each shroud and mark the impeller and the turbine disc, with chalk, to indicate the points from which metal is to be removed. Where a large amount of unbalance has to be corrected, it is advisable to remove about half the required amount of metal, and to recheck the balance in case the angle of unbalance has changed. If the indicated unbalance at the impeller periphery exceeds 10 grammes, and previous balancing corrections have left little material for further correction at this point, it may be advisable to remove the impeller from the centre shaft and to dynamically balance it and the pivot as a unit, before attempting to correct the unbalance in the complete main shaft assembly. Instructions for balancing the impeller and pivot are contained in pages 21 to 26.

Correcting unbalance at impeller end (right-hand plane)

Unbalance at the impeller end of the main shaft assembly is corrected by removing metal from the periphery of the impeller backplate between adjacent vanes at the unbalanced positions, Fig. 17. Template T.72922, Fig. 13, is provided to act as a guide when removing this metal and to ensure that the limit is not exceeded at any one point. The removal of the maximum permissible amount of metal from any one sector is equivalent to a correction of approximately 3 grammes. If the unbalance is less than 3 grammes, the amount of metal to be removed can be estimated as a proportion of the area exposed above the template. Metal may be removed by hand filing, or by means of a power-driven rotary file, or by any other suitable means. All sharp edges must be eliminated and all file marks and scratches must be polished out, using a rotary polishing bob and metal polish. Finally, the bared surface of the metal must be protected by a coating of Ercalene lacquer.

1. Having removed the upper portion of the impeller shroud, position covers T.72946 and T.72919 over the left and right supports, ensuring that these covers are correctly fitted so as to exclude all swarf and filings.

2. Rotate the impeller, by hand, until the positions from which metal is to be removed, are conveniently situated. Lock the impeller, using holding attachment T.71076 by passing the $\frac{3}{8}$ in. B.S.F. bolt through one of the holes in the attachment and screwing it into one of the threaded extractor holes in the centre-shaft flange; this bolt must not enter the centre-shaft flange for a distance greater than 0·4 in., as if it is screwed in further it will damage the impeller.

3. Cover the open top of the lower portion of the impeller shroud with a sheet, to prevent the ingress of filings and other foreign matter, Fig. 12.

4. Using template T.72922, Fig. 21, remove the requisite amount of metal from the periphery of the impeller backplate.

5. Remove the template and thoroughly clean the impeller, removing all traces of filings and swarf. Remove the holding attachment, the sheet, and the bearing covers. Refit the upper portion of both shrouds.

6. Recheck the balance, and, if necessary, repeat the foregoing instructions until the balance is satisfactory.

Correcting unbalance at turbine end (left-hand plane)

Unbalance at the turbine end of the main shaft assembly is corrected by removing metal from the balancing rim on the rear face of the turbine disc; if there is insufficient material available on the rear rim, due to previous corrections, it is permissible to remove metal from the rim on the front face of the disc. The depth to which metal may be removed from these balancing rims must not exceed the depth of the balancing rim above the general level of the turbine disc, and must be blended smoothly into the remainder of the rim. If a portion of the balancing rim is removed to the maximum depth permissible, the removal of a segment of balancing rim 1 inch in length is equivalent to a correction of about 2·25 grammes.

1. Having removed the upper portion of the turbine disc shroud, position covers T.72946 and T.72919 over the left and right supports, ensuring that these covers are correctly fitted so as to exclude all swarf and abrasive dust.

2. Mount packing piece T.72955 and grinding attachment T.72952 on the grinding platform at the driving end of the machine; the platform is already mounted on the base of the machine—page 13, Op. 8. Secure these items to the platform by means of the studs and nuts provided, Fig. 14.

3. Secure two stop plates T.72954 to the turbine blades, as close to the disc as possible, one on either side of the grinding attachment. These

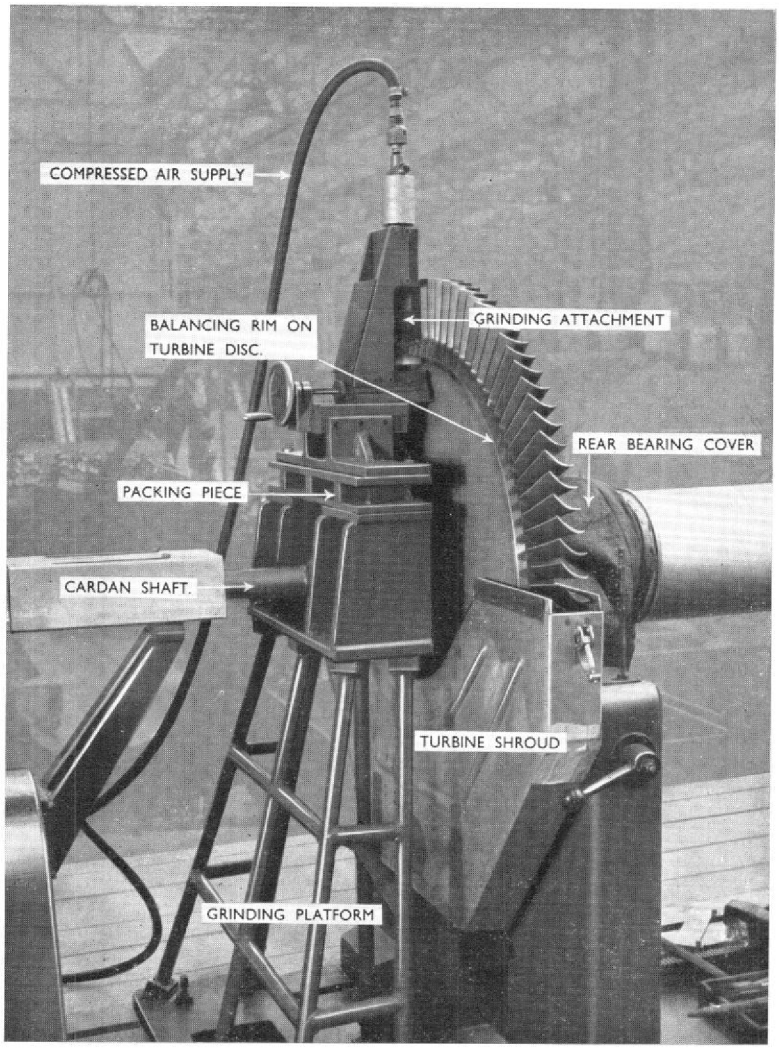


Fig. 14. Grinding attachment used to correct unbalance at turbine end of main shaft assembly.

stop plates should be positioned so that they will limit the arc through which the turbine disc can be rotated according to the amount of metal it is required to remove from the balancing rim. If it is required to hold the main shaft stationary, use locking fixture T.72947, or alternatively holding attachment T.71076.

4. Cover the open top of the lower portion of the turbine disc shroud with a sheet to prevent the ingress of abrasive dust and other foreign matter.

5. Use the grinding attachment to remove the necessary amount of metal from the balancing rim on the turbine disc. If there is insufficient material available on the rear rim of the turbine disc, due to previous corrections, it is permissible to remove metal from the rim on the front face of the disc. This may be done by modifying main base T.75899 and tool post T.75894 as necessary to enable grinding attachment T.72948 to be applied to the front face of the turbine disc, or, alternatively, provided great care is taken, a suitable portable grinding wheel may be used by hand.

6. Remove the grinding attachment, the stop plates, and, if used, the locking fixture. Thoroughly clean the main shaft assembly to remove all traces of filings, swarf, and abrasive dust, and remove the bearing covers, and the sheet.

7. Recheck the balance, and, if necessary, repeat the foregoing operations until the balance is satisfactory.

REMOVING MAIN SHAFT FROM MACHINE. *Ensure that the bearing pedestals are locked.*

1. Remove the upper portion of impeller shroud T.75611 and the upper portion of turbine disc shroud T.75632, and remove the four bolts and nuts which couple the Cardan shaft to the drive coupling on the turbine disc.

2. Remove the two keep plates which secure the rear bearing half shell to the pedestal on the left support and slacken off the six adjusting screws in the left bearing pedestal.

3. Use lifting tackle T.72942 to transfer the main shaft assembly from the balancing machine to cradle trolley T.72419. Ensure that the main shaft is securely clamped in the cradle before removing the lifting tackle.

4. Remove the drive coupling from the turbine disc.

5. Remove the clamping strip, and the half bearing shell, from the rear bearing housing.

6. Use spanner T.72785 in conjunction with $\frac{1}{4}$ in. square drive wrench T.73936 to remove the impeller pivot nut. Remove the cup locking washer and the distance piece, and use extractor T.72475 to draw off the slave ball bearing. Remove the adjusting washer.

7. Eliminate all sharp edges and polish out all grinding or file marks and scratches from the positions where metal has been removed for balancing purposes. Protect the bared surface of the impeller by applying a coating of Ercalene lacquer.

Balancing main shaft assembly using Gisholt, 3 U.J.P., dynetric balancing machine. (Alternative to Avery 7208).

SETTING UP MACHINE

1. Taking great care not to cause damage by bending, disconnect the wires which connect the work supports to the nodal bar and pick-up.

2. *If necessary,* traverse the right-hand work support to the right to enable the two short mandrels T71072. to be removed.

3. Fit the two long mandrels T.71090. These mandrels take the form of $1\frac{3}{4}$ in. diameter tubes and are mounted, parallel to, at the same centre level as, and between the two 5 in. diameter bed bars of the balancing machine. The mandrels are supported in holes provided in the work supports, at $11\frac{1}{4}$ in. centres, equidistant about the centre of the machine, to supplement the main bed bars and to provide a mounting for items such as the impeller shroud. Traverse the right-hand work support as necessary to insert and support these two mandrels.

4. Slacken the six socket-headed screws in each of the two spherical half bearing shells T.72473 and place one shell in each work support. Loosely retain the shells in the supports by securing two locking plates T.72474 to each support by means of four $\frac{1}{4}$ in. B.S.F. socket-headed screws; tighten these screws finger-tight only. Fig. 21 illustrates the arrangement of these parts and those referred to in Op. 5.

5. Place front half bearing T.72914 in the spherical shell on the left-hand support, ensuring that the groove in the periphery of the bearing locates on the shell. Loosely retain the half bearing by securing two keep plates T.76464 to the spherical shell by means of four $\frac{5}{8}$ in. by $\frac{1}{4}$ in. Whitworth set-screws; position these keep plates so that the $\frac{1}{8}$ in. by 0·010 in. lip engages the upper edge of the half bearing; tighten the screws finger-tight only.

6. Using the handles provided, traverse the work supports until the front half bearing and the rear shell are approximately 48 inches between centres; they will then be in about the right positions to receive the slave ball bearing, fitted to the pivot, and the rear bearing housing.

7. *If necessary,* remove the short nodal bar, and substitute the long nodal bar, positioning the right-hand pick-up and the nodal bar supports to suit; use the spanner provided to secure the nodal bar and the pick-up in position.

