

Chapter Fifty

ROTAX TURBO-STARTER, TYPE CT.0101.

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ROTAX STARTER

de Havilland
Ghost Forty-eight

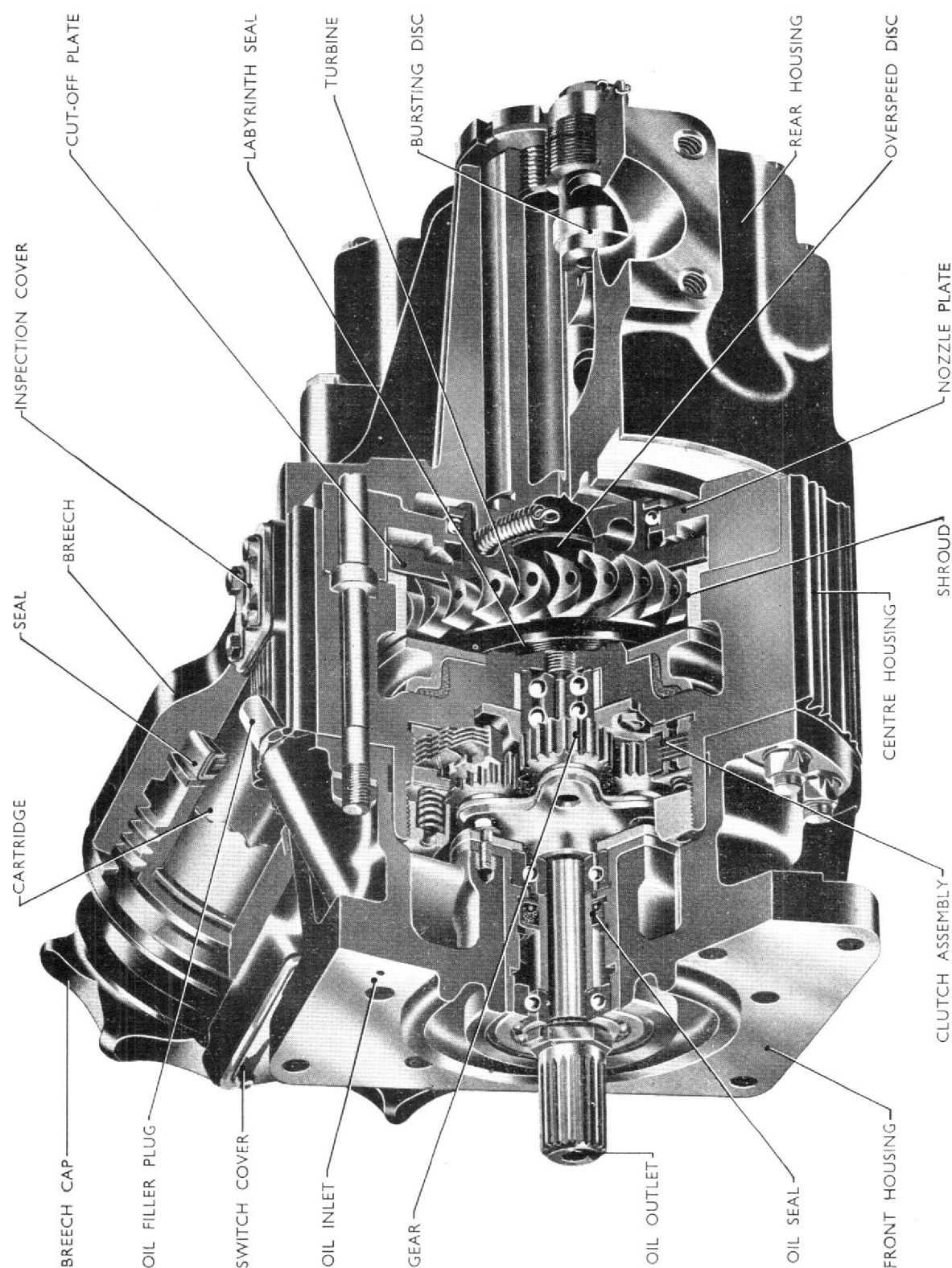


Fig. 1. Sectioned view of starter.

GENERAL SPECIFICATION

Ambient temperature at breech : 15 deg. C.
Breech : 2 shot
Output shaft speed : 10000 r.p.m.
Output shaft torque : 90 lb.ft.
Turbine speed at instant of engagement : 5000 r.p.m.

Max. horsepower at 8450 r.p.m. : 137 B.H.P.
Duration of operation : 3.2 sec.
Clutch setting—running : 160 lb.ft.
—breakaway : 250 lb.ft.
Rotation from drive end : Clockwise
Maximum operating temperature : 165 deg. C.
Mounting : Flange

Weight :
Electrical connection :

60 lb.
4 pin Breeze plug,
British Air Ministry
Stores Ref. 5X/6006,
Mating socket Ref.
5X/6009.

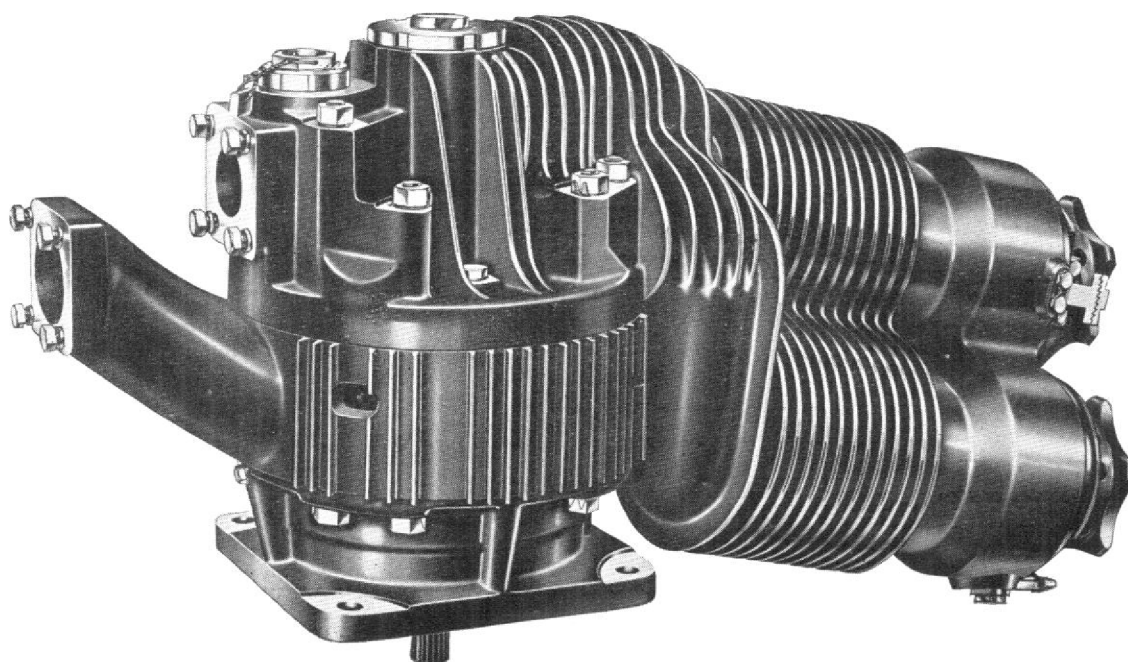


Fig. 2. Type C.T.0101 turbo-starter.

The information contained in this chapter has been supplied by Rotax Limited, and is a reproduction of Rotax Technical Manual, dated August 1952, and Rotax Service and Overhaul Manual, dated December 1952, for the Type C.T.0101 turbo-starter.

THIS CHAPTER is applicable to both the Ghost 48 Mk. 1 and Ghost 48 Mk. 2.

This Rotax turbo-starter has been developed for the de Havilland Ghost Engines, type 48 Mk. 1 and 48 Mk. 2, so that rapid starting, 10 seconds to idling, can be accomplished in service. It is capable of developing 137 B.H.P. and is fired electrically from the aircraft electrical system, thus providing a completely self-contained starting system.

The basic standard Rotax turbo-starter is the type C.T.0101. When mod. S.789 (Ghost mod. 569) is incorporated a 24 blade rotor and new nozzle ring is fitted and the starter type number is C.T.0101/1. Mod. S.5091 (Ghost mod. 891) incorporates sintered clutch plates and rings to permit the use of oil to specification D.E.D.2479 or 2487 when the type number becomes C.T.0101/2.

The nature of both construction and performance of these starters is such, that absolute cleanliness must be observed throughout all servicing operations, and for this reason the work bench should be clean and tidy before attempting to dismantle the starter, and adequate room provided to lay out the component parts in an orderly manner as a precaution against their possible loss or damage.

To enable high speed and high power starting to be accomplished with such a comparatively small unit many safety features have been incorporated; these are as follows:—

Overload clutch allows re-engagement into

engine which is running at a low speed or stationary.

Overspeed plate limits speed if re-engaged with engine running at high speed.

Excess pressure relief disc.

Electrically-fired cartridge cannot be ignited until both breeches are safe.

Self-contained multi-breech with no rotating parts.

Sealed and therefore altitude and environment proofed cartridge.

Gearbox oil lubricated from engine oil system.

There are three outstanding advantages of this starter: Firstly, the considerable reduction in time taken to bring the engine to idling speed, in this instance, from 45-60 seconds to 10-15 seconds: Secondly, no starter trolley or similar unit is required on dispersal as the turbo-starter is entirely self-contained: Thirdly, two cartridges, separately fired, permit a second attempt at starting should the first fail. This second attempt may be made 15 seconds after the first.

GENERAL DESCRIPTION

Each starter comprises three main light alloy castings; front, centre and rear housings.

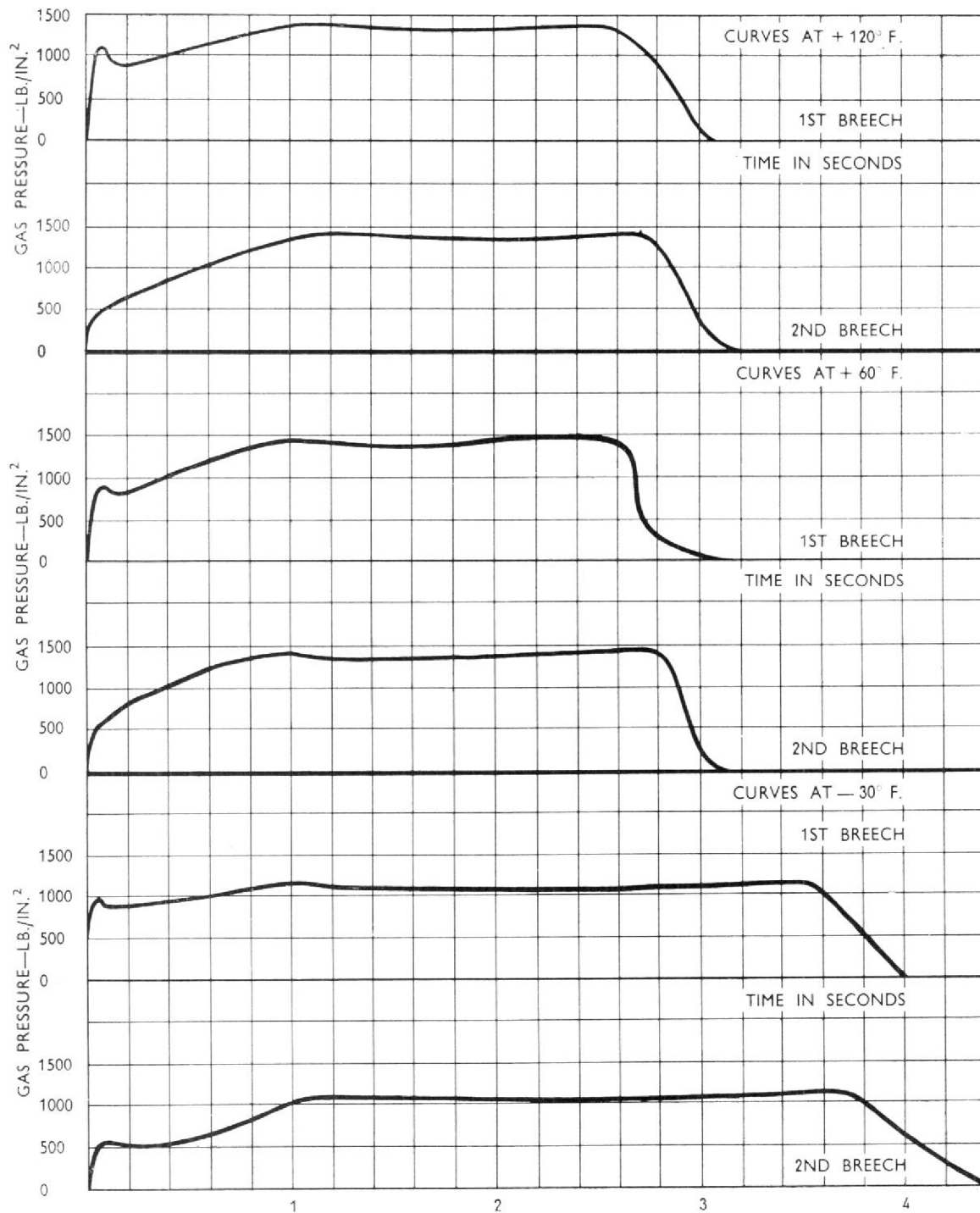


Fig. 3. Typical cartridge burning times.

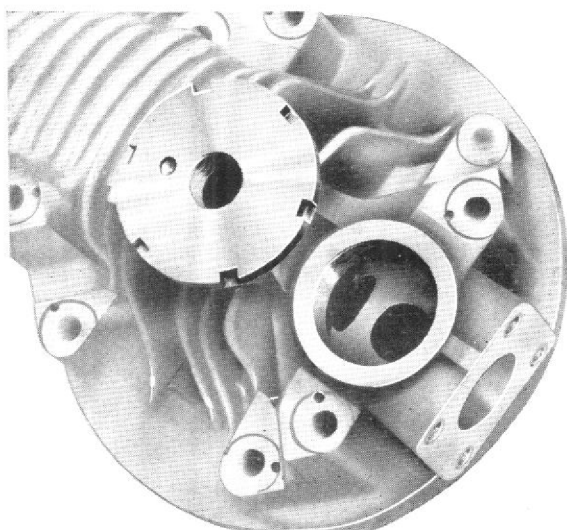


Fig. 4. Rear housing.

FRONT HOUSING

This housing forms the mounting flange and houses the drive shaft and planetary gear carrier, drive shaft bearings and oil seal. Oil lubrication passages are in this housing to take oil from, and return oil to, the main lubrication system of the engine. A filler plug is available for priming the gearbox prior to mounting the starter on the engine. The front housing engages on a spigot on the centre housing.

CENTRE HOUSING

This housing embodies the clutch assembly, annulus and pinion gears, turbine rotor and its bearing, exhaust ring, shroud, cut-off plate and nozzle plate.

To examine the cut-off plate position a small inspection cover is arranged in this housing.

A detailed description of these parts will be given later in this chapter.

REAR HOUSING

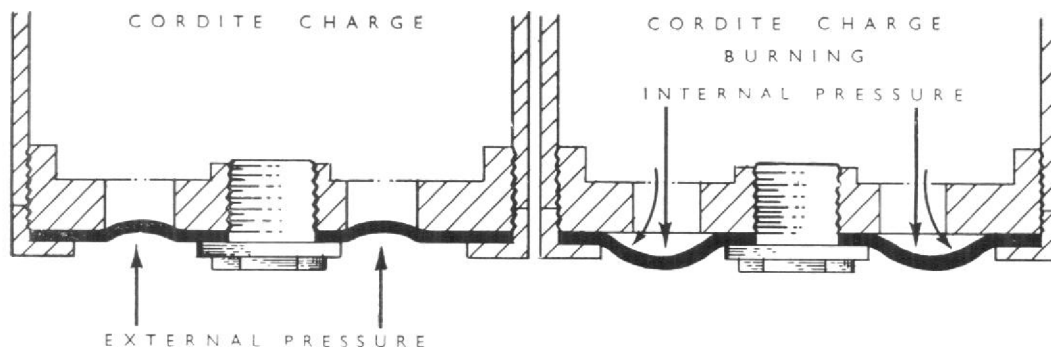
This is virtually the twin breech housing, the chambers being interconnected by passages in the casting. From a common chamber the gases pass through four holes to the nozzles. Cartridges are fitted into the breech caps, then introduced to the breech, and locked. As the cartridges are electrically fired it is convenient to incorporate the plug and switches at the breech cap end of the housing. A safety disc is included at the opposite end of the housing.

CARTRIDGE

The cartridge propellant used is in the form of a coated charge of tubular cordite weighing 720 grams. It is contained in a duralumin case and completely sealed so that it is altitude, tropic and water-proofed. Each case is a free fit in the breech, thus it can be removed quite easily after use, refilled, sealed and prepared for future use. The burning times under various temperatures are indicated in Fig. 3.

One end of the cartridge contains a fuse, fired electrically via a spring-loaded contact in the centre of the breech cap. This end of the cartridge is flanged in the same manner as a rifle cartridge, so that it will engage in the offset groove in the breech cap.

At the other end of the cartridge the sealing is arranged by a screwed cap, drilled for the escape of the propulsive gas, and closed by a thin magnesium disc on the outside of the drilled holes. This thin disc is easily sheared and burnt by pressure and heat from inside, but, as it is backed by the undrilled part of the cap, it is not easily pierced by external pressure. Thus it is impossible for the pressure, to which the end of the cartridge is subjected when the adjacent cartridge is fired, to burst the disc and thereby destroy the seal or allow the cordite to be ignited. Fig. 5 shows in diagrammatic



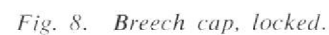
INNER SURFACE OF SEAL IS SUPPORTED THUS, HIGH EXTERNAL PRESSURE WILL NOT BREAK SEAL.

OUTER SURFACE OF SEAL IS SUPPORTED ONLY AT THE EDGES OF INNER AND OUTER DIAMETERS THUS COMPARATIVELY LOW PRESSURE WILL BREAK SEAL

Fig. 5. Cartridge seal.



cartridge seal, the risk of igniting one cartridge from the other is not encountered. For certain specific installations only, it is possible to fit a modified breech cap so that compressed air can be used for operating the starter. Before attempting to incorporate this modification reference should be made to Rotax, or similar authority, for current details. Each breech cap is screwed into its respective chamber by hand pressure only and locked by two sets of ratchet teeth, one on the cap, the other on the chamber. See Figs. 7 and 8. Just before engagement of these locking ratchets a spring-loaded contact plunger on the breech lines up with an insulated slip-ring block on the cap and completes the firing circuit. The switches in



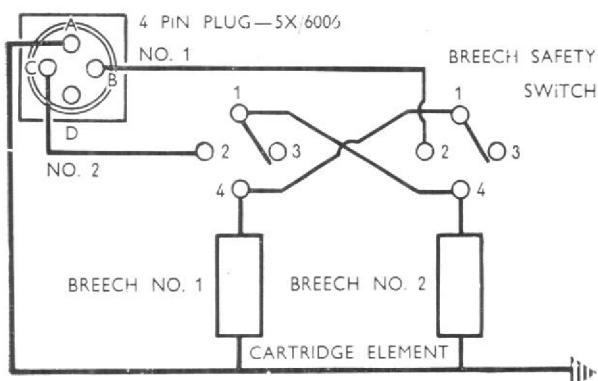


Fig. 9. Breech wiring diagram.

the recess at the extremity of the breech are interconnected in such a way that it is impossible to fire either cartridge until both caps are screwed to a safe operating position. See diagram, Fig. 9.

To facilitate the removal of the cartridge case from the breech an offset groove is machined in the breech cap, into which the flange on the cartridge case engages, and a flat spring set inside the cap on the opposite side to the groove retains the flange in the groove. This spring is shown quite clearly in Fig. 10.

SAFETY DISC. This is a disc of nickel held in an assembly, the parts of which are shown in Fig. 11. It is inserted into the rear of the starter, immediately under the combustion chambers, as shown in Fig. 14, and should the pressure inside the starter rise above 2,000 lb. per sq. in., it allows the gas to escape through a short branch pipe into the turbo-starter exhaust pipe. Excessive pressures could be caused by: faulty cartridges, blocked nozzles, two cartridges igniting simultaneously, very high ambient temperature of the cartridges in the starter.

NOZZLE RING AND OVERSPEED CUT-OFF PLATE. The nozzle ring is clamped between the rear and

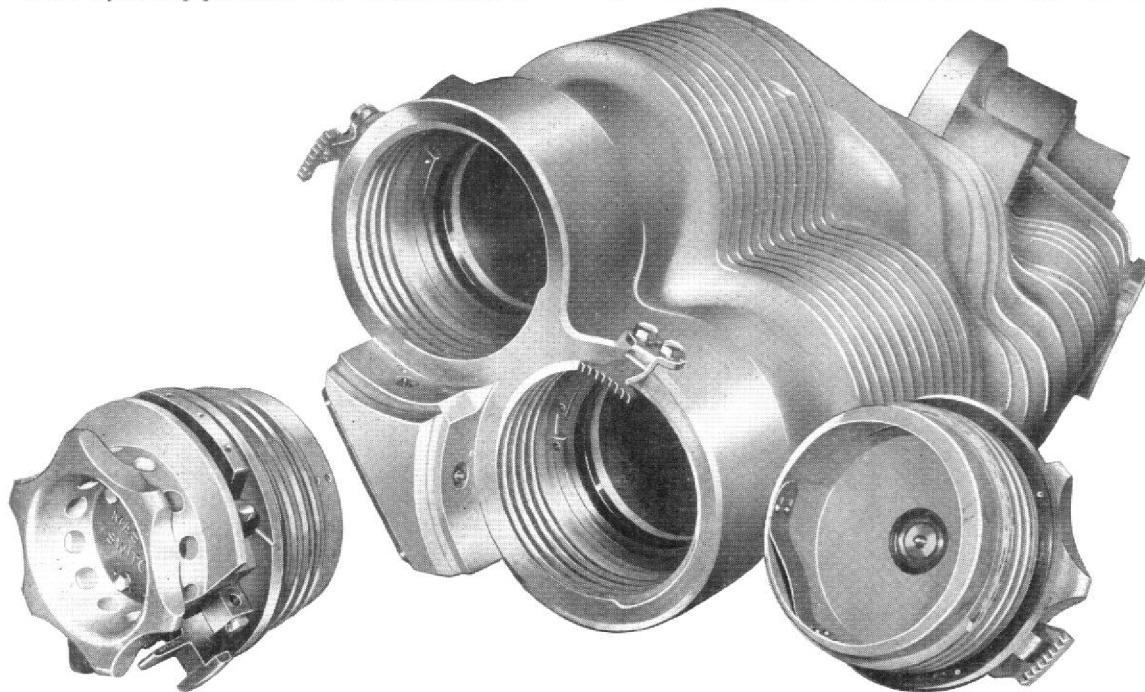


Fig. 10. Breech chambers and caps.

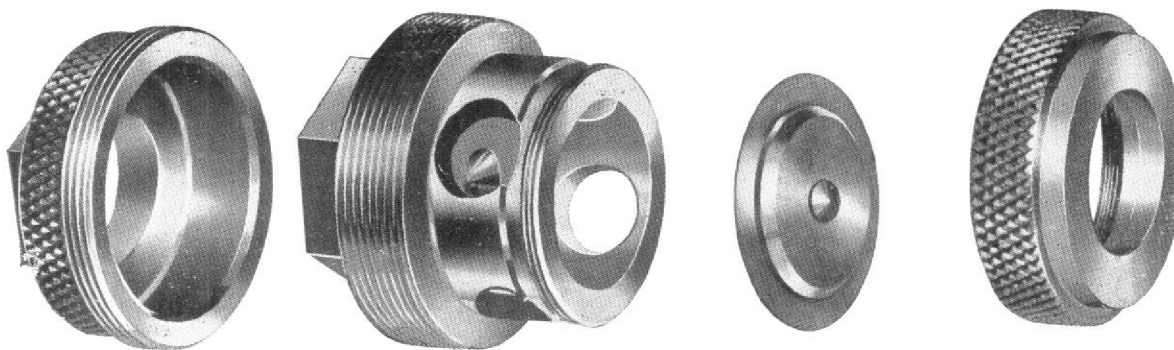


Fig. 11. Safety disc assembly.

centre housings and located so that four equidistant nozzles, with replaceable inserts, coincide with the four cored passages in the rear housing. The inserts are of sintered titanium carbide, are very hard wearing and, being replaceable, increase the life of the plate. Carried on a single row ball bearing, in the inner diameter of the nozzle ring, is the cut-off plate which has its travel limited to 30 deg. by four equidistant stop-pins. To prevent damage to the bearing, due to soot deposits, a carbon seal is fitted into the inner diameter of the ring between the bearing and cut-off plate.

The overspeed device, as its name implies, limits the rotor speed if the drive is allowed, by some means, to run free, or, if the starter is inadvertently operated a second time while the engine turbine is still rotating at relatively high speed after the first operation. In principle it consists of a flanged circular plate mounted on a bearing in the nozzle ring and held rotationally by circumferentially fitted coil springs. A cupped disc slotted axially on its outer diameter, and secured to the rotor shaft is a clearance fit within the bore of the plate. Centrifugal forces at rotor speeds above 50,000 r.p.m. cause the segments of the cupped disc to open outwards and grip the bronze lining of the cut-off plate which commences to rotate, the gases then impinge on the paddles adjacent to the holes in the cut-off plate, which correspond to the nozzles, and these gases drive the cut-off plate through 30 deg., against the resistance of its circumferential springs, until it abuts against the stop pins. The force of the gases thus retains the cut-off plate against the stop pins until the cartridge has expended its energy. In this position the gases are prevented from reaching the rotor wheel, but instead, are directed outwards and downwards, passing outside the shroud ring and entering the main exhaust. Fig. 12 shows the essential parts of the overspeed device.

ROTOR. Produced from special heat-resisting steel the rotor is carried on one double row ball bearing in the main housing. The turbine blades which are integral with the rotor, are impulse type and no stator or guide vanes are used. Labyrinth rings are machined on the exhaust side of the rotor and the face of the casing to restrict the passage of gas to the bearing which is retained on the rotor shaft by the sun pinion of the reduction gear. The outer race of the bearing is retained in the casing by a flanged retaining plate secured by four bolts.

EXHAUST CHAMBER. This is embodied in the centre housing with a steel shroud. It has a refractory liner behind it to insulate the reduction gear casing from excessive heat.

REDUCTION GEAR AND CLUTCH. The drive from the rotor shaft is transmitted to the engine starter gear train by a single stage epicyclic reduction gear giving a step down ratio of 5-1. Four planet pinions are carried on the output shaft spider, these mesh with the sun-wheel of the rotor shaft, and the annulus gear which surrounds the assembly.