8. Place the lower portion of impeller shroud T.72471 adjacent to the left-hand work support and lightly clamp its supports to the two mandrels; do not finally tighten these clamps or the steady brackets which are on the front of the shroud until the main shaft has been mounted in the balancing machine.

9. Similarly, mount the lower portion of turbine shroud T.72950 adjacent to the right-hand work support.

10. Mount checking fixture T.72951 on the two mandrels between the impeller shroud and the right-hand work support.

PREPARING MAIN SHAFT

1. Position rear half bearing shell T.72935 between the two flanges of the rear bearing housing, on the sector which is clear of the oil connections and the cooling air block, and align the nine threaded holes in the shell with those in the larger flange on the bearing housing. Secure the half shell to the rear bearing housing with three plain washers and set-screws T.72936; these set-screws will pass through the $\frac{5}{16}$ in. B.S.F. holes in the bearing housing flange and screw into the $\frac{1}{4}$ in. B.S.F. holes in the half shell; fit one set-screw in each end of the shell, and the third into the centre one of the nine holes.

2. Swing the main shaft assembly in the cradle of transport stand T.72419, through 90 degrees, so that the main shaft is horizontal and the cradle clamps are uppermost. Lock the stand cradle.

3. Slide the accessory drive shaft (see below), external serrations first, into the pivot so that these external serrations engage in those within the pivot, and retain it by fitting the spring and spring collar, or sleeve, and circlip as appropriate.

It is permissible to use any of the following alternative combinations:—

Accessory drive shaft	*Spring*	*Spring Collar*	*Sleeve*	*Circlip*
T.72464 or 27543	45865 or Item 16 of T.72929, 30, 31, or 32	27547 or Item 14 of T.72929, 30, 31, or 32	—	40905
	or alternatively (mod. 136)			
91478	—	—	91477	40905
	or alternatively (mod. 154)			
91321	—	—	—	40905

Numbers without the prefix 'T' are engine part numbers—the last shaft (Part No. 91321) being the current engine build standard.

4. Place adjusting washer T.75631, with the chamfered end of its bore towards the impeller, on to the pivot.

5. Place slave ball bearing T.72461 on to the pivot, and use inserting tool T.75657 and a hide-faced hammer to drive the bearing into position gently.

6. Slide locating coupling T.72460 over the pivot, and, using spanner T.72463, screw coupling nut T.72462 on to the pivot threads.

7. Engage the serrations on driving coupling T.72459 with the internal serrations in the accessory drive shaft, aligning the four half holes in the periphery of the coupling flange with the elongated holes in the locating coupling.

MOUNTING MAIN SHAFT IN MACHINE

1. Lower lifting tackle T.72942 into position and attach it to the centre shaft, remove the cradle clamps and hoist the main shaft assembly clear of the stand.

2. Transfer the main shaft assembly to the balancing machine and lower it into position, so that the impeller will be towards the driving head of the machine.

3. As the assembly is lowered into position, guide the slave ball bearing into the half bearing on the left-hand work support of the balancing machine, and the rear bearing housing into the spherical shell on the right-hand support; making any necessary final adjustments to the positioning of the work supports.

4. Loosely secure the rear half bearing to the spherical shell by means of two keep plates T.76464 and four $\frac{5}{8}$ in. by $\frac{1}{4}$ in. Whitworth setscrews; position these keep plates so that the $\frac{1}{8}$ in. by 0·010 in. lip engages the upper edge of the half bearing; tighten these screws finger-tight only.

5. Use feeler gauges to ensure that a clearance is maintained between the safety bearings in the rear bearing housing and the extension shaft—the clearance should be approximately equal all the way round. Use the twelve adjusting screws to finally adjust and align the spherical shells, ensure that the ball bearing is square with the axis of the shaft, that the safety bearing clearance is maintained, and that the assembly will rotate freely in its bearings. Finally tighten the keep plates.

6. Connect up the machine drive, using four slave nuts, with captive washers, T.71075; ensure that these nuts are tightened evenly.

7. Reconnect the wires betwen the nodal bar and the work supports; ensure that the work supports are free.

8. Turn the rotating protractor of the machine to zero, and, in line with the sighting lines, make a chalk mark on the front and rear flanges of the centre shaft, to act as a zero datum.

9. Lubricate both bearings, with clean approved engine oil and check that the assembly rotates freely, when turned by hand. Adjust the position of the lower portion of the impeller and turbine shrouds as necessary and clamp them in position.

10. Ensure that the pick-up wires, nodal bar, and pick-ups are correctly positioned and connected, and that the moving parts can move freely.

11. Screw dial indicator standard base T.72918 into the $\frac{5}{16}$ in. B.S.F. hole in lock plate T.72474 which is fitted to the left-hand work support and, using a dial test indicator supported from this base, check the front face of the impeller for swash and eccentricity. Transfer the dial test indicator to checking fixture T.72951 and check the rear face of the impeller. Transfer the standard base T.72918 to the right-hand work support, and, supporting the dial test indicator from this base, check the turbine disc. Record both swash and eccentricity, and ensure that they are within the limits at all points.

12. Place the upper portion of shroud T.72471 over the impeller so that it mates up with the lower portion which has been fitted already. Rotate the main shaft by hand, through at least one complete revolution, to ensure that the impeller is clear of the shroud at all points; if necessary, adjust the position of the shroud until the required clearance is obtained. When everything is satisfactory, tighten the bolts and clamps which secure the shroud.

13. Similarly, fit the upper portion of turbine disc shroud T.72950 over the turbine disc.

CORRECTING UNBALANCED FORCES

The unbalanced forces in the main shaft assembly should be corrected in a similar manner to that described on pages 17 and 18, with the following exceptions. Use covers T.72919 and T.72920 to protect the bearings. Attach holding attachment T.71076 to the bracket provided on the rear face of the impeller shroud. Before commencing to carry out Op. 2 on page 17, use the four $\frac{1}{2}$ in. Whitworth screws to bolt grinding attachment platform T.72953 to the front bar carriage of the rear work support, and clamp the platform to the rear bar by means of the clamp and hand nut provided.

REMOVING MAIN SHAFT FROM MACHINE

1. Remove the upper portion of impeller shroud T.72471 and the upper portion of turbine disc shroud T.72950, and uncouple the drive.

2. Remove the two keep plates which secure the rear half bearing to the spherical shell.

3. Use lifting tackle T.72942 to transfer the main shaft assembly from the balancing machine to cradle trolley T.72419. Ensure that the main shaft is securely clamped in the cradle before removing the lifting tackle.

4. Remove driving coupling T.72459, and use spanner T.72463 to unscrew coupling nut T.72462. Use extractor T.72475 to draw off the slave ball bearing and remove the adjusting washer. Extract the circlip from the front of the pivot and remove the accessory drive shaft together with the sleeve or spring collar and spring as appropriate.

5. Remove the three set-screws and the half shell from the rear bearing housing.

6. Eliminate all sharp edges and polish out all grinding or file marks, and scratches, from the positions where metal has been removed for balancing purposes. Protect the bared surface of the impeller by applying a coating of Ercalene lacquer.

Balancing impeller using Avery type 7208, 20-2000 lb., electro-dynamic machine.

Normally, during overhaul, the impeller and pivot need not be dynamically balanced as a separate unit, even after renewal of the pivot; any unbalance of the impeller being corrected in conjunction with the complete main shaft assembly. An exception may have to be made, however, where previous balancing corrections at the periphery of the impeller backplate have left little material for further corrections. In such instances, if, when dynamically balancing the complete main shaft assembly, the indicated unbalance at the impeller periphery is greater than 10 grammes, it may be advisable to remove the impeller from the centre shaft and to dynamically balance the impeller and pivot as a unit, before attempting to correct the unbalance in the complete main shaft assembly. Any replacement impeller will have been dynamically balanced before its dispatch from the manufacturers. Throughout the following operations, scrupulous cleanliness must be maintained as even small particles between mating faces may destroy the necessary precise alignments. Therefore, before assembling any item, ensure that it is perfectly clean.

SETTING UP MACHINE (Fig. 15 overleaf)

1. Place one bearing pedestal T.75400 on the left vertical support, and the second on the right support. Bolt the pedestals to the supports through the four $\frac{3}{8}$ in. elongated holes which are provided in the base of each pedestal. If the machine is being set up for the first time, great care must be taken to align the bearing pedestals so that they are square to the centre line (working axis) of the balancing machine and concentric with that centre line. When they have been aligned correctly, it is advisable to dowel the pedestals in position, and to mark them so that for each subsequent occasion they can be fitted correctly without difficulty.

2. Engage the dovetail slide of one of the twelve removable adjusters T.75405 into each of the twelve dovetail slots, three of which are machined in each side of both pedestals; each 2 B.A. adjusting screw must be fitted so that its head is on the narrower side of the dovetail slide. Unscrew each adjusting screw until its hardened tip is flush with the surface of the slide.

3. Place one spherical half bearing shell T.75420 in the pedestal on the left support, and the second in the pedestal on the right support. Loosely retain the right half bearing shell by securing two keep plates T.75403 to the pedestal by means of the $\frac{5}{16}$ in. B.S.F. socket-headed screws provided. Loosely retain the left half bearing shell by securing combined lock plate and dial test indicator stand T.75637 to the operator's side of the pedestal, and by securing a keep plate T.75403 to the remote side. Tighten the socket-headed screws finger-tight only.

4. Place one half bearing T.75606 in the spherical shell on the left support, and the second on the right support; ensure that the $1\frac{7}{16}$ in. groove in the periphery of the half bearing locates on the spherical shell. Loosely retain each half bearing in its shell by securing two keep plates T.75404 to each shell by means of four $\frac{5}{8}$ in. by $\frac{5}{16}$ in. Whitworth set-screws; tighten these screws finger-tight only. If either of the half bearings is new and has not been used before, the diameter may have sprung in slightly when it was parted from the rest of the complete ring. This can cause it to nip the outer race of the ball bearing and cause ovality of the outer race and loss of end float in the bearing, this will seriously affect the accuracy of the balancing operation. Therefore, make a check by applying marking blue to the half bearing and checking the marking on the outer race of the slave ball bearing when it is tried in position. Local high spots should be rectified by grinding the half bearing, using a suitable grinding wheel. A high degree of accuracy and finish are not essential, provided that the ball bearing is not nipped in the half bearing.