This annulus gear is splined externally to engage with the three steel plates of the multiplate clutch, which takes up the initial shock of engagement, whilst the sintered bronze-on-steel plates are machined to engage with the housing. The clutch plates are forced together by a number of short strong helical springs carried in counterbores in the screwed adjustment ring which does not rotate when the clutch slips. The ring is screwed into the reduction gear case and the clutch is normally set to slip at a torque of 160 to 180 lb. ft. The clutch holds the annulus gear stationary under normal operation so that rotation of the sun-wheel causes the planetary pinions to carry the spider round with them. Under shock loading the annulus gear rotates due to clutch slip, thus no movement,

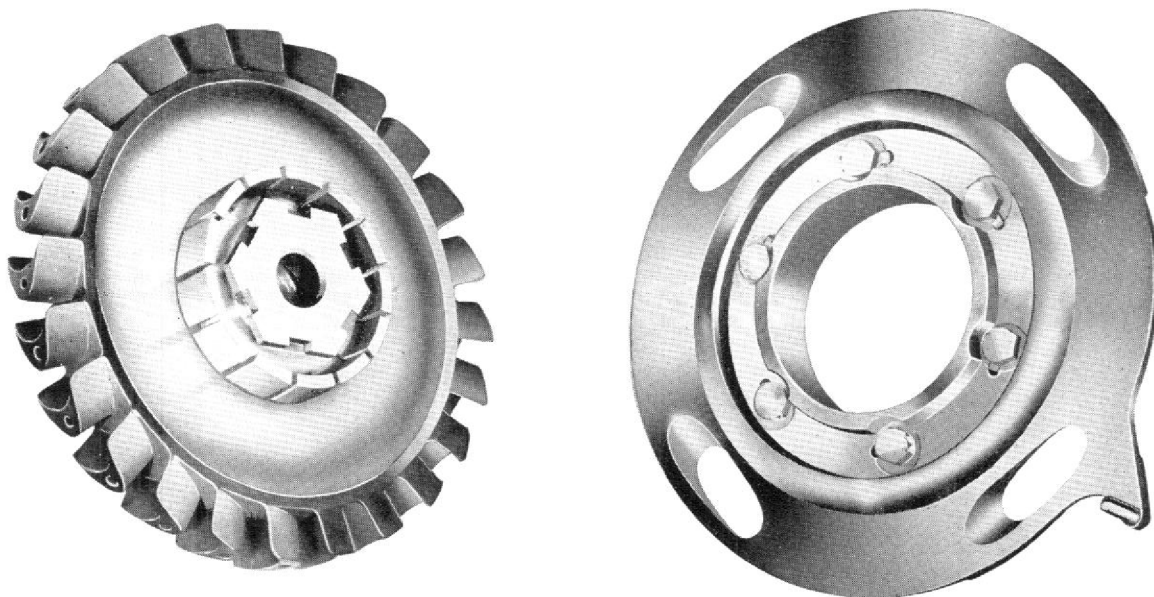


Fig. 12. Rotor and overspeed cut-off plate.

or limited movement, of the spider occurs depending on the rate of clutch slip. The output shaft, which is integral with the planetary spider, runs in two single row ball bearings, the inner one being located axially in the starter body by a flanged housing, the outer one being secured to the shaft by a hexagon nut and tabwasher. A distance piece separates the inner races of the bearings and rotates with the shaft within an oil seal. The end of the output shaft protrudes through the mounting flange of the starter body and is splined to engage with the starter drive on the engine. See Fig. 13.

LUBRICATION. Only oil to D.E.D. specification 2479* should be used in this starter; where the engine oil specification is not the same, reference should be made to Rotax or similar authority before the starter is fitted to the engine. A hole is drilled in the mounting flange and registers with a hole in the engine flange thus oil, specification D.E.D. 2479, from the engine lubrication system is fed into the gearbox. The output shaft is drilled axially through its length and the oil from the reduction gear case returns through this hole to the engine sump.

A priming connection is provided adjacent to the cut-off plate inspection cover for use if the engine has not been used for more than seven days. Special sealing permits oil to circulate through the reduction gear, clutch, and rotor bearing only. No attempt should be made to lubricate the cut-off plate bearing.

OPERATION

Operation of this starter is quite simple and is initiated by the pilot, who selects a particular cartridge by means of the D.7802 switch. This switch is so arranged that it automatically makes the circuit, after being operated, to the alternate cartridge but prevents the firing of the alternate cartridge until 20 seconds have elapsed. When the cartridge has been selected the push-button is operated and the electrical current flows through the circuit via a micro-switch on the side of the breech chamber into the breech cap and so through the fuse to earth. This ignites the primer and fires the charge which burns for a period of $2\frac{1}{2}$ to $3\frac{1}{2}$ seconds according to the ambient temperatures and pressures. Pressure is referred to in this particular instance because if a previous operation has burst the safety disc, there will be no pressure build up in the chamber and the burning time, which is normally $2\frac{1}{2}$ to $3\frac{1}{2}$ seconds, will be extended. An indication that the safety disc has been burst will be the slow exit of gas from the exhaust. The gas created by the combustion of the charge, at a maximum temperature of 1,750 deg. C. and a pressure of 1,200 lb. per square inch, passes into a common chamber, in which is situated the safety disc. From the combustion chamber, the gas, still expanding, passes through the four tangentially-placed turbine nozzles, through coinciding ports in the overspeed cut-off plate to impinge upon the rotor blades. The gases then pass into the exhaust duct, thence to atmosphere via the exhaust pipe. Acceleration of the rotor is very rapid and to

* See also third paragraph on page 3.

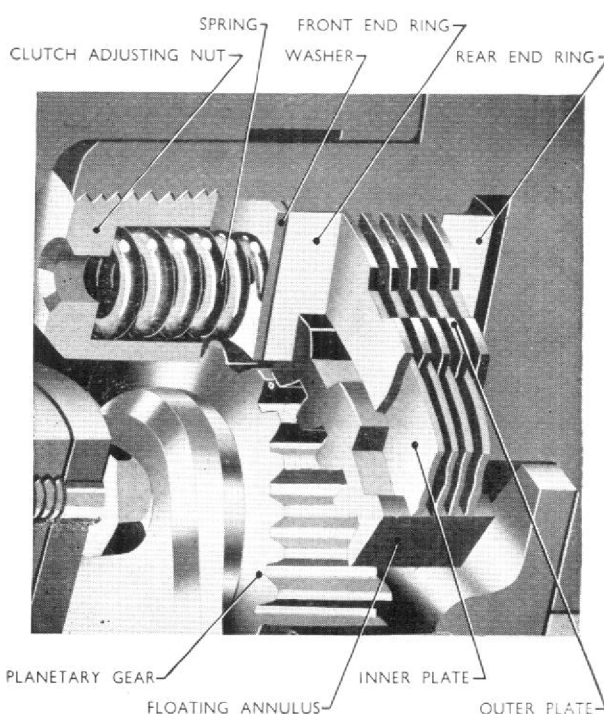


Fig. 13. Clutch assembly.

prevent shock loading being placed on the gas turbine engine gears, the clutch which is set to slip at a torque of 160 to 180 lb. ft. comes into operation by virtue of the fact that the annulus gear rotates with the steel clutch plates whilst the sintered bronze plates remain stationary in the housing. The planetary gears rotating with the annulus gear will not transmit any movement to the drive shaft, which at the moment of engagement remains stationary. As the inertia of the engine is overcome, clutch slip is reduced and the drive shaft speed increases. In one second the output shaft speed has attained approximately 2,500 r.p.m., and at the end of three seconds approximately 7,500 r.p.m. The overspeed device, as its name implies, limits the rotor speed if the drive to the engine should break down, or in the event of the starter being operated a second time while the turbine is still rotating at relatively high speed after the first operation. The construction of this overspeed device is described on the facing page.

LOADING

All cartridges should be carried in a suitable satchel so that when loading one cartridge it is unnecessary to place the other in a position where it may be damaged or collect foreign matter.

It is essential that the cartridge be examined carefully for roughness, dents, bulges, etc., in the duralumin case and if there is any doubt as to its serviceability it should be returned to the stores. A faulty cartridge case may be difficult to remove from the breech. The contact base of the primer



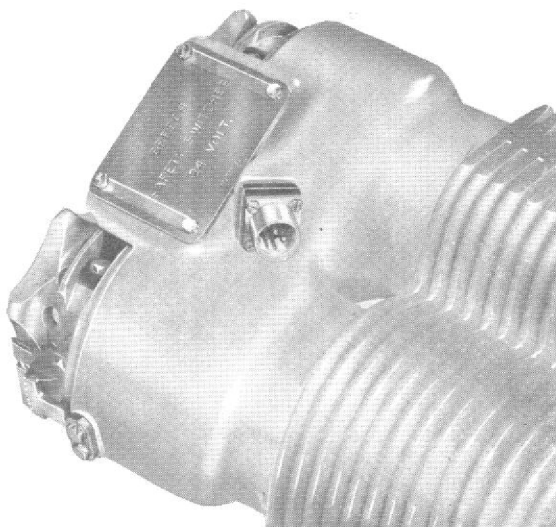


Fig. 15. Electrical plug and switch inspection cover.

must be clean and free from oil or grease. Any residue of the previous charge, such as loose carbon or fragments of burst disc must be removed. The plunger, inside the breech cap, must be examined. It may be found advantageous to insert the cartridge flange under the spring and turn the cartridge in the breech cap ensuring easy rotary movement of the cartridge flange in the slot. The cap should screw home without undue force, provided the locking ratchet on the cap is held clear of the fixed rack until they are lined correctly on the last turn of the cap. Under no circumstances must a tommy bar be used to tighten the cap. If the cap will not go home fully by hand pressure, the cartridge, breech and breech cap must be thoroughly examined for cleanliness. After the correct priming of the engine fuel system has been carried out and all primary details of the starting completed the selector switch should be operated and the starter button which fires the cartridge pressed. Engine light-up should occur in approximately two seconds, the starter continuing to assist the engine until it is entirely self-sustained and capable of

acceleration. Full details for priming the engine are contained in chapter 8.

EXTRACTION OF CARTRIDGES

Do not leave cartridges fired or unfired in the breech longer than is necessary or a maximum of eight hours. Removal is easier while the breech is warm and if the breech has been properly cleaned after the previous operation. If the cap is difficult to turn a tommy bar $\frac{5}{16}$ in. diameter, and 9 in. in length may be used. It is emphasised that this concession is only permitted in the removal of the cap.

INSTALLATION

This starter having been designed specifically for the de Havilland Ghost Engine type 48 Mk. 1 and 48 Mk. 2, can be mounted in one position only and full details of the mounting are shown in Fig. 14. Further information with regards to the installation of this starter are given in chapter 19, but the following points which should be noted and remembered with regards to this particular starter.

OIL PRIMING AND ELECTRICAL INSTALLATION

If the engine has been standing idle for more than seven days or immediately after installation of a new engine or turbo-starter the clutch and reduction gear housing must be primed with the correct grade of engine oil using the priming connection adjacent to the overspeed cut-off inspection plate. As it is impossible to more than half fill the gearbox, only approximately $\frac{1}{4}$ pint of oil will be required. The electrical installation for this starter is quite simple but it may vary with certain installations. However the same essential factors in the circuit must be included in each case. The circuit must be arranged so that it is impossible to fire both cartridges simultaneously; it must also include a delay mechanism so that a delay of one minute is placed on the circuit to prevent the second charge being fired within that period, but it must be possible in the event of emergency to

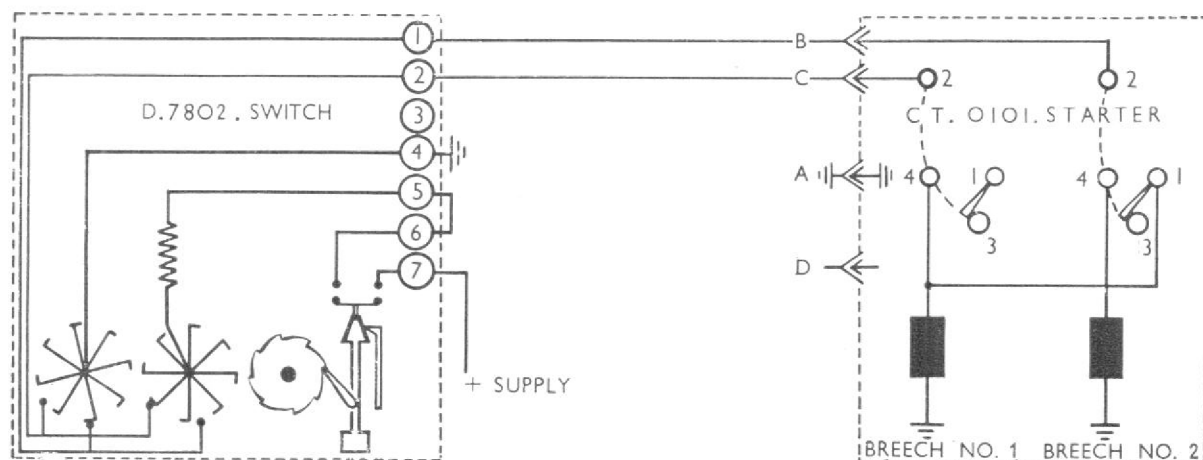


Fig. 16. Selector switch and starter.

over-ride this delay and reduce the delay period to approximately twenty seconds. An indexing switch should be included so that the current is applied to each breech alternatively and some indication of the circuit selected should be provided. It must be arranged so that current is also passed to the high energy ignition unit at the same time as the circuit is made to either breech. Current limiting resistance must be provided in the firing circuit to prevent high and dangerous currents passing through the comparatively low rated cables, a typical circuit diagram being shown in Fig. 16 overleaf.