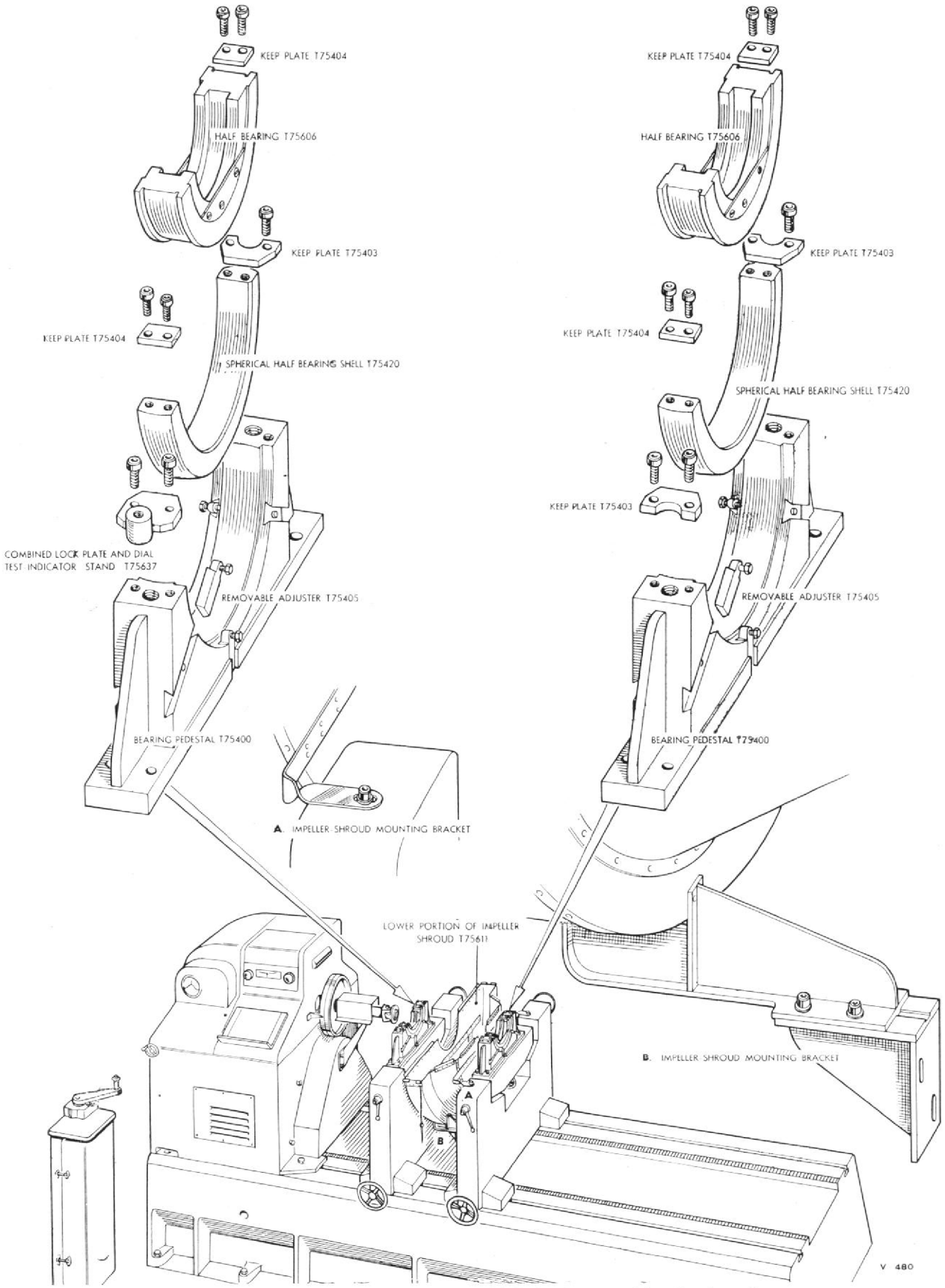


Fig. 15. Setting up Avery type 7208 balancing machine for impeller.

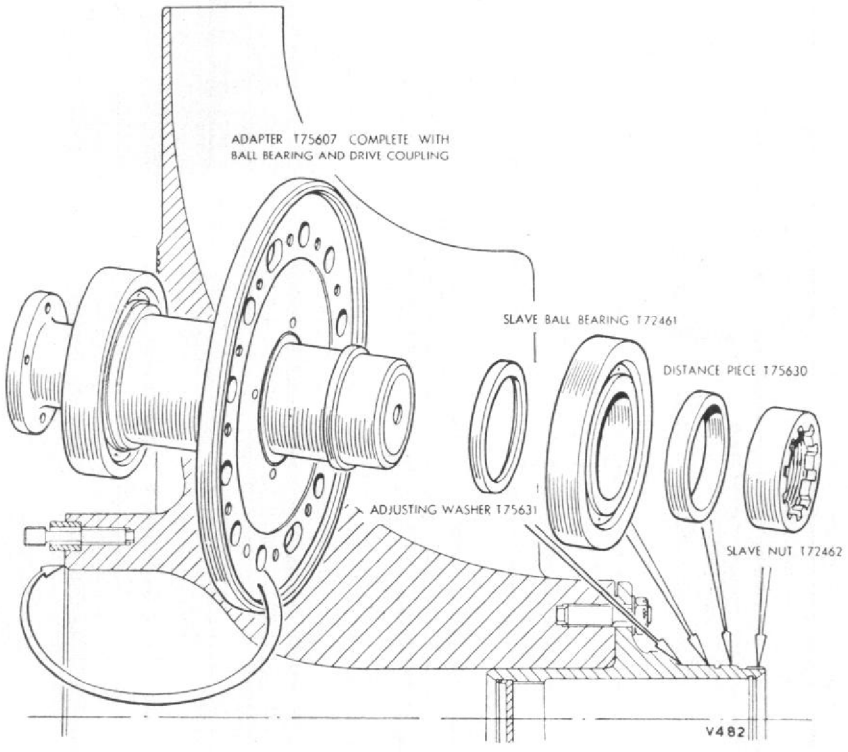


Fig. 16. Preparing impeller for balancing in Avery type 7208 machine.

5. Using the handles provided, traverse the vertical supports until the half bearings are approximately 21½ inches between centres ; the half bearings will then be in about the right positions to receive the slave ball bearings fitted to the pivot and the adapter.

6. Place the lower portion of impeller shroud T.75611 between the two vertical supports and secure it to the right vertical support by means of the brackets and screws provided—see A and B on Fig. 15. Do not finally tighten the securing bolts.

PREPARING IMPELLER (Fig. 16)

1. *If necessary,* use lifting eye T.72476 to place the impeller in cradle trolley T.76578, as described on page 3, Op. 1. Swing the cradle through 180 degrees, so that the pivot is uppermost, and lock the cradle in position. Remove the lifting eye.

2. Place adjusting washer T.75631, with the chamfered end of its bore towards the impeller, on to the pivot.

3. Place slave ball bearing T.72461 on to the pivot, and use inserting tool T.75657 and a hide-faced hammer to drive the bearing into position gently.

4. Place distance piece T.75630 on to the pivot, and secure these items by screwing on slave nut T.72462 ; use spanner T.72463 to tighten the slave nut.

5. Swing the cradle through 180 degrees, so that the rear face of the impeller is uppermost, and lock the cradle in position.

6. Position adapter T.75607, complete with its ball bearing and drive coupling, over the centre shaft studs in the rear face of the impeller ; the recess in this adapter fits over the spigot on the impeller. Secure the adapter with twelve slave washers and nuts, which must be of identical weight. *If the impeller spigot is undersize, use :—*

T.75608 Adapter, 0·010 in. undersize
T.75609 Adapter, 0·020 in. undersize
T.75610 Adapter, 0·030 in. undersize

MOUNTING IMPELLER IN MACHINE.
Ensure that the bearing pedestals are locked.

1. Swing the cradle, of cradle trolley T.76578, through 90 degrees so that the cutaway portion of the cradle is uppermost and the impeller is in its normal installed attitude.

2. Taking care that neither slave ball bearing is damaged, pass a suitable rope sling round the plain portion on the adapter at the rear of the impeller and a second rope sling round the boss on the front of the impeller. Couple these slings to either end of lifting sling T.75892, and, using a suitable hoist, transfer the impeller from the cradle trolley to the balancing machine ; the rear face of the impeller must be towards the driving head of the machine.

3. As the impeller is lowered into position, guide

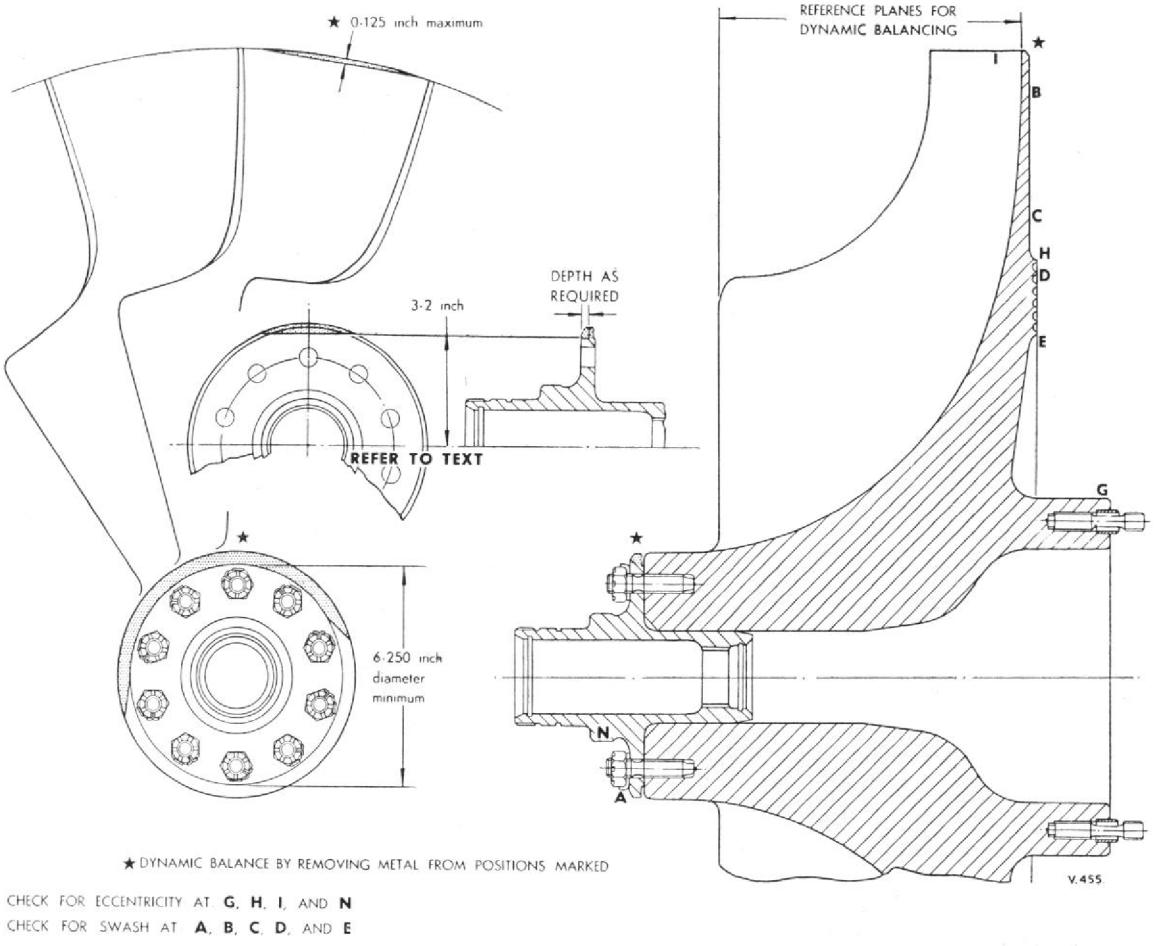


Fig. 17. Reference planes and limits for balancing impeller.

the ball bearings into the half bearings on the vertical supports of the balancing machine; making any necessary final adjustments to the positioning of the vertical supports.

4. Using the twelve adjusting screws, finally adjust and align the spherical shells; ensuring that the impeller will rotate freely in the two ball bearings. Finally tighten the keep plates.

5. Screw dial indicator standard base T.72918 into the $\frac{5}{16}$ in. B.S.F. threaded boss on lock plate T.75637 which is fitted to the left support. Using a dial test indicator supported from this base, check the rear face of the impeller for swash and eccentricity at the stations specified in the Table of Fits and Clearances, and ensure that it is within the limits; these stations are indicated by letters on Fig. 17. Similarly, check the pivot.

6. Place the upper portion of impeller shroud T.75611 over the impeller so that it mates up with the lower portion which has been fitted already. Rotate the impeller by hand, through at least one complete revolution, to ensure that it is clear of the shroud at all points; if necessary, adjust the position of the shroud until the required clearance is obtained. The clearance should not be more than about $\frac{1}{2}$ in. and must be, as nearly as possible, equal at all points—the shroud being concentric with the impeller, and fitting closely around the impeller boss. When everything is satisfactory, tighten the bolts and clamps which secure the shroud.

7. Lubricate the slave ball bearings with clean approved engine oil, and check that the impeller rotates freely. The half bearings should be concentric with the centre line of the balancing machine within 0·002 inch. Correct positioning of the impeller and pivot can be checked thus. Release the right support and rock the pivot, using the finger-tip only; it should be quite free and require very little pressure to push it backwards and forwards between the stops. Lock the right support and repeat this check on the left support.

8. Couple up the machine drive, using special bolts and nuts T.75411.

CORRECTING UNBALANCED FORCES
(Fig. 17 and 18)

As stated already, it is assumed that the operator is fully conversant with the operating

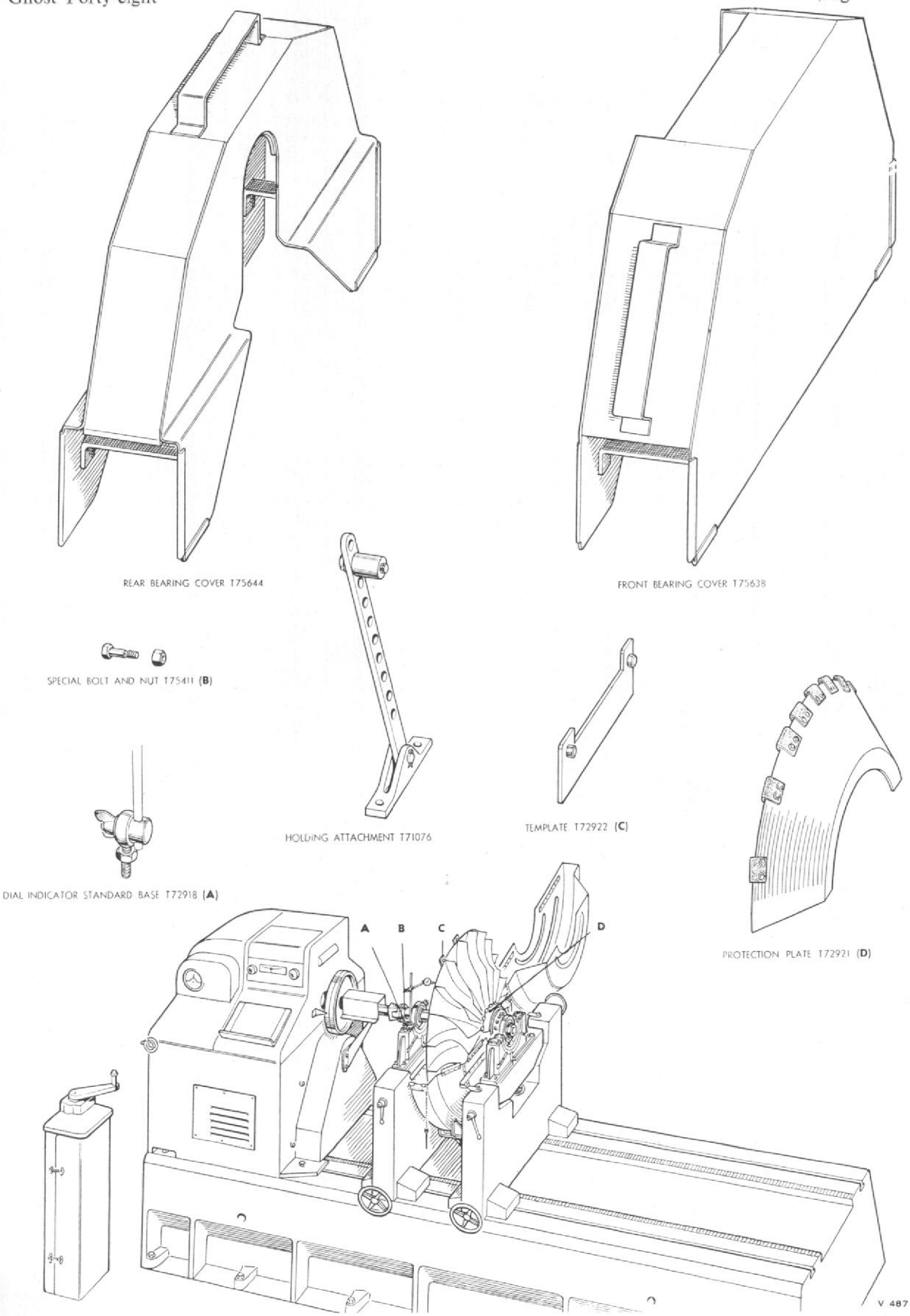


Fig. 18. Impeller in Avery type 7208 balancing machine; showing tools used when correcting unbalanced forces.

and setting of the balancing machine, and with the technique of balancing.

The unbalanced forces in the impeller are corrected by removing metal from the periphery of the impeller backplate, between adjacent vanes at the unbalanced positions, and from the periphery of the pivot flange, Fig. 17. The manufacturing drawing specifies that the assembly of the impeller and pivot shall be balanced to within 7·5 gramme inches in each of the two reference planes ; Fig. 17 indicates these references planes, and the limits which control the removal of metal for balancing purposes. Usually, in practice, the impeller is balanced to within 0·5 gramme at the calibrating radius in each reference plane.

Template T.72922, Fig. 21, is provided to act as a guide when removing metal from the periphery of the backplate ; the template also ensures that the limit is not exceeded at any one point. The removal of the maximum permissible amount of metal from any one sector is equivalent to a correction of approximately 3 grammes. If the unbalance is less than 3 grammes, the amount of metal to be removed can be estimated as a proportion of the area exposed above the template. Protection plate T.72921 is fitted into the recess between the pivot flange and the impeller to protect the light-alloy impeller whilst metal is removed from the pivot flange. Metal may be removed at this point up to the maximum indicated by the shaded area on Fig. 17, and at the required angular relation to the impeller. If segments of the area shown in the inset are cut to varying depths, the correction obtained rises from 1·35 gramme inches to 2·44 gramme inches per 0·010 in. for the first 0·100 in. of axial length, where the flange is chamfered. The maximum correction, for a cut to the full depth of the flange, is 73·3 gramme inches. At both positions, the metal may be removed by hand filing, or by means of a power-driven rotary file, or by any other suitable means. Where a large amount of unbalance has to be corrected, it is advisable to remove about half the required amount of metal, and to recheck the balance in case the angle of unbalance has changed. Finally, all sharp edges must be eliminated and all file marks and scratches must be polished out, using a rotary polishing bob and metal polish, and the bared surface of the metal protected by a coating of Ercalene lacquer.

1. Having ascertained the amount and direction of the unbalanced forces, remove the upper portion of the impeller shroud. Position covers T.75644 and T.75638 over the left and right supports and the ball bearings ; ensure that these covers are correctly fitted so as to exclude all swarf and filings.

2. Rotate the impeller, by hand, until the positions from which metal is to be removed, are conveniently situated. Lock the impeller by passing a bolt through one of the holes in holding attachment T.71076 and screwing it into one of the extractor holes in the adapter plate.

3. Cover the open top of the lower portion of the impeller shroud with a sheet to prevent the ingress of filings and other foreign matter.

4. Using template T.72922 and protection plate T.72921, as appropriate, remove the requisite amounts of metal from the periphery of the backplate and the pivot flange.

5. Remove the template and thoroughly clean the impeller, removing all traces of filings and swarf. Remove the protection plate, the holding attachment, the sheet, and the bearing covers. Refit the upper portion of the impeller shroud.

6. Recheck the impeller balance, and, if necessary, repeat the foregoing operations until the balance is satisfactory.

REMOVING IMPELLER FROM MACHINE.
Ensure that the bearing pedestals are locked.

1. Remove the upper portion of impeller shroud T.75611, and uncouple the machine drive.

2. Use lifting sling T.75892, as described on page 23, to transfer the impeller to cradle trolley T.76578. Ensure that the impeller is securely clamped to the cradle before removing the sling.

3. Swing the cradle, of the cradle trolley, through 90 degrees, so that the impeller pivot is pointing downwards.

4. Remove the twelve slave nuts and washers which secure adapter T.75607, to the rear of the impeller.

5. Screw three extractor bolts T.73066 into three equally spaced extractor holes in the flange of the rear adapter, and, by evenly and progressively screwing in these extractor bolts, force the adapter, complete with its ball bearing and drive coupling, off the impeller spigot. Remove the adapter.

6. Swing the cradle through 180 degrees, so that the pivot is uppermost.

7. Use spanner T.72463 to remove the slave ring nut, and extractor T.72475 to draw off the slave ball bearing. Remove the adjusting washer.

8. If necessary, eliminate all sharp edges and polish out any tool marks or scratches from the positions where metal has been removed for balancing purposes. Apply a coat of Ercalene lacquer to ensure that the bared surface of the metal is protected.

9. Screw lifting eye T.72476 on to the pivot, and, using a suitable hoist, transfer the impeller from the cradle trolley to transport box T.72509, or, alternatively, to box trolley T.77555.