PERIODIC INSPECTION IN SERVICE

The amount of servicing which can be carried out whilst the starter is installed is comparatively small and is confined to cleaning the breech chambers and caps to remove traces of burnt cordite and fragments of cartridge burster discs. If carbon or metal fragments are not cleaned out frequently reloading is difficult since the new cartridge will not go fully home and will consequently prevent breech caps from locating properly and completing the circuit. Special cleaning brushes are available. One is designed for cleaning the bore, a second for the extreme inside end of the breech and a third for the breech threads; the handle for the first two mentioned is interchangeable. Use of these brushes greatly facilitates the cleaning which, as mentioned previously, must be carried out frequently.

Should difficulty be encountered in fitting the breech into the cap, check the earthing strip, as it is possible for carbon deposits to locate under the strip and prevent the spring action which is necessary for easy insertion of the cartridge. This deposit can usually be removed quite easily by soaking it with methylated spirit or trichlorethylene.

Similarly stiffness in movement of the contact plunger may be encountered; here again the deposit can be removed by soaking it with methylated spirit or trichlorethylene and working the

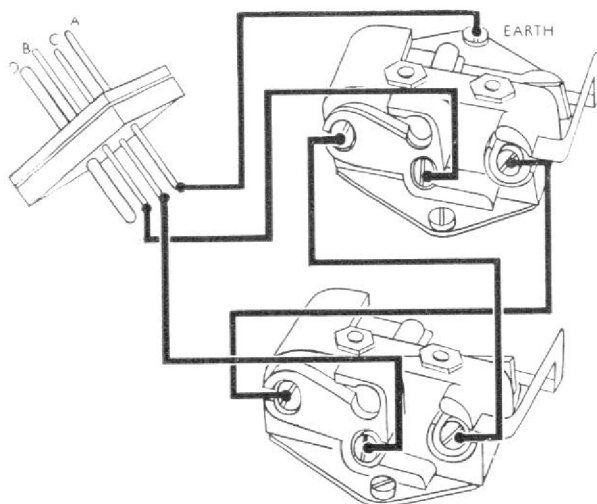


Fig. 17. Practical wiring diagram.

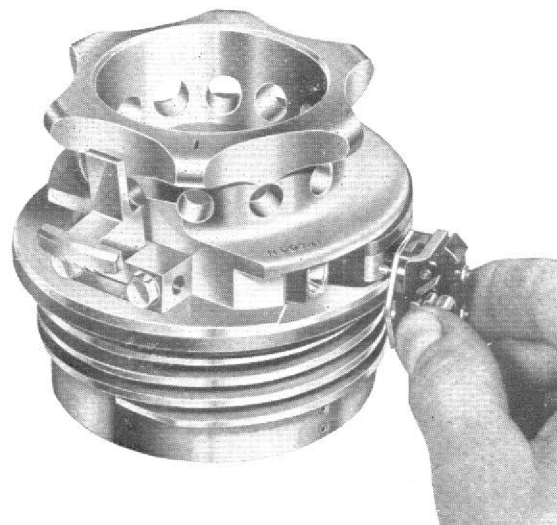


Fig. 18. Correct positioning of switch plunger.

contact plunger up and down until its movement is quite free.

Always ensure that the breech cap and breech threads are lightly lubricated with graphite grease.

The switches should be examined for their correct make and break action. This can be determined by turning the breech cap and ensuring that the switch plunger moves the contact arm over just as the ratchets engage. If a switch is considered unserviceable it should be removed and a new one substituted. The connections and positions of the switches are shown in Fig. 17. When fitting a new switch it is essential to place it in such a position that the plunger rests on the full width of the slip ring as indicated in Fig. 18. Slight adjustment of the switch in the housing is permitted by the elongated slots.

Examination of the slip ring is essential as damage to the surface may interfere with the correct operation of the switch plunger. For example, with the plunger resting in a groove on the slip ring it is possible that the switch will operate erratically. Continuity can be checked as detailed in the Defect Diagnosis chart on page 14.

Examination of the overspeed cut-off through the access plate (see Fig. 19) in the housing will not be necessary since satisfactory operation of the starter will, normally, have been observed during the last attempt to start the engine. However, cases have been experienced of C.T.0101 and C.T.0101/1 turbo-starters being rendered inoperative due to the seizure of the cut-off plate in its open position caused by a build up of carbon deposit.

At frequent intervals the cut-off plate inspection cover should be removed and the cut-off plate checked for freedom of movement and correct return. If, however, excessive effort is required to re-set the cut-off plate, or alternatively after 100 operations, it is recommended that the carbon

deposit is removed and the procedure adopted as described in "Inspection for freedom of movement of cut-off plate".

Prior to reassembling the safety disc ensure that all the threads and seatings are clean, and smear the threads with graphite grease.

In view of the experience gained it has been found that the most common cause of failure is due to mis-handling of the cartridges either in storage or transit, and it is recommended that the following instructions be obeyed by service users. Failure to obey them will entail a risk of starting failures, burst discs, etc.

1. If one cartridge in a twin breech has been fired and the second is for any reason withdrawn before being fired the following procedure must be followed:—

- (a) The cartridge must be replaced in the breech in the next barrel to be fired, normally the one from which it was taken

OR

- (b) The cartridge must be returned to the ammunition depot for refilling. It must not be returned to store.

Note—A cartridge under this heading will be smoke blackened on the smaller end due to the firing of the first cartridge in the breech.

2. The starter breech must be recharged with cartridges from the aircraft stowage compartment. Any cartridge remaining seven days in aircraft stowage in the tropics must be considered time expired and must be returned to the ammunition depot for refilling.

3. Aircraft stowage should be so arranged that cartridges can be withdrawn in the order of insertion, e.g., a clip holding the requisite number which only permits insertion from the right and extraction left would ensure this.

4. Stowage temperatures must be limited to 70 deg. C. maximum in flight for 2½ hours only; or on the ground, plus 45 deg. C. maximum, minus 10 deg. C. minimum. If necessary, protection from the sun must be provided in the tropics, and in arctic conditions, storage in a warm hut.

5. Two cartridges must be fitted at all times during firing.

6. Subject to the above the life of cartridges stored in good service magazines will be considered provisionally to be five years in temperate climates and two years in the tropics. Every effort should be made to provide good magazine storage on aerodromes.

INSPECTION FOR FREEDOM OF MOVEMENT OF CUT-OFF PLATE

Before commencing this operation ensure that all tools, marked with an asterisk in the list on

page 15, are available, together with the essential replacements listed below.

Part No.	Description	Qty.
N.23539/7	Tab washers	15
N.83287	Tab washer	1
N.99674	Lock washers	2

Prior to dismantling remove the bursting disc and examine the seating. Should this be damaged or below 0.130 inch in width on the exhaust side the starter should be classified as repairable and overhauled and tested as described on page 17 to 46.

Dismantle the starter as described in Fig. 20 to 27 on page 17 and 18. Carefully remove the carbon from the two ports on the nozzle ring until the two threaded holes are clear. Remove the nozzle ring and cut-off plate assembly as described in the caption to Fig. 28. Remove the cut-off plate from nozzle ring, see Fig. 36 and 37, page 20. Clean nozzle ring and cut-off plate as follows.

Place the nozzle ring and cut-off plate in boiling water and maintain at this temperature for approximately 2½ hours to soften the carbon. Take great care at all times to ensure that the lapped face of the nozzle ring is not scratched or damaged in any way. This surface forms a seal with the corresponding face in the breech housing which is to be lapped in again during assembly. Therefore, the prevention of any scratches will reduce to a minimum the amount of time necessary for the rebedding of these components. Remove all traces



Fig. 19. Inspection of cut-off plate.

of carbon from the face of the breech housing using fine emery cloth soaked in methylated spirit. **DO NOT** scrape the surface which mates with the nozzle ring.

Using a blunt instrument such as a screw-driver, remove the carbon from the ports in the four passages to the nozzle ring, exercising care that no damage is done to the face. The particles of carbon must be removed by inverting the housing and shaking, this is important. At this stage, it is also advisable to clean off any carbon which may be adhering to the overspeed clutch ring of the rotor wheel assembly using grade 320 (or finer) emery cloth soaked in methylated spirit. Remove the nozzle ring and cut-off plate from soak and dry thoroughly. The carbon should now be in a sufficiently soft state to come away by use of methylated spirit alone. If any scraping is necessary, however, confine it on the nozzle ring, to the areas which are not lapped in. Blow off any carbon dust afterwards.

Small cracks, due to differential expansion of the nozzle ring, are liable to appear on the carbon ring labyrinth close to the nozzle exits, and extend to the unsupported edge of the labyrinth. This condition is in no way unusual, but should these cracks extend the full depth, or through the entire thickness, of the labyrinth, the nozzle ring must be rejected. Buckling of the labyrinth is permissible up to a maximum total of 0.020 inch.

Before assembly, lap in the nozzle ring as described in Fig. 60 and 61 on page 26 and 27

and in the associated text. Fit the cut-off plate into the nozzle ring as in Fig. 100 on page 39. Re-bed the cut-off plate to the carbon ring by working the cut-off plate between the stops. Apply a spring balance to the trigger, noting the reading at which the trigger begins to move which should be between 4 and 4½ lb.

Assemble the starter as described on page 42 to 44, Fig. 113 to 120.

COLD STORAGE

Adequate information on the effect of handling and vibration on cold cartridges is not yet available. In the meantime, cartridges below minus 10 deg. C. should be treated as fragile and handled with care. The risk is that the frozen charge may crack if roughly handled and give an abnormally high pressure when it is eventually fired.

TOOLS

(PAGE 15 and 16)

Due to the very fine limits imposed, a great deal of care is necessary in both dismantling and reassembly, for the slightest damage done in either process may have serious effects on the performance and reliability of the starter. In order to facilitate the work, a complete set of tools has been designed and no attempt should be made to service the starter until these items are available.

DEFECT DIAGNOSIS

<i>Fault.</i>	<i>Possible cause.</i>	<i>Correction.</i>
One cartridge does not fire	Defective cartridge or possible delayed action	Fire second charge or wait one full minute and change cartridge.
	Breech cap not correctly fitted	Wait one full minute and screw cap fully home.
	Break or high resistance in firing circuit	Wait one full minute and test the circuit at the firing pin—to do so remove both cartridges and replace one breech cap. Check continuity by means of a 30 V. voltmeter, across the exposed pin and the barrel assembly. Replace this breech cap, and remove the other breech cap and check between the other pin and barrel assembly. It is essential to place the selector switch in the respective firing position.
Cartridge fires but engine mainshaft does not turn	Safety disc blown	This will be indicated by a heavy discharge of yellow smoke for several seconds. Fit new safety disc assembly.
	Overspeed cut-off not reset	Remove the inspection plate and check the correct position of the stop peg. This is indicated on the casting.
	Starter drive failure	Check as above. Check that the cut-off plate operates correctly. Remove starter and fit replacement.
	Dog clutch in engine fails to engage	Ensure overspeed cut-off has reset.
	Slipping clutch	Remove starter and fit replacement. Strip starter for complete examination.

Revised by Amendment No. 139
November, 1958

SPECIAL EQUIPMENT

<i>Tool No.</i>	<i>Description</i>	<i>Illustrated in fig.</i>	<i>Purpose</i>
NT.4422 *	Tool	21	Separating front and centre housings
NT.4423 *	Tool	23, 24, 25	Separating centre and rear housings
NT.4039A *	Tool	26, 27	Removal of studs
NT.4039B *			
NT.4100 *	Tool	28	Removal of nozzle ring and cut-off plate
NT.4030 *	Adapter	41	Removal of sun gear nut
NT.4431 *	Carrier	58	Holding breech housing
NT.4427 *	Lapping tool	58	Lapping nozzle face of breech housing
NT.4428 *	Lapping block	60	Lapping nozzle ring
NT.4430 *	Alignment gauge	82	Aligning holes in clutch nut and main housing
NT.4033 *	Adapter	118	Fitting front housing nuts

Tools marked with an asterisk () are also used in the operations concerned with the inspection for freedom of movement of the cut-off plate.*

NT.4007	Tool	30	Removal of "Clupet" seals
NT.4107	Adapter	33	Removal of cap nut
NT.5171	Spanner		
NT.4001	Tool	41	Removal of sun gear nut
NT.4005	Bench Block	45, 74, 78	Clutch dismantling and assembly, etc.
NT.4006	Tool	45, 78	
NT.4011	Securing tool	48, 110	Removal and replacement of output shaft nut
NT.4012	Bench block	50, 96, 107, 116	Work on front housing
NT.864	Rack press	—	Various pressing purposes
NT.4008B	Base	52	Removal of oil seal
NT.4010	Punch		
NT.4733	Tray	52	Safe storage of planet gear parts
NT.4720	Cleaning brush set	Not illustrated	For cleaning the bore of the breech, the extreme end of the breech, and the breech threads, etc.; the handle for the first two being interchangeable
NT.4721			
NT.4722			
NT.4723			
NT.4724			
NT.4785	Test rig	62	Testing switches
NT.4433	Tool	63	Mounting rotor for shot blasting
NT.4036	Clamping ring	67	Preparation for hydraulic test
	Plugs and nuts	68	
NT.4014	Clamp	78	Assembly of clutch

*Revised by Amendment No. 124
April, 1956*

SPECIAL EQUIPMENT (*continued*)

<i>Tool No.</i>	<i>Description</i>	<i>Illustrated in fig.</i>	<i>Purpose</i>
NT.4106	Test rig	81	Clutch setting
NT.4113	Mandrel	83	Checking rotor bearing
NT.4114	Mandrel	83	
NT.4115	Mandrel	83	
NT.4013	Test fixture and nut	83, 84	
NT.5170	Gauge	86	Checking overspeed clutch ring
R.548	Gauge (similar to NT.5170)	Not illustrated	
NT.4015	Test fixture	89	Checking sun gear
NT.4429A	Test fixture	93, 94	Checking truth of rotor in housing
NT.4429B			
NT.4019	Test plate	96, 97	Measurement of liner to nozzle face
NT.4021	Machining fixture	98	Holding liner in drilling machine
NT.4116	Cutter	98	Machining liner
NT.4022	Punch	99	Fitting new cap to liner
NT.4028A			
NT.4028B			
NT.4028C	Test rig and weights	101 to 105	Test and setting of cut-off plate, etc.
NT.4028D			
NT.4028E			
NT.4008A	Adapter	106	Fitting new oil seal
NT.4008B	Base		
NT.4009	Punch		
NT.4004	Gauge	111	Checking drive shaft
NT.4109	Gauge	112	
NT.4039A	Assembly ring	114, 115	Assembly of studs to housings
NT.4039B	Plug		
NT.4039C	Plug		
NT.4035	Gauge	120	Alignment of exhaust flanges
NT.4036	Test rig	70 and 71	Hydraulic test

3 torque spanners similar to Acratork Nos. A, A2, B1.