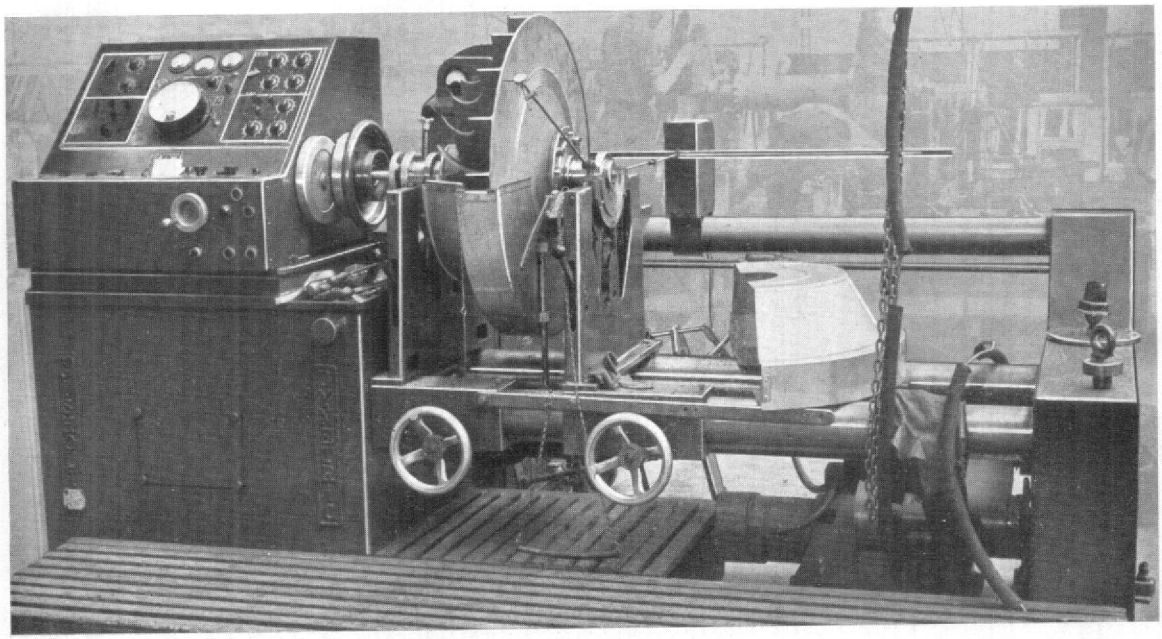


Fig. 19. Impeller in Gisholt 3 U.J.P. balancing machine.

Balancing impeller, using Gisholt, 3.U.J.P., dynetric balancing machine (alternative to Avery 7208)

SETTING UP MACHINE (Fig. 19, 20, and 21)

1. Taking great care not to cause damage by bending, disconnect the wire which connects the left-hand work support to the nodal bar immediately in front of the 'pick-up' coil which is mounted on the auxiliary bed bar at the rear of the machine. Similarly, disconnect the right-hand pick-up.

2. *If necessary,* traverse the right-hand work support to the right to enable the two long mandrels T.71090 to be removed.

3. Fit the two short mandrels T.71072 ; see Op. 3 "Setting Up Machine" on page 19.

4. Slacken the six $\frac{1}{4}$ in. B.S.F. socket-headed screws in each of the two spherical half bearing shells T.72473, and place one shell in each work support. Loosely retain the shells in the supports by securing two locking plates T.72474, counterbored face uppermost, to each support by means of four $\frac{1}{4}$ in. B.S.F. socket-headed screws ; these screws must not project above the surface of the locking plates, and should be tightened finger-tight only.

5. Place one of the two half bearings T.72914 in each spherical shell, ensuring that the groove in the periphery of each half bearing locates on the spherical shell. Loosely retain each half bearing by securing two keep plates T.76464 to the spherical shell by means of four $\frac{5}{8}$ in. by $\frac{1}{4}$ in. Whitworth set-screws ; position each keep plate so that the $\frac{1}{8}$ in. by 0·010 in. lip engages the upper edge of the half bearing ; tighten these screws finger-tight only.

6. Using the handles provided, traverse the work supports until the half bearings are approximately 21½ inches between centres ; the half bearings will then be in about the right positions to receive the slave ball bearings fitted to the impeller adapters.

7. Place the lower portion of impeller shroud T.72471 between the two work supports and lightly clamp its supports to the two mandrels by means of the clamps provided ; do not finally tighten these clamps or the steady brackets which are on the front of the shroud until the impeller has been mounted in the balancing machine.

8. *If necessary,* remove the long nodal bar, and substitute the short nodal bar, positioning the right-hand pick-up and the nodal bar supports to suit ; use the spanner provided to secure the nodal bar and the pick-up in position.

PREPARING IMPELLER

The couplings and adapter assemblies have been individually dynamically balanced and, therefore, attention must be paid to any correlation marks, and numbered bolts, nuts, etc., must be assembled at the correct positions.

1. *If necessary,* mount the impeller in cradle trolley T.76578 as described in Op. 1 on page 3.

2. Proceed as described in Op. 3 to 7 "Preparing Main Shaft" on pages 19 and 20.

3. Swing the cradle through 180 degrees, so that

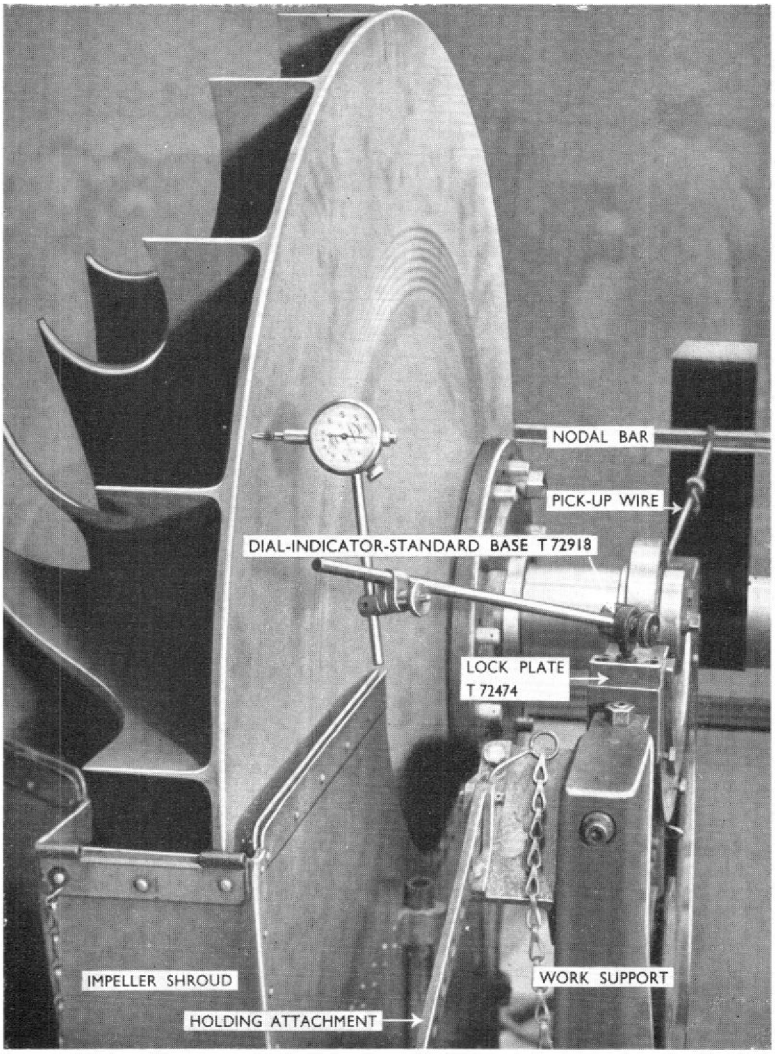


Fig. 20. Using dial test indicator supported on dial-indicator-standard base T.72918 and lockplate T.72474 to check rear face of impeller for swash, in Gisholt 3 U.J.P. machine.

the rear face of the impeller is uppermost, and lock the cradle in position.

4. Position rear end adapter T.72925, complete with its ball bearing, etc., over the centre shaft studs in the rear face of the impeller; the recess in this adapter fits over the spigot on the impeller. Secure the adapter with twelve slave washers and nuts which must be of identical weight.

MOUNTING IMPELLER IN MACHINE (Fig. 19)

1. Swing the cradle, of cradle trolley T.76578, through 90 degrees so that the cutaway portion of the cradle is uppermost and the impeller is in its normal installed attitude.

2. Taking care that neither slave ball bearing is damaged, pass a suitable rope sling round the plain portion on the adapter at the rear of the impeller and a second rope sling round the boss on the front of the impeller. Couple these slings to either end of lifting sling T.75892, and, using a suitable hoist, transfer the impeller from the cradle trolley to the balancing machine; the pivot must be towards the driving head of the machine.

3. As the impeller is lowered into position, guide the ball bearings into the half bearings on the work supports of the balancing machine; making any necessary final adjustments to the positioning of the work supports.

4. Couple the machine drive to the driving coupling on the pivot, using four slave nuts, with captive washers T.71075; ensure that these nuts are tightened evenly.

5. Reconnect the wires between the nodal bar and the work supports; ensure that the work supports are free.

6. Using the twelve adjusting screws, finally adjust and align the spherical shells; ensuring that the impeller will rotate freely in the two ball bearings. Finally tighten the keep plates.

7. Make a chalk mark on the impeller to act as a zero datum, in line with the sighting line which is provided on the balancing machine.

8. Screw dial indicator standard base T.72918 into the $\frac{5}{16}$ in. B.S.F. threaded boss on lock plate T.72474 which is fitted to the rear support. Using a dial test indicator supported from this base, check the rear face of the impeller for swash and ensure that it is within the limits, Fig. 20. It will be necessary to remove this dial test indicator before the covers, which are used when correcting unbalanced forces, can be fitted over the bearings. Similarly, check the pivot.

9. Place the upper portion of impeller shroud T.72471 over the impeller so that it mates up with the lower portion which has been fitted already. Rotate the impeller by hand, through at least one complete revolution, to ensure that it is clear of the shroud at all points; if necessary, adjust the position of the shroud until the required clearance is obtained. The clearance should not be more than about $\frac{1}{2}$ in. and must be, as nearly as possible, equal at all points—the shroud being concentric with the impeller, and fitting closely around the impeller boss. When everything is satisfactory,

tighten the bolts and clamps which secure the shroud.

10. Lubricate the slave ball bearings with clean approved oil, and check that the impeller rotates freely.

11. Ensure that the pick-up wires, nodal bar, and pick-ups are correctly positioned and connected, and that the moving parts can move freely.

CORRECTING UNBALANCED FORCES

The unbalanced forces in the impeller should be corrected as described on page 25. The covers which should be used to protect the front and rear bearings when the impeller is being balanced in the Gisholt 3 U.J.P. machine are T.72919 and T.72920. Holding attachment T.71076 should be attached to the bracket which is provided on the rear face of the impeller shroud, Fig. 21.

REMOVING IMPELLER FROM MACHINE

The impeller should be removed from the machine and the slave parts removed from the impeller with the same tools and in a similar manner to that described on page 26.

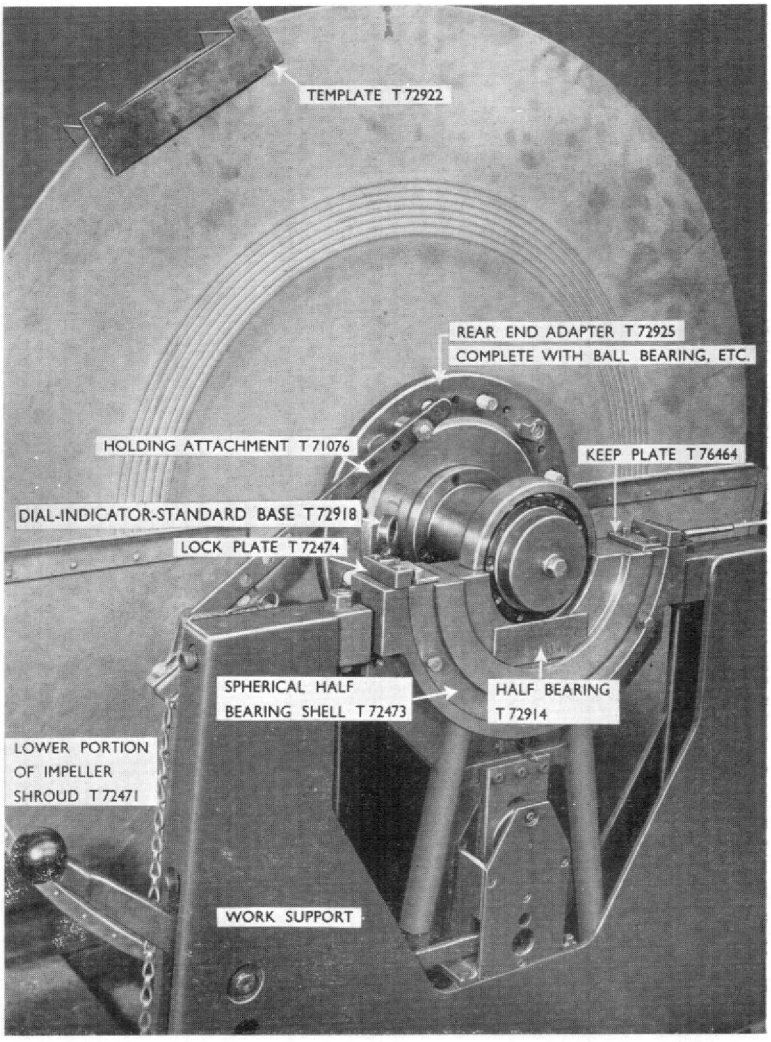


Fig. 21. Holding attachment T.71076 and template T.72922 applied to impeller, in Gisholt 3 U.J.P. machine.

Balancing centre shaft complete with extension shaft, rear bearing, and hub shaft, using Avery type 7208, 20-2000 lb., electro-dynamic balancing machine.

Normally, it is not necessary to dynamically balance the centre shaft, complete with extension shaft, rear bearing, and hub shaft, even if it has been necessary to renew the extension shaft, or the hub shaft, or both, or any of the bolts and nuts, etc. If, however, a centre shaft is renewed, it will be necessary to dynamically balance it complete with the extension shaft, rear bearing, and hub shaft.

SETTING UP MACHINE (Fig. 22 overleaf)

1. Place one bearing pedestal T.75400 on the left vertical support, and the second on the right support. Bolt the pedestals to the supports through the four $\frac{3}{8}$ in. elongated holes which are provided in the base of each pedestal. If the machine is being set up for the first time, great care must be taken to align the bearing pedestals so that they are square to the centre line (working axis) of the balancing machine and concentric with that centre line. When they have been aligned correctly, it is advisable to dowel the pedestals in position, and to mark them so that for each subsequent occasion they can be fitted correctly without difficulty.

2. Engage the dovetail slide of one of the removable adjusters T.75405 into each of the six dovetail slots in the left pedestal ; each 2 B.A. adjusting screw must be fitted so that its head is on the narrower side of the dovetail slide. Unscrew each adjusting screw until its hardened tip is flush with the surface of the slide.

3. Place one spherical half bearing shell T.75420 in the pedestal on the left support and retain it loosely in the pedestal by securing two keep

plates T.75403 to the pedestal, by means of the $\frac{5}{16}$ in. B.S.F. socket-headed screws provided; tighten these screws finger-tight only.

4. Place one half bearing T.75606 in the spherical shell on the left support, ensuring that the $1\frac{7}{16}$ in. groove in the periphery of the half bearing locates on the spherical shell. Loosely retain the half bearing by securing two keep plates T.75404 to the spherical shell by means of four $\frac{5}{8}$ in. by $\frac{5}{16}$ in. Whitworth set-screws; tighten these screws finger-tight only. If the half bearing is new and has not been used before, the diameter may have sprung in slightly when it was parted from the rest of the complete ring. This can cause it to nip the outer race of the ball bearing and so cause ovality of the outer race and loss of end float in the bearing which will seriously affect the

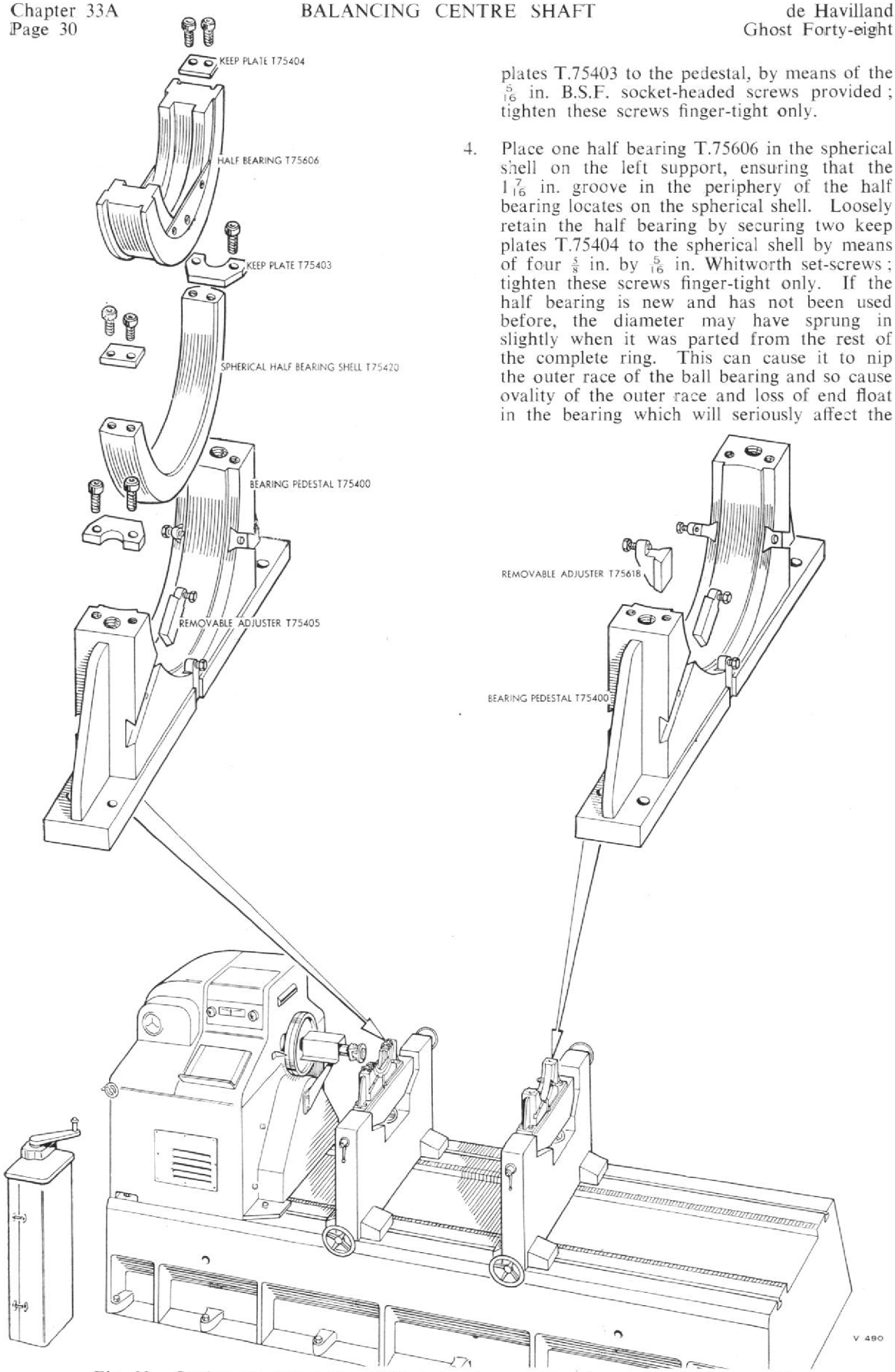


Fig. 22. Setting up Avery type 7208 balancing machine for centre shaft assembly.

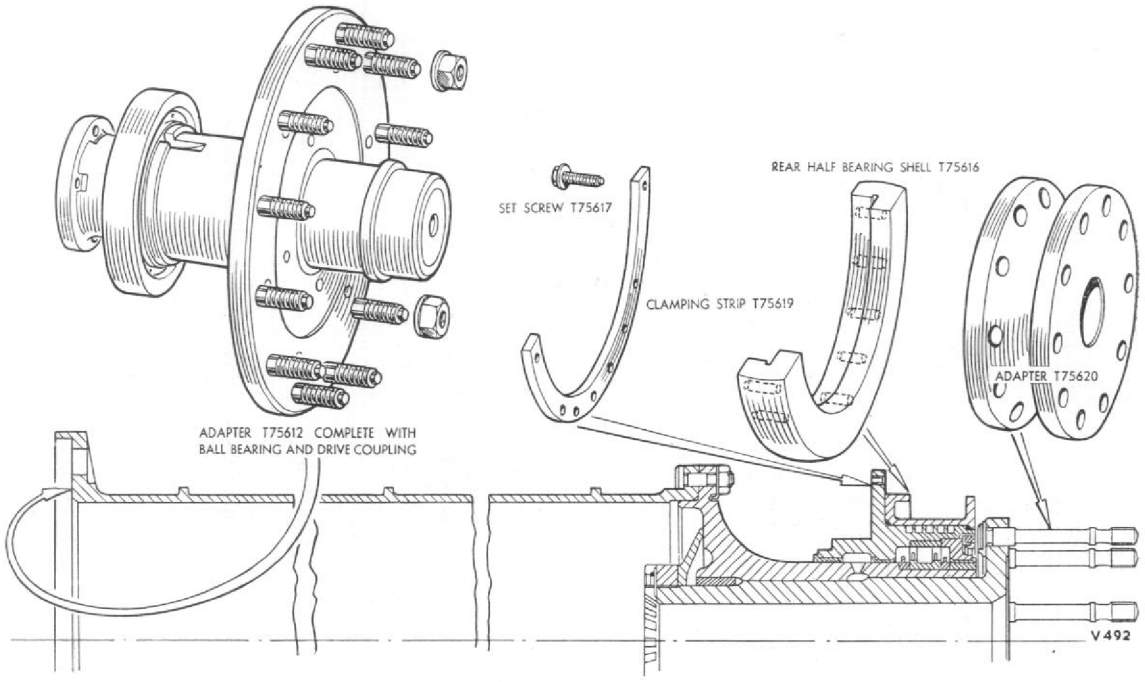


Fig. 23. Preparing centre shaft assembly for balancing in Avery type 7208 machine.

accuracy of the balancing operation. Therefore, make a check by applying marking blue to the half bearing and checking the marking on the outer race of the slave ball bearing when it is tried in position. Local high spots should be rectified by grinding the half bearing, using a suitable grinding wheel. A high degree of accuracy and finish are not essential, provided that the ball bearing is not nipped in the half bearing.