FURTHER EQUIPMENT

Means of accurately turning and grinding.
Vertical drilling machine.
Balancing rig similar to that shown in Fig. 64.

DISMANTLING

Overhaul after 250 operations

Before dismantling the starter remove the oil priming plug from the front housing, drain off the oil and replace plug.

Complete dismantling may now be carried out in accordance with the following instructions and illustrations and in the sequence detailed; read the captions in Fig. No. sequence.

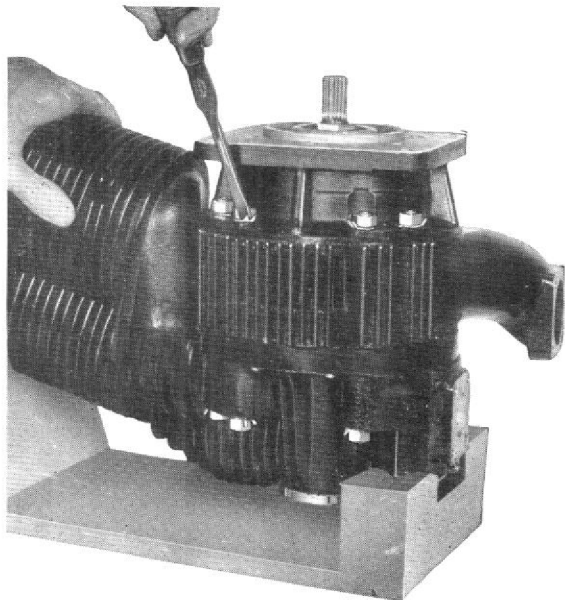


Fig. 20. Release locking tabs and cut wire locking as necessary. Remove the eight $\frac{3}{8}$ in. B.S.F. nuts which unite the front and centre housings.

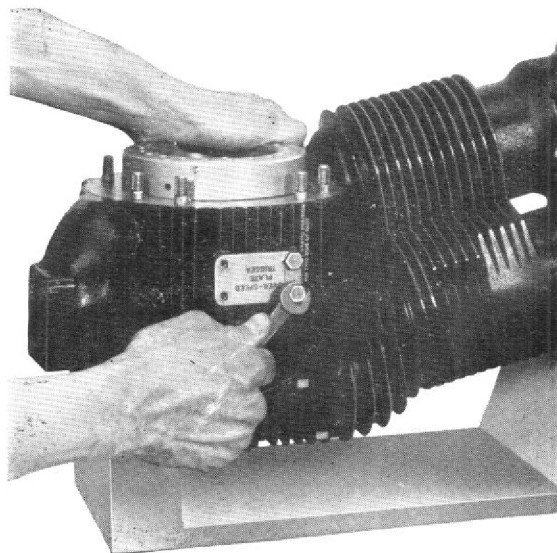


Fig. 22. Remove the four screws and locking straps securing the access cover of the overspeed plate trigger. Remove cover and copper washer.

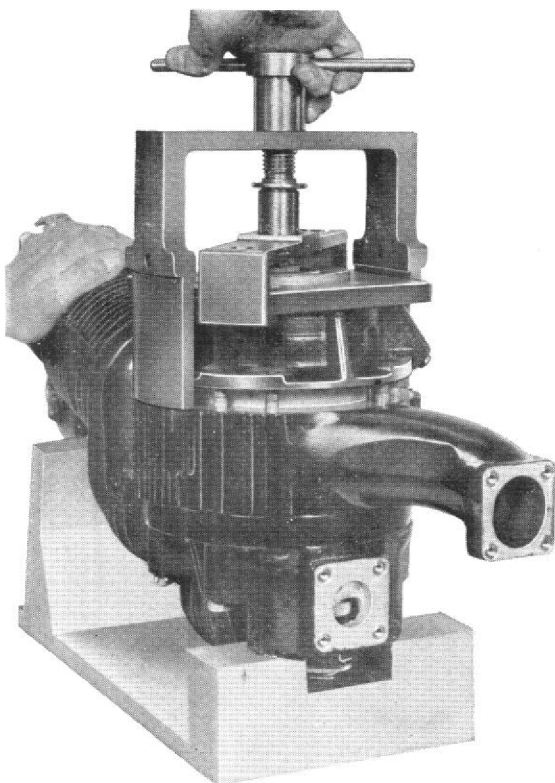


Fig. 21. Using special tool NT.4422 remove the front housing from the centre housing.

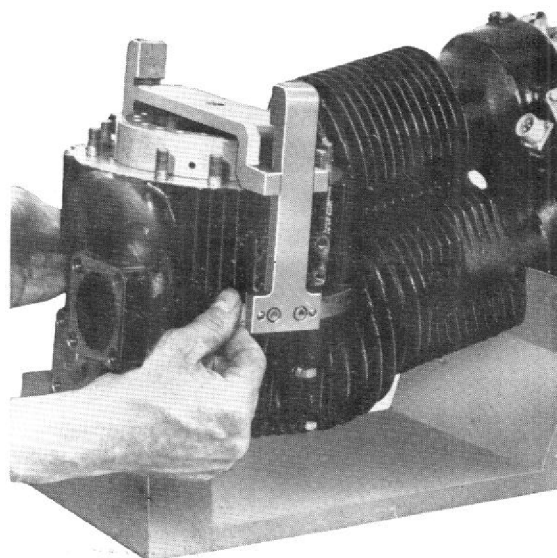


Fig. 23. Separate the centre and rear housings using tool NT.4423. View shows the first part of the tool being placed in position.

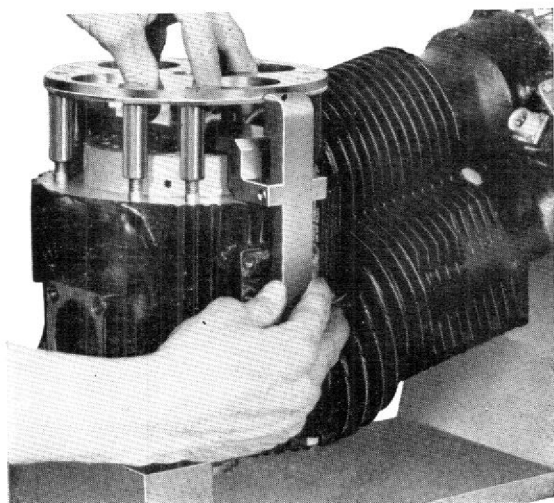


Fig. 24. View showing the first and second parts of tool NT.4423 in position.

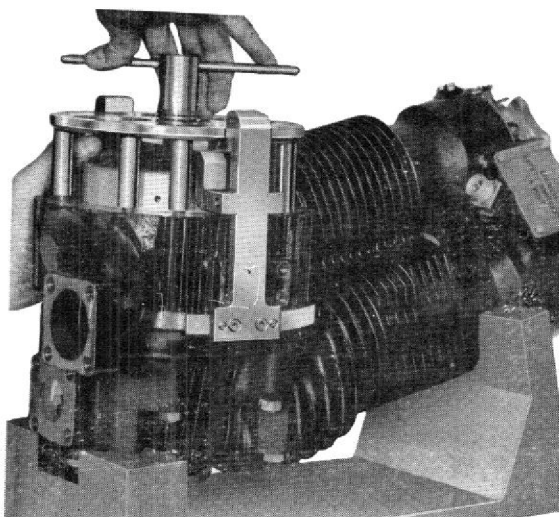


Fig. 25. View showing the complete tool in position, i.e., handle and ballrace have been fitted. To release centre housing turn handle clockwise. Remove the centre housing from the breech and nozzle assembly. Take care not to lose any of the eight dowels, located by the rotor wheel shroud, which may be loose.

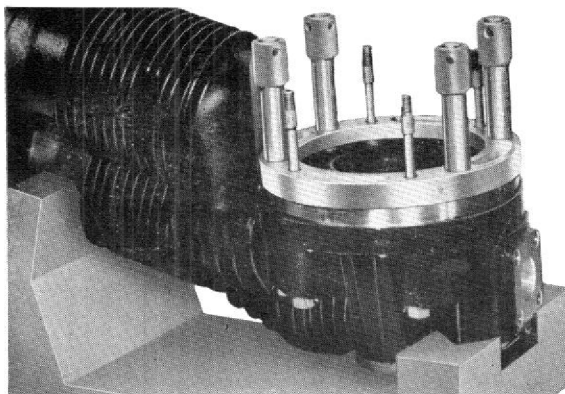


Fig. 26. Fit tool NT.4039A over studs and secure in position by fitting four short plugs NT.4039B.

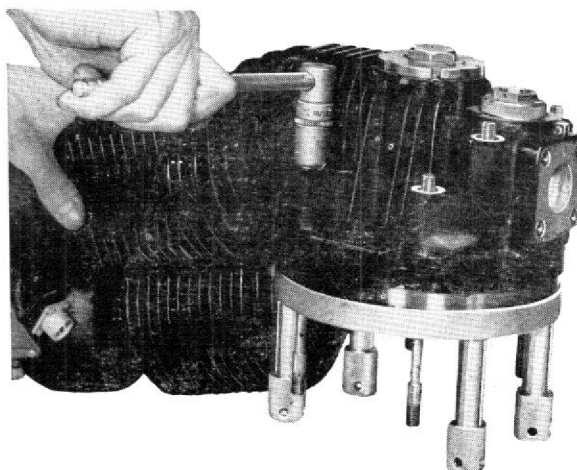


Fig. 27. Remove the eight nuts at the rear of the breech housing, and remove the tools NT.4039A and B. Withdraw the eight studs.

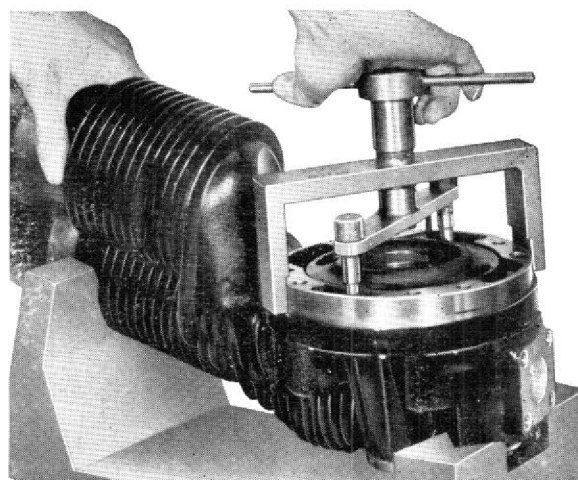


Fig. 28. Fit tool NT.4100, securing in position by inserting threaded studs into extractor holes in nozzle ring. View shows nozzle ring and cut-off plate assembly being removed. Collect the two springs. Important Note—The four cut-off plate stop bolts located in the nozzle ring assembly must not be removed.

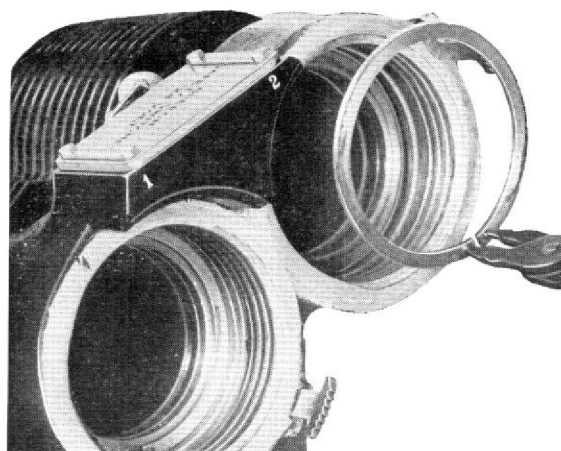


Fig. 29. After removal of the two breech caps, remove the circlips retaining the "Clupet" seals.



Fig. 30. Using tool NT.4007, remove the "Clupet" seals. Make sure that the jaws of the tool are well behind the seal. It may be necessary to clean out the carbon deposited behind the seal to allow the jaws to fully expand.