5. Engage the dovetail slide of one of the removable adjusters T.75405 into each of the three dovetail slots in the right-hand face of the right pedestal, and, similarly, fit three removable adjusters T.75618 in its left-hand face; each 2 B.A. adjusting screw must be fitted so that its head is on the narrower side of the dovetail slide. Unscrew each adjusting screw until its hardened tip is flush with the surface of the slide.

6. Using the handles provided, traverse the vertical supports until the pedestals are approximately 38 inches between centres; they will then be in about the right positions to receive the slave ball bearing, fitted to the front of the centre shaft, and the rear bearing housing.

PREPARING CENTRE SHAFT ASSEMBLY (Fig. 23)

1. Having assembled the centre shaft, extension shaft, rear bearing, and hub shaft as described on pages 5 to 9, position the cradle of transport stand T.72419 so that the centre shaft is vertical with the impeller flange uppermost.

2. Position adapter T.75612, complete with its ball bearing and drive coupling, on the centre shaft; the studs in the adapter flange must pass through the holes in the centre shaft flange, and the adapter flange must spigot into the recess in the latter. Secure the adapter with the twelve slave nuts and captive washers provided. *If the recess in the centre shaft flange is undersize, use:—*

   T.75613 Adapter, 0·010 in. undersize
   T.75614 Adapter, 0·020 in. undersize
   T.75615 Adapter, 0·030 in. undersize

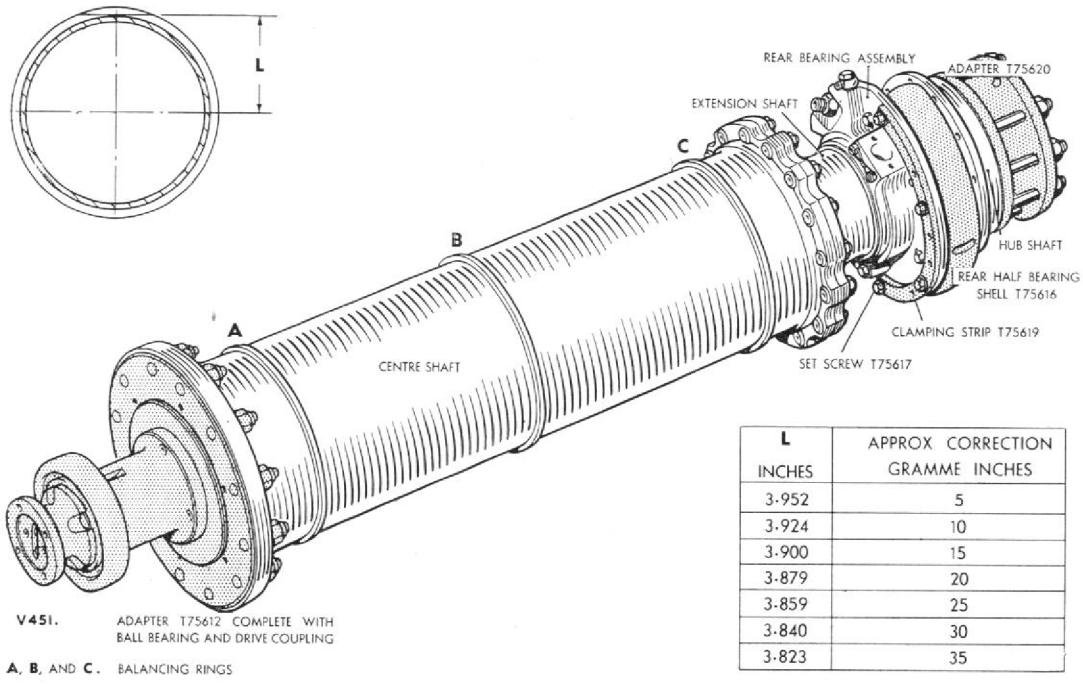
3. Swing the cradle, in the stand, through 180 degrees, so that the hub shaft is uppermost.

4. Remove the adhesive tape which was applied to secure the turbine disc bolts temporarily. Assemble adapter T.75620, over the turbine disc bolts, so that the spigot on the adapter fits into the recess in the hub shaft flange. Secure the adapter to the hub shaft with the correct turbine disc bolt washers and nuts. *If the recess in the hub shaft flange is undersize, use:—*

   T.75621 Adapter, 0·005 in. undersize
   T.75622 Adapter, 0·010 in. undersize
   T.75623 Adapter, 0·020 in. undersize

5. Position rear half bearing shell T.75616 between the two flanges of the rear bearing housing, on the sector which is clear of the oil connections and the cooling air block, and align the ten threaded holes in the shell with those in the larger flange on the bearing housing.

6. Position clamping strip T.75619 on the front



L INCHES	APPROX CORRECTION GRAMME INCHES
3·952	5
3·924	10
3·900	15
3·879	20
3·859	25
3·840	30
3·823	35

Fig. 24. Centre shaft assembly prepared for balancing.

face of the larger rear-bearing-housing flange so that the eight holes in the clamping strip line up with the corresponding holes in the half shell. Secure the clamping strip and the half shell to the rear bearing housing; with four plain washers and set-screws T.75617; these set-screws will pass through the clearance holes in the clamping strip and through the $\frac{5}{16}$ in. B.S.F. holes in the bearing-housing flange to screw into the $\frac{1}{4}$ in. B.S.F. holes in the half shell; fit one set-screw in each end of the strip and shell, and the other two into the 3rd and 6th holes.

7. Swing the cradle, in the stand, through 90 degrees, so that the centre shaft is horizontal and the cradle clamps are uppermost.

MOUNTING ASSEMBLY IN MACHINE.
Ensure that the bearing pedestals are locked.

1. Lower lifting tackle T.72942 into position and attach it to the centre shaft, remove the cradle clamps and hoist the centre shaft clear of the stand.

2. Transfer the centre shaft to the balancing machine, and lower it into position so that the impeller flange will be towards the driving head of the machine.

3. As the assembly is lowered into position, guide the slave ball bearing into the half bearing on the left vertical support of the balancing machine, and the rear bearing housing into the pedestal on the right support; making any necessary final adjustments to the positioning of the vertical supports.

4. Loosely secure the rear half bearing shell to the pedestal on the right support by securing two keep plates T.75403 to the pedestal by means of the $\frac{5}{16}$ in. B.S.F. socket-headed screws provided; tighten these screws finger-tight only.

5. Use feeler gauges to ensure that a clearance is maintained between the safety bearings in the rear bearing housing and the extension shaft —the clearance should be approximately equal all the way round. Use the twelve adjusting screws to finally adjust and align the spherical shells. Ensure that the ball bearing is square with the axis of the shaft, that the safety bearing clearance is maintained, and that the assembly will rotate freely in its bearings. Finally tighten the keep plates. The half bearings should be concentric with the centre line of the balancing machine within 0·002 inch, and the safety bearing clearance should be not less than 0·003 inch. Correct positioning of the centre shaft assembly can be checked thus. Release the left support and rock the shaft, using the finger-tips only; it should be quite free and require very little pressure to push it backwards and forwards between the stops. Lock the left support and repeat this check on the right support.

6. Connect up the machine drive, using four special bolts and nuts T.75411; tighten the nuts evenly.

7. Assemble sighting plate T.75641 on the left pedestal, and T.75642 on the right pedestal.

8. Lubricate both bearings, with clean approved engine oil and check that the assembly rotates freely, when turned by hand.

CORRECTING UNBALANCED FORCES
(Fig. 24, and 25 overleaf)

As stated previously, it is assumed that the operator is fully conversant with the operating and setting of the balancing machine, and with the technique of balancing. The unbalanced forces in the centre shaft assembly are corrected by removing metal from any one, or all three of the three integral rings, marked A, B, and C on Fig. 24. A and C are used as the reference planes for balancing purposes. In the case of force unbalance, i.e., where the unbalance at each reference plane acts in the same direction, metal should be removed equally from each of the three rings, A. B. and C. In the case of couple unbalance, i.e., where the unbalance at each reference plane acts in opposite directions, metal should be removed from rings A and C only. A portable grinding attachment, mounted on a tool post bolted to the base of the balancing machine, is employed to remove metal as necessary, and after completion of the balancing operations Ercalene lacquer is used to protect the bared surface of the metal. This assembly, comprising the centre shaft, extension shaft, rear bearing, and hub shaft should be dynamically balanced to within 0·5 gramme at the radius of the reference planes. The small diagram and table on Fig. 24 provide a guide from which the amount of metal to be removed to correct unbalance can be estimated.

1. Having ascertained the amount and direction of the unbalanced forces, mark the balancing rings on the centre shaft, with chalk, to indicate the points from which metal is to be removed.

2. Position cover T.75638 over the left ball bearing, and cover T.72946 over the right bearing; ensure that these covers are correctly fitted so as to exclude all swarf and abrasive dust.

3. Bolt main base T.75899 to the base of the balancing machine, and tool post T.75894 to the base. Mount grinding attachment T.72948, or any suitable portable grinding attachment, on the tool post, Fig. 25. Spanner T.76087 is provided for use with this grinding attachment. Where this grinding equipment is not available, the required amount of metal may be removed by hand, provided that great care is taken, using a suitable portable hand grinder and grinding wheel; e.g. the grinding wheel used with grinding attachment T.72952 for removing metal from the turbine disc.

4. Use locking fixture T.72947 to lock the assembly.

5. Use diamond tool T.75689, *when necessary*, to true the surface of the grinding wheel.

6. Clamp stop collar T.76088 around the centre shaft, and adjust the position of the two stops, so that, in conjunction with the stop rod which projects from the grinding attachment, Fig. 25, the centre shaft can be rotated through the required angle during the next operation.

7. Use the grinding attachment to remove the required amount of metal from the balancing rings, making reference as necessary to the inset on Fig. 24.

8. Thoroughly clean the assembly removing all traces of swarf and abrasive dust. Remove the grinding attachment. Release the locking fixture. Remove the stop collar. Remove the two covers.

9. Recheck the balance, and, if necessary, repeat the foregoing operations until the balance is satisfactory.

REMOVING ASSEMBLY FROM MACHINE
Ensure that the bearing pedestals are locked.

1. Uncouple the machine drive. Remove the two keep plates which secure the rear bearing half shell to the pedestal on the right support. Slacken off the six adjusting screws in the right bearing pedestal.