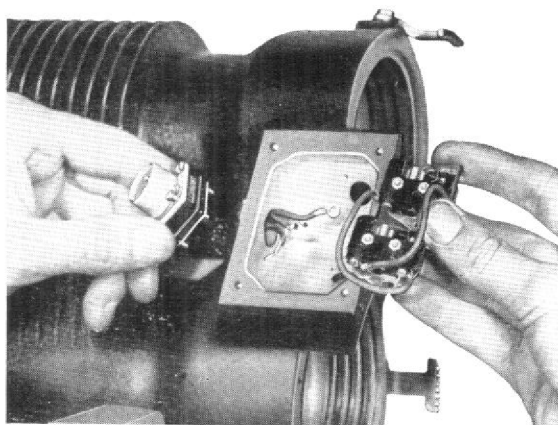


Fig. 31. Remove the breech safety switch cover and cork gasket. Disconnect and remove the switches and plug assembly.

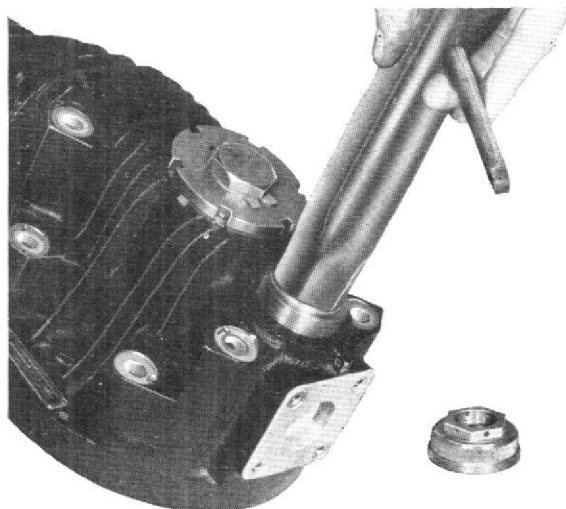


Fig. 32. Remove the bursting disc assembly.



Fig. 33. Remove centre plug. Fit tool NT.4107 in position by means of a $\frac{1}{8}$ in. (AF) Allen Key, and, using spanner NT.5171 remove the cap nut (it may be necessary to warm the casting).

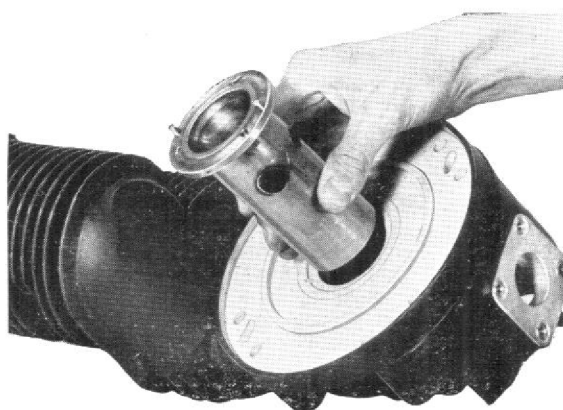


Fig. 34. Note: The operations associated with this figure, which involve the removal of the inlet bush, should be carried out at every overhaul. The bush may be removed in the following manner. Using a blunt screwdriver or similar instrument remove as much carbon as possible from the internal bore and ports of the bush. Raise the temperature of the casting to 100 deg. C. (immersion in boiling water is the best method.) Using a press having a capacity of about 2,000 lb. and supporting the breech casting close to the bush (not on the nozzle ring face) exert sufficient pressure on the bush to remove it from the casting. Caution—Take care that the thread is not damaged during this operation.

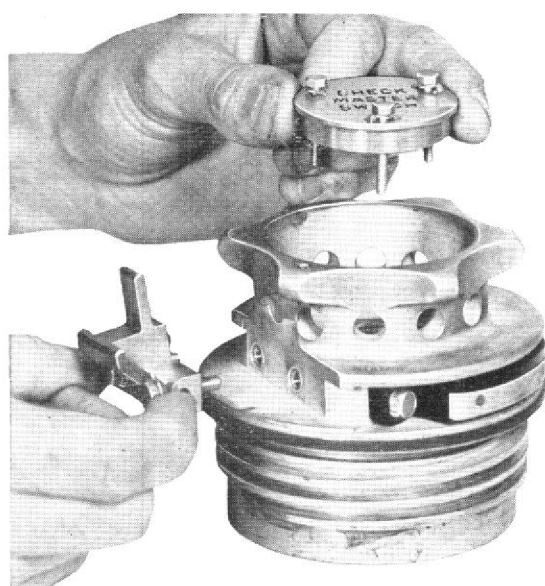


Fig. 35

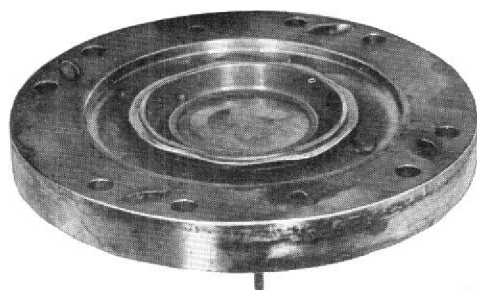
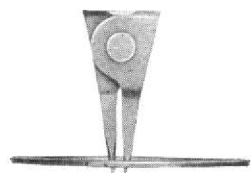


Fig. 36



Fig. 37

Fig. 35. Note : This operation need only be carried out if the breech caps require replacing. Remove the three screws and tab washers securing the cover plate. The items removed by the operation will be required for fitting to the new breech caps.

Fig. 36. Remove the circlip, wave washer, shims, and bearing ring from the cut-off plate and nozzle ring assembly. Remove the sixty-eight stainless steel balls and place in a suitable container to avoid loss.

Fig. 37. Remove the cut-off plate from the nozzle ring. Caution : Take care not to damage the carbon bearing ring located in the nozzle ring.

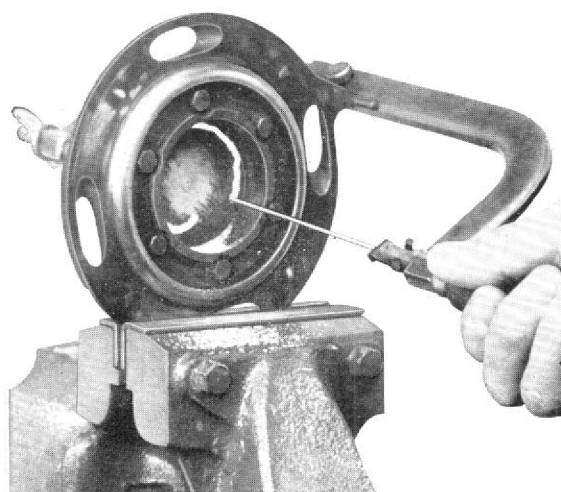


Fig. 38. If the sintered bronze liner is satisfactory but the sealing cap is damaged, proceed as follows, taking care that the liner is not injured in the process. Using a hand brace and a $\frac{1}{8}$ in. drill, pierce the damaged cap. With a hack saw frame and "Abra file" as illustrated, cut around the cap. Carefully ease out the remainder of the cap with the aid of a pair of pliers.



Fig. 39. Remove the rotor shroud. Note : Slight distortion may tend to make the shroud bind in the housing, this does not necessarily mean that it is unserviceable.

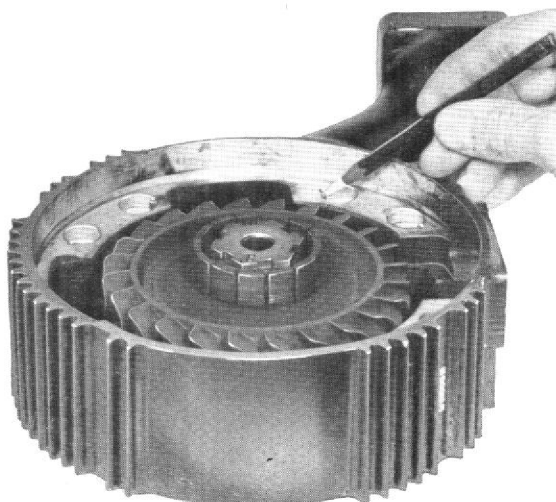


Fig. 40. Remove the eight dowels.

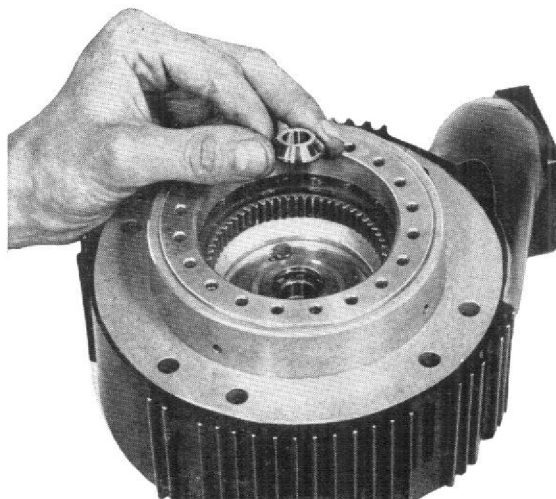


Fig. 43. Remove the sun gear spacer.

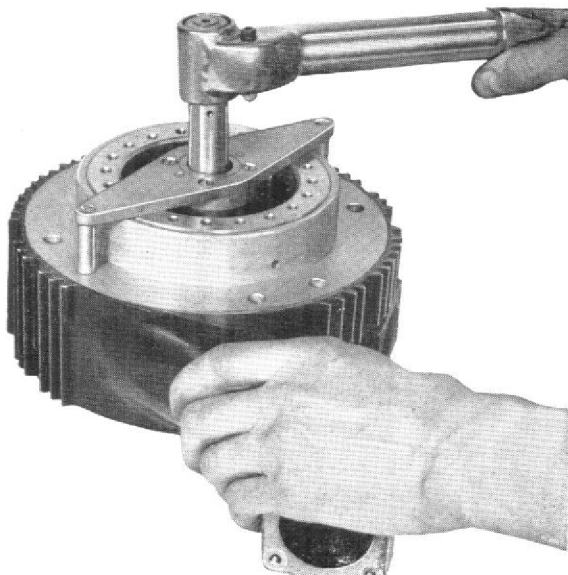


Fig. 41. Release sun gear locking tab and using tools NT.4001, NT.4030, and torque spanner or suitable "T" wrench, remove the sun gear nut (right-hand thread).

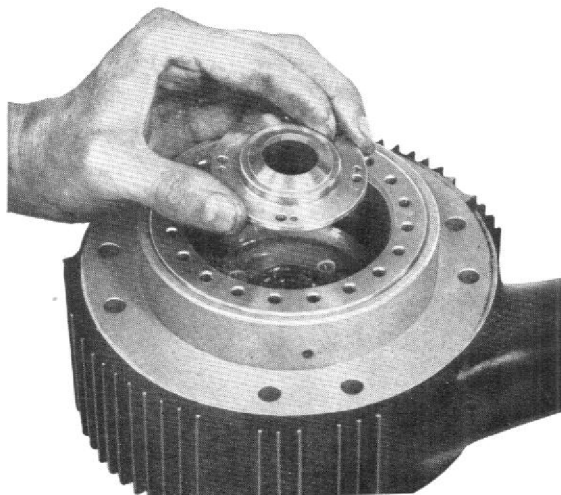


Fig. 44. Remove the four screws and tab washers securing the rotor ball race clamp plate, and remove plate. Carefully mark the rotor ball bearing and housing to ensure that on reassembly the bearing is not inverted. Remove the bearing and **immediately wrap** to protect it from foreign particles.

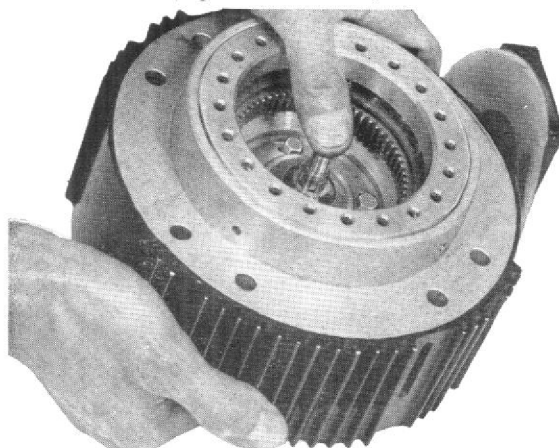


Fig. 42. Remove the sun gear. Carefully ease out the rotor wheel assembly.



Fig. 45. Using bench block NT.4005 and clutch adjusting bar NT.4006 remove clutch adjusting nut and clutch springs. Caution: Tape the thread of the clutch nut to protect it from damage.

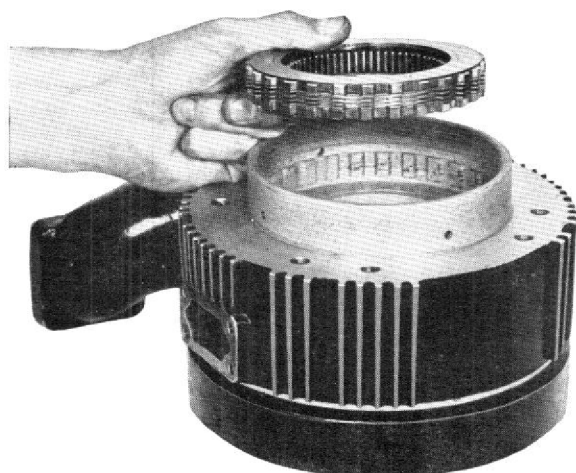


Fig. 46. Withdraw the clutch pack and annulus gear from the centre housing. Note: If clutch is not marked this should be done on dismantling. See assembly instructions.