2. Use lifting tackle T.72942 to transfer the assembly from the balancing machine to transport stand T.72419. Ensure that the centre shaft is securely clamped in the cradle before removing the lifting tackle.

3. Remove the adapter, complete with its ball bearing and drive coupling, from the front flange of the centre shaft.

4. Remove the clamping strip, and the half bearing shell, from the rear bearing housing.

5. Eliminate all sharp edges, and polish out all grinding marks or scratches from the positions where metal has been removed for balancing purposes. Protect the bared surface of the metal by applying a coating of Ercalene lacquer.

6. Remove the adapter from the hub shaft, and temporarily secure the turbine disc bolts with adhesive tape.

Balancing centre shaft complete with extension shaft, etc., using Gisholt, 3 U.J.P., dynetric balancing machine (alternative to Avery 7208)

SETTING UP MACHINE

Set up the balancing machine as described on page 19, but position the work supports approximately 38 inches between centres.

PREPARING CENTRE SHAFT ASSEMBLY

1. Position the cradle of transport stand T.72419 so that the centre shaft is vertical with the impeller flange uppermost.

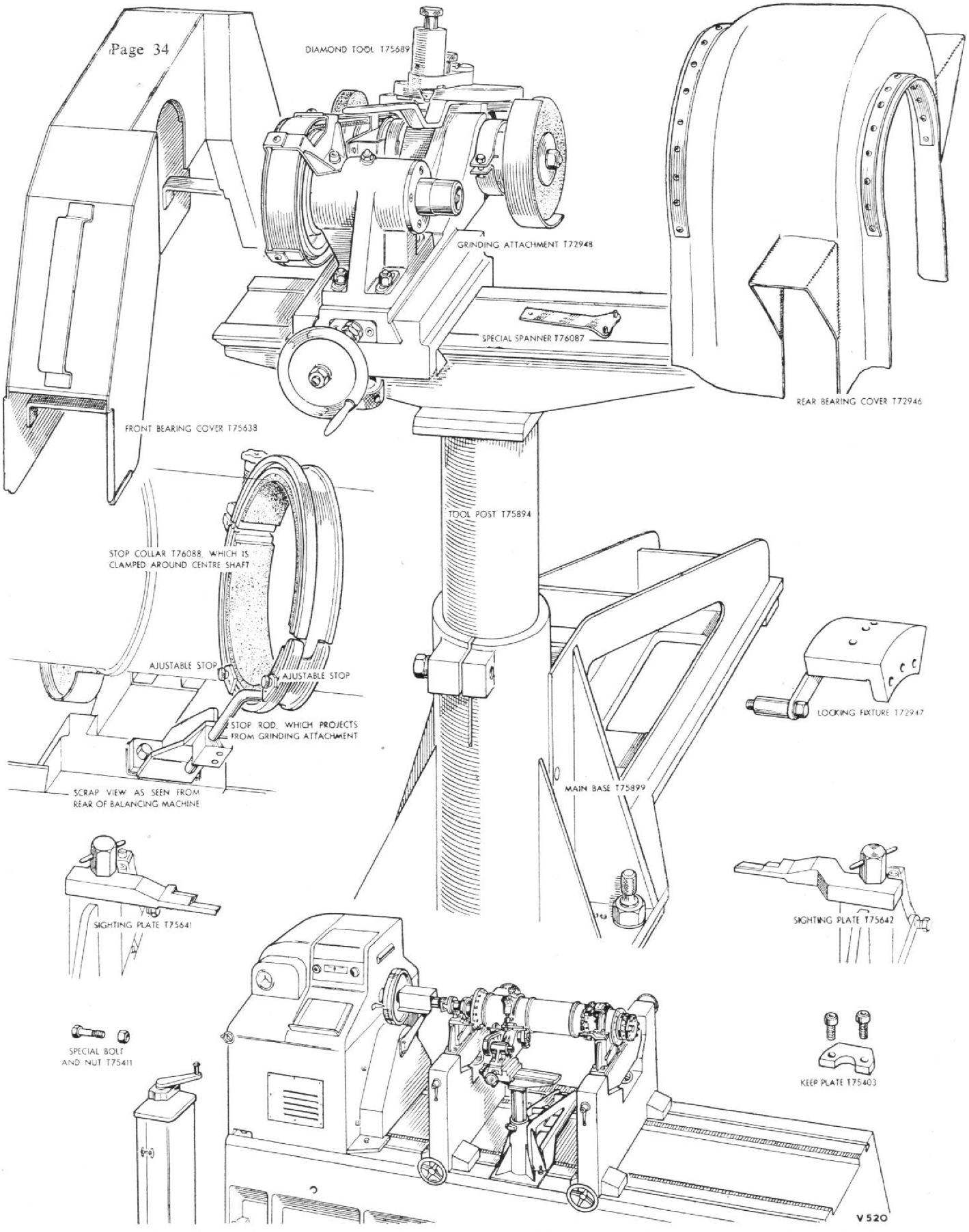


Fig. 25. Centre shaft assembly in Avery type 7208 balancing machine; showing tools used when correcting unbalanced forces.

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2. Position adapter T.72929, complete with its ball bearing and drive coupling, on the centre shaft; the studs in the adapter flange must pass through the holes in the centre shaft flange, and the adapter flange must spigot into the recess in the latter. Secure the adapter with the twelve slave nuts and captive washers provided. *If the recess in the centre shaft flange is undersize use :—*

   T.72930 Adapter, 0·010 in. undersize
   T.72931 Adapter, 0·020 in. undersize
   T.72932 Adapter, 0·030 in. undersize

3. Swing the cradle, in the stand, through 180 degrees, so that the hub shaft is uppermost.

4. Remove the adhesive tape which was applied to temporarily secure the turbine disc bolts. Assemble adapter T.75620, over the turbine disc bolts, so that the spigot on the adapter fits into the recess in the hub shaft flange. Secure the adapter to the hub shaft with the correct turbine disc bolt washers and nuts. *If the recess in the hub shaft flange is undersize use :—*

   T.75621 Adapter, 0·005 in. undersize
   T.75622 Adapter, 0·010 in. undersize
   T.75623 Adapter, 0·020 in. undersize

5. Position rear half bearing shell T.72935 between the two flanges of the rear bearing housing, on the sector which is clear of the oil connections and the cooling air block, and align the nine threaded holes in the shell with those in the larger flange on the bearing housing. Secure the half shell to the rear bearing housing with three plain washers and set-screws T.72936; these set-screws will pass through the $\frac{5}{16}$ in. B.S.F. holes in the bearing housing flange and screw into the $\frac{1}{4}$ in. B.S.F. holes in the half shell; fit one set-screw in each end of the shell, and the third into the centre one of the nine holes.

6. Swing the cradle, in the stand, through 90 degrees, so that the centre shaft is horizontal and the cradle clamps are uppermost.

MOUNTING ASSEMBLY IN MACHINE

1. Lower lifting tackle T.72942 into position and attach it to the centre shaft, remove the cradle clamps and hoist the centre shaft clear of the stand.

2. Transfer the centre shaft to the balancing machine, and lower it into position so that the impeller flange will be towards the driving head of the machine.

3. As the assembly is lowered into position, guide the slave ball bearing into the half bearing on the left work support of the balancing machine, and the rear bearing housing into the pedestal on the right support; making any necessary final adjustments to the positioning of the work supports.

4. Loosely secure the rear half bearing to the spherical shell by means of two keep plates T.76464 and four $\frac{5}{8}$ in. by $\frac{1}{4}$ in. Whitworth set-screws; position these keep plates so that the $\frac{1}{8}$ in. by 0·010 in. lip engages the upper edge of the half bearing; tighten these screws finger-tight only.

5. Use feeler gauges to ensure that a clearance is maintained between the safety bearings in the rear bearing housing and the extension shaft—the clearance should be approximately equal all the way round. Use the twelve adjusting screws to finally adjust and align the spherical shells. Ensure that the ball bearing is square to the axis of the shaft, that the safety bearing clearance is maintained, and that the assembly will rotate freely in its bearings. Finally tighten the keep plates.

6. Connect up the machine drive, using four slave nuts, with captive washers, T.71075; ensure that these nuts are tightened evenly.

7. Reconnect the wires between the nodal bar and the work supports; ensure that the work supports are free.

8. Mount front sighting plate T.72944 on the locking plate, which retains the spherical shell in the left-hand work support, nearest the operator; engage the location slot in the sighting plate over the locking plate and retain the sighting plate by screwing its captive securing screw into the $\frac{5}{16}$ in. B.S.F. hole in the locking plate. The knife-edge on the sighting plate should lie adjacent to the impeller flange on the centre shaft. Similarly, mount rear sighting plate T.72945 on the right-hand work support.

9. Turn the rotating protractor of the machine to zero, and, in line with the sighting plates, make a chalk mark on the front and rear flanges of the centre shaft, to act as a zero datum.

10. Ensure that the pick-up wires, nodal bar, and pick-ups are correctly positioned and connected, and that the moving parts can move freely.

11. Lubricate both bearings, with clean approved engine oil and check that the assembly rotates freely, when turned by hand.

CORRECTING UNBALANCED FORCES

The unbalanced forces in the centre shaft assembly should be corrected as described on page 33. When the centre shaft is being balanced in the Gisholt 3.U.J.P. machine, use cover T.72919 to protect the front ball bearing, and main base T.75893 to carry the tool post and grinding attachment.

REMOVING ASSEMBLY FROM MACHINE

The centre shaft assembly should be removed from the machine and the slave parts removed

from the assembly in a similar manner to that described on page 33.

ESSENTIAL RENEWALS

The following parts will be required each time the main shaft assembly is reassembled.

Part No.	*Description*	*Qty.*
N.4491	Tab washer for impeller pivot studs, pre-mod. 254	10
N.4504	Tab washer for impeller pivot studs, mod. 254	10
SP.9.E.8	Split pin for:—	
	Impeller pivot nuts	10
	Centre shaft nuts	12
N.4172	Circlip for accessory drive shaft plug, pre-mod. 258	1
N.4250	Circlip for accessory drive shaft plug, mod. 258	1
601424	Tab washer for sealing housing locking bolt	1
27388	Locking washer for sealing housing retaining nut	1
AGS.1138D	Joint washer for cooling oil pipe unions	2
—	22 S.W.G. stainless steel locking wire	as reqd.
N.1493	Joint washer for oil drain and feed banjo connections	4
AGS.518E	Tab washer for cooling air block bolts	2
21304	Circlip for hub shaft nut	1
N.3717	Tab washer for centre shaft bolts	16
N.3765	Tab washer for centre shaft studs	12
600542	Triple tab washer for turbine disc bolts, pre-mod. 279, mod. 588	2
98986	Triple tab washer for turbine disc bolts, mod. 588	2
98987	Double tab washer for turbine disc nuts, mod. 588	2
N.2883	Cup locking washer for front bearing nut	1