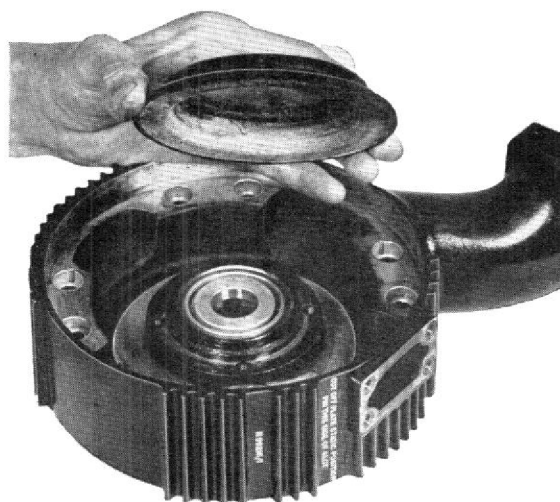


Fig. 47. Remove the four screws and tab washers securing the asbestos-lined shroud. Remove shroud.

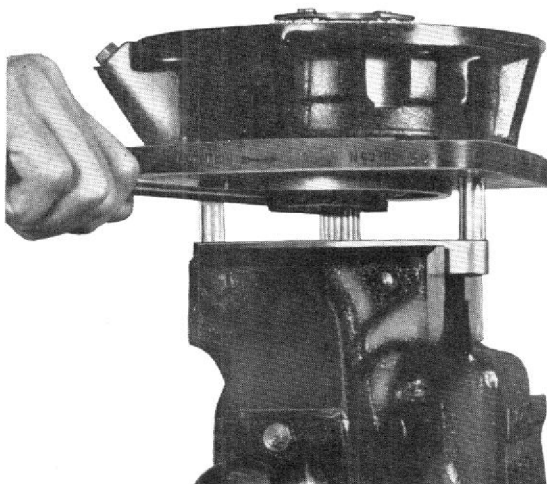


Fig. 48. Securing tool NT.4011 in a vice use a $\frac{5}{8}$ in. open-ended spanner to remove the output shaft nut. Remove tab washer.

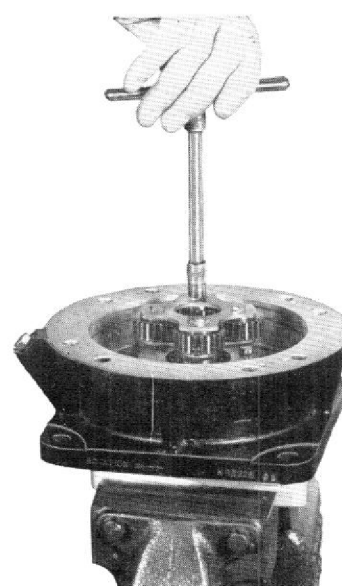


Fig. 49. With front housing still supported as for previous operation slacken off, but on no account remove, the four screws securing the planet gear retaining plate. Note: This operation is associated with the dismantling of the planet gear assembly which will be fully dealt with at a later stage. In practice it is found convenient to slacken off these four screws whilst the planet assembly is held firmly in the securing tool NT.4011. Press out the output shaft complete with planet gear assembly. (A light press may be used.) Wrap in clean tissue paper.



Fig. 50. Remove front bearing as shown. The bearing spacer located between the front and rear bearings can now be withdrawn. (For this operation the housing is removed from securing tool NT.4011, turned over and placed on bench block NT.4012.) Remove the three screws and tab washers securing the rear bearing clamp plate and remove plate. Remove the rear bearing, tapping the casting if necessary to ease it. Note: It is advisable to wrap these bearings to protect them.

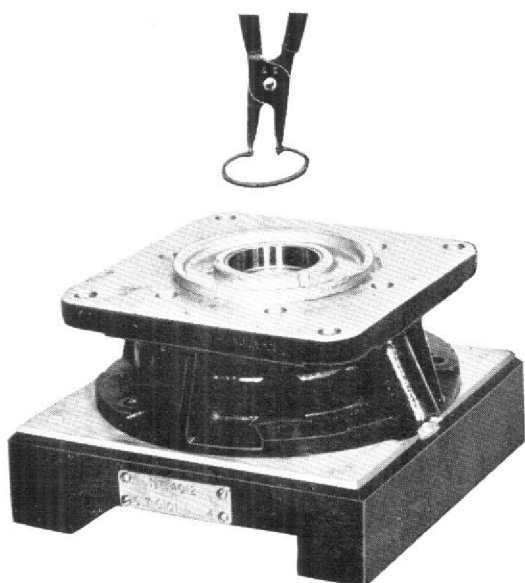


Fig. 51. Remove circlip.



Fig. 52. Using rack press NT.864, base NT.4008B and punch NT.4010 press out the oil seal. Note: Once removed, the oil seal cannot be refitted and must be renewed.

DISMANTLING THE PLANET GEAR

Note: In order that the importance of following the instructions for dismantling the planet gear assembly can be realised, its construction will first be outlined and it is advisable to read completely through the details of all operations before any attempt is made at dismantling.

Reference to Fig. 53 will show that the complete gear consists of four pinion groups, each made

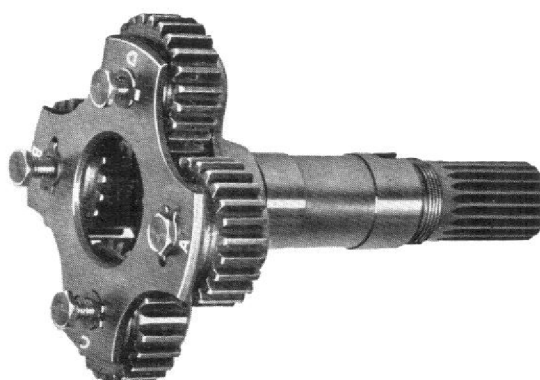


Fig. 53. Planet gear assembly.

up of the pinion, its bearing needle rollers (17 in number), and the top and bottom washers.

The pinions are free to revolve on equidistant pins which are integral with the output drive shaft.

The pinion groups are retained in position by a planet retaining plate and four screws (which were slackened in operation Fig. 49).

Although the component parts of these four pinion groups are identical and interchangeable at the time of manufacture, conditions in service may render them dissimilar due to a certain amount of "mating" or tracking and they may be no longer interchangeable.

Tracking takes place mainly on the washers, where, due to the action of the ends of the needle rollers a groove may be formed whilst the lower one may become "stepped" due to the undercut at the base of the planet pinion pin on its under side.

The amount of "tracking" may be very small and of no consequence so long as the components are reassembled in the same way, but if the washers are inverted the irregularities no longer "mate" and trouble may arise, and in order to prevent this, certain precautions must be taken. Thus, the principle of "put back as taken off" must at all times be borne in mind.

Inspection will show that each pinion group bears a separate letter, i.e., A, B, C, D, stamped on the arm of the retaining plate, the pinion, and the arm of the spider at the base of the planet pinion pin.

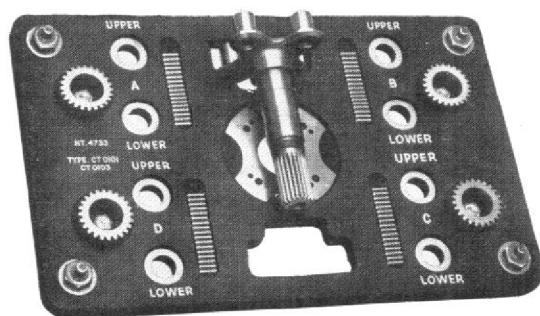


Fig. 54. Special tray NT.4733.

A special tray NT.4733 (illustrated in Fig. 54) is used to receive the components as they are dismantled and this is divided into four groups of recesses to hold the parts, each group being lettered to correspond with the letter of the four pinion groups. Central recesses are provided to accommodate the retaining plate and spider.

The tray is further furnished with legs and distance pieces at each corner, so that if a number of starters are being dealt with, the trays filled with components can be stacked on top of each other, provided that each alternate one is turned round the other way so that the upper half of the spider in its lower tray fits into the recess on the lower side of the upper tray.

With this tray placed in a position where it will not be interfered with or knocked over, the dismantling operations may be proceeded with in the following sequence.

- A. Support complete assembly in a vertical position so that pinions cannot fall off when retaining plate is removed.
- B. Remove the four retaining screws already eased off in operation Fig. 49, and place each in the hole bored in the pinion recess of the tray, and under its corresponding group number.
- C. Lift off the retaining plate and place the same way up in its recess in centre of tray.
- D. Starting with group A remove upper washer and place in upper washer recess of tray taking care to keep it the same way up. (Recess Group A is, of course, used.)
- E. Using a pair of tweezers remove the seventeen needle rollers and place them all together in their recess (Group A) keeping like ends together.
- F. Remove pinion and place same way up in recess on tray (Group A).



Fig. 55. Planet gear assembly, partly dismantled.

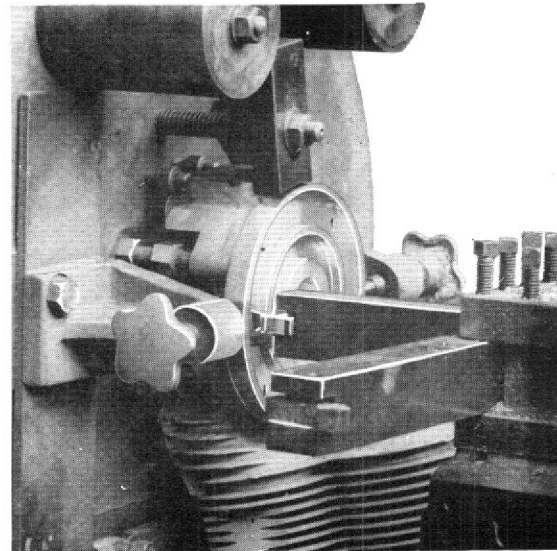


Fig. 56. Turning rear housing face.

- G. Remove lower washer and place same way in lower recess of tray (Group A).

Repeat operation D to G for groups B, C, D, using corresponding recesses in tray.

- H. Place spider and output drive shaft unit in its recess in tray. Fig. 55 shows the assembly with its groups in various stages of dismantling.

INSPECTION

Note: These notes comprise inspection preliminary to reassembly and cover most of the details. Certain items are better carried out during the assembly operation and are therefore dealt with on page 34 to 40.

CLEANLINESS

Before inspection of the various components can be satisfactorily carried out, it is essential that they should be thoroughly cleansed and free from carbon deposit. This should be carried out as detailed in the following paragraphs.

REAR HOUSING AND BREECH ASSEMBLY

To soften the carbon deposit immerse the complete housing in hot water for a period of two hours. Using a blunt instrument such as a screwdriver, decarbonise all gas passages, exercising care at the four cored holes in the nozzle ring face to ensure that no damage is done to the face. The carbon deposit at these points is extremely hard. Complete the initial decarbonising by cleaning the internal bores and threads using the brushes NT.4720, NT.4721, NT.4722, NT.4723 and NT.4724.

Remove all traces of "Heldite" compound by the use of Grade 320 (or fine) emery cloth, which has been previously soaked in methylated spirit. Complete the operation by wiping over with a clean rag similarly soaked in spirit.

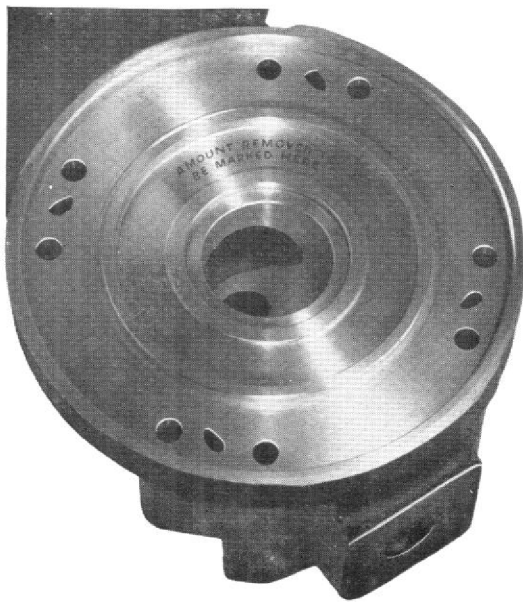


Fig. 57. Rear housing, showing position of mark amount of metal removed from face.

If erosion and surface shrinkage adjacent to the four cored passages is such that less than $\frac{1}{8}$ in. land is shown between the passages and stud holes or undercut after a light lapping with tool NT.4427 and H.500 O.P. compound, then the casting should be mounted in a lathe, as shown in Fig. 56, and the face turned in accordance with the following instructions.

Using a diamond tool turn the face to remove the damage done by erosion until at least $\frac{1}{8}$ in. land is present. The maximum amount to be removed in this manner must not exceed 0.015 in. The same amount to be removed right across the face to maintain correct relationship between faces. The only part which need not be turned is that shown in Fig. 57 where the amount removed should

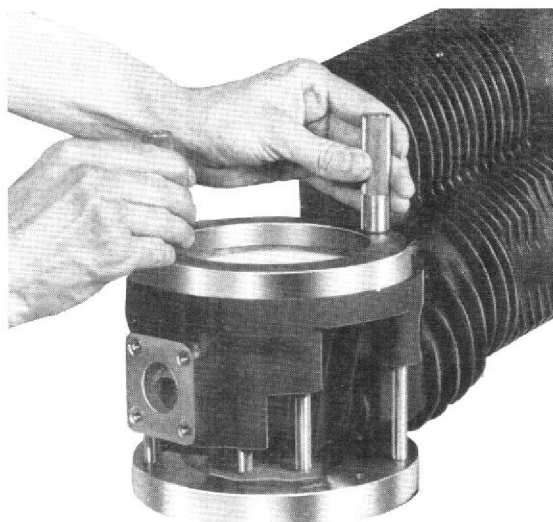


Fig. 58. Lapping rear housing face.

be stamped. The undercut should be carefully maintained.

The following lapping-in operation should follow turning. Mount the breech housing on Carrier NT.4431, and using tool NT.4427 spread a small quantity of H.500 O.P. compound over its nozzle face and lap to obtain perfectly flat finish with at least $\frac{1}{8}$ in. land between cored passages and stud holes or undercut. *Note:* This lapping operation alone may be sufficient if only very slight erosion has taken place. Remove all traces of compound on completion of the operation, using benzene.

INLET BUSH

Clean in a similar manner to that adopted for the breech casting.

CUT-OFF PLATE AND LINER ASSEMBLY

Clean off all carbon deposits by the use of Grade 320 (or finer) emery cloth soaked in methylated spirit.

Discard the cut-off plate if:—

1. Buckling is such that flat side of flange is more than 0.030 in. out of flat.
2. Burning on the other side has extended more than 0.050 in. into the face.
3. Any of the port pads has more than 0.020 in. radius at any point on leading edge adjacent to "burning" area.
4. Cracking between parts and outside diameter is obviously more than superficial.

Note: Sintered bronze liner or 2 B.A. screws must not be removed unless found faulty. Removal means replacement by new part.

Check the inside diameter of the liner at a number of points over its length to the dimension $2.136 \pm \begin{smallmatrix} .001 \\ -.000 \end{smallmatrix}$ in.

If found to be outside the permissible limits a new complete assembly must be fitted.

If the sealing cap is damaged but the liner and cut-off plate are serviceable, remove the damaged cap in the manner detailed on page 20, Fig. 38. Then press home a new sealing cap using tool NT.4022 as illustrated on page 39, Fig. 99.

ROTOR BEARING

This should be inspected for signs of pitting of the balls and if present, discard the bearing and replace. Detailed checking of the rotor bearing should be undertaken on reassembly as detailed in Fig. 83 and 84.

Note: Due to construction, the bearing will feel worn unless clamped in its working position.

BURSTING DISC

Discard old one and replace with new.

CORK GASKETS

Inspect to ensure that they are in no way damaged. Renew if necessary.

The circlip, wave washer, shims, plain washer and bolts should be thoroughly cleaned in methylated spirit. Inspect the balls for signs of pitting or corrosion, if evident, renew. *Note*: Only stainless steel balls should be used. It will be seen that provision is made for 69 balls but only 68 are employed.

NOZZLE RING ASSEMBLY

Thoroughly clean in a similar manner to that employed for the cut-off plate; take care not to damage the sealing ring and note that the four stop bolts must not be removed unless damaged.

Inspect the carbon sealing ring face for signs of damage and if found to be unsatisfactory the complete nozzle ring assembly, including the four stop bolts and tab washers, must be renewed.

Replacement of the nozzle ring should be made if:—

1. Starter has been fired 250 times or more.
2. (Where suitable projector is available) area of any one nozzle throat exceeds 0.016 square inches.
3. Land between nozzle inlet and bolt holes, or edge of sealing face is less than $\frac{1}{16}$ in. after grinding up to 0.002 in. from face and lapping flat.
4. Severe cracking is evident in the throats.

Faulty nozzles may be replaced by bringing the temperature of the nozzle ring up to 300 deg.

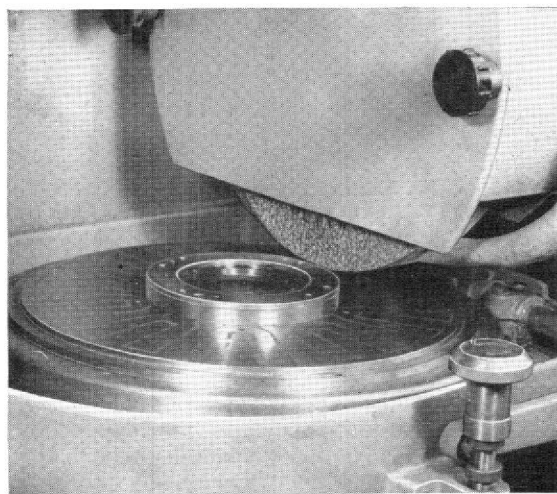


Fig. 59. Grinding nozzle ring face.



Fig. 60. Lapping nozzle ring face.

C. when old ones can be easily pressed out. The ring should then be re-heated to 300 deg. C. and the new inserts pressed in. Conditions of service may, however, cause the fit to vary and if any difficulty is experienced the complete nozzle ring should be returned to our nearest Service Department or authorised service station.

If these points are satisfactory but the nozzle ring shows signs of erosion it is permissible to grind and lap the face in accordance with the following instructions, Fig. 59.

Grind the nozzle ring face on a rotary table grinder, removing not more than 0.002 in.

On completion of the grinding operation lap the face using lapping block NT.4428 and H.500 O.P. compound to obtain a perfect surface, Fig. 60.

With the breech housing on carrier NT.4431 fit the handles from tool NT.4427 to the nozzle ring assembly and using a small quantity of H.500 O.P. compound lap the nozzle ring to the breech housing, Fig. 61.

After this operation the nozzle and breech housing should be considered as paired.

Take care to remove all traces of compound with benzine.

SHROUD

Thoroughly clean the assembly in a similar manner to that employed for the cut-off plate. Inspect the internal bore for signs of scoring due to distortion causing it to foul the rotor. Inspect for signs of erosion. Shroud should be discarded if:—

1. Minimum diameter is less than 5.125 in.
2. Cracking is severe.
3. Erosion is present to a depth over 0.020 in. in the bore.

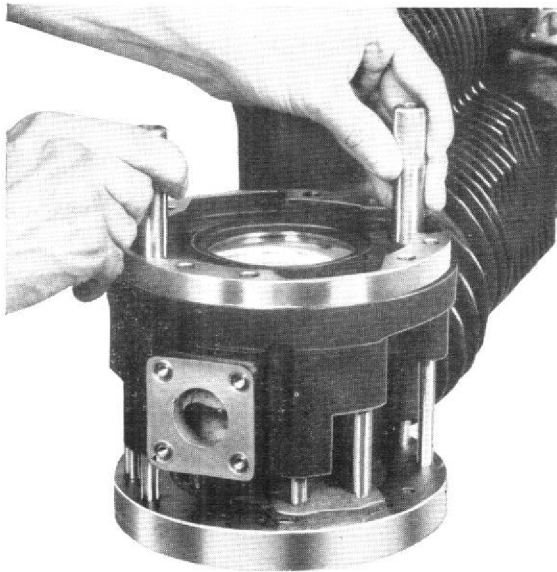


Fig. 61. Lapping nozzle ring to breech housing.

BREECH CAPS

Inspect the ratchet for wear, if worn renew. Check the centre plunger for freedom of movement, and if found to be sticking it can be freed by pouring in a small quantity of methylated spirit or trichlorethylene, working the plunger until it is free.

Inspect the rubber sealing ring to ensure that it is bonded to the cap. If faulty renew the complete breech cap and brass washer assembly.

Inspect side spring and contact strip for damage. Renew breech cap assembly if either are faulty.

Inspect the earthing strip to ensure that its movement is not restricted by carbon deposit, and if necessary, remove the strip, clean away the deposit and replace strip, coating the threads of the retaining screw with bakelite cement. If the strip is cracked or damaged in any way it should be renewed.

Inspect threads of breech cap. If damaged renew complete assembly.

Note: Where for any reason the cap is to be renewed do not scrap original one but return to manufacturers for rectification.

ASBESTOS LINED SHROUD

Thoroughly clean, and inspect the condition of the asbestos. If damaged or badly burned, renew.

HOUSINGS

Thoroughly clean main housing with hot water, followed by methylated spirit, finishing with benzene. For front housing use benzene only.

Inspect for distortion, cracks, or mechanical damage. Inspect the threaded inserts to ensure that they are not damaged. Renew housing if damaged.

ANNULUS AND SUN GEAR

Inspect for signs of wear, if worn renew.

CLUTCH PLATES

Inspect for scoring, bronze pick-up on the steel plates and "dishing." If any of the plates are unsatisfactory the complete pack should be discarded and a new pre-bedded, numbered set installed.

CLUTCH SPRINGS

Test the springs; each, when compressed to 0.600 in., should exert a force of 80 lb. $\pm$ 10 lb. Each set should be within 5 lb.

PLANET CARRIER ASSEMBLY

Inspect the needle rollers, if showing signs of wear renew. Inspect centre bore of the gears and carrier pins for wear, if detected, carrier must be renewed. If one or more of the gears shows signs of wear a complete new set of four must be fitted. Inspect the eight spacers for signs of excessive wear, renewing as necessary.

Inspect the splines of the drive shaft to ensure that the shaft has not been twisted due to clutch setting being too high or to clutch seizure.

SAFETY SWITCHES

Remove the base plates from the switches by removal of the two screws and nuts and mount each switch in turn on the test rig NT.4785, checking to ensure that the contacts operate, Fig. 62.

OUTPUT SHAFT BEARINGS

Check for roughness in turning or for excessive side or end play. Renew if wear is evident.

OIL SEAL

This should be renewed at each overhaul.

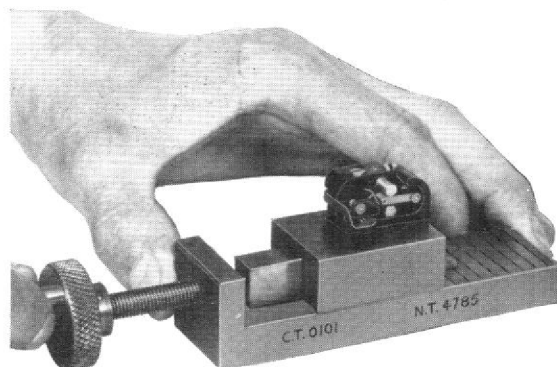


Fig. 62. Checking safety switch on test rig.



Fig. 63. Rotor prepared for shot blasting.

DRIVE SHAFT BEARING SPACER

Ensure that the bearing surface is perfectly smooth and free from scores over the area of the spacer which runs in the oil seal. Renew if damaged.

BREECH SEALS (CLUPET)

Thoroughly clean the seals with methylated spirit. Inspect for any signs of damage. The inner surface particularly should be free from scores.

CUT-OFF PLATE RETURN SPRINGS

Check the tension of the spring which, when extended to 3.510 in. from a free length of 2.375 in. must exert a nominal pull of 10.7 lb., spring dimensions being taken from loop centres.

SAFETY SWITCHES AND 4-PIN PLUG

Inspect the leads for security and the soldered tags for dry joints. Renew leads if necessary.

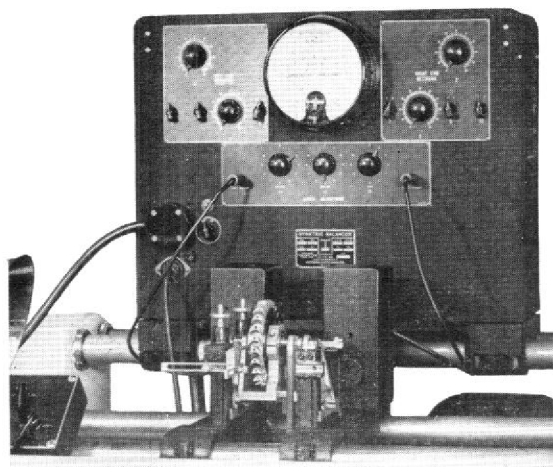


Fig. 64. Rotor mounted on balancing rig.

ROTOR

Thoroughly clean the rotor assembly, except rotor blades, using emery cloth grade 320 (or finer), soaked in methylated spirit.

After this initial cleaning fit special tool NT.4433 and lightly shot blast the rotor blades. Ensure that the holes in the rotor blades are quite free from shot and carbon deposits—Fig. 63.

Note: If a drill is used for this purpose care must be taken to ensure that it does not damage the rotor or remove any metal but only removes the carbon deposit.

After cleaning, inspect the rotor and renew if:—

1. Erosion has proceeded further than 0.065 in. into the blade leading edge.
2. Any cracks are evident in rim at blade roots.
3. Pitting due to corrosion has extended more than 0.010 in. into surface, especially at or around blade roots.



Fig. 65. Fitting inlet bush.

Check rotor overall diameter against dimension of $5.111 \pm .001$ in. and if more than 0.005 in. total increase has taken place at blades edges, inlet side, the assembly should be mounted in a suitable grinding machine and ground to original limits. Take care to maintain concentricity with the ball race diameter to within 0.0005 in. total indicator reading.

After this operation the rotor will require re-balancing, the holes in the centre of each blade only being used. Do not drill flanged nut.

Assemble the cleaned rotor, as shown in Fig. 88, to a suitable balancing rig. The same bearing should be used for this test as will be used when assembled, thus if the original one was rejected on inspection, the new one should be used for the balancing operation, Fig. 64.

Check for true balance, drilling the rotor blade holes if necessary, but in strict conformity with the following instructions.

1. Do not drill more than nine adjacent holes.
2. Maximum drilling per hole not to exceed $0.125 \pm \begin{smallmatrix} .003 \\ -.000 \end{smallmatrix}$ in. dia. $\times$ 0.468 in. max. depth.
3. In extreme cases holes may be further opened out to 0.147 in. max. dia. and 0.250 in. max. depth.

Special care should be taken to see that the sun gear is correctly fitted and that the "X" on the gear lines up with the "X" on the rotor splines.

A new rotor will include in addition to the clutch ring, the sun gear, spacer, washer and nut. Should the rotor be satisfactory the overspeed clutch ring should be checked dimensionally and must be within the limits detailed on page 35, Fig. 85 and 86.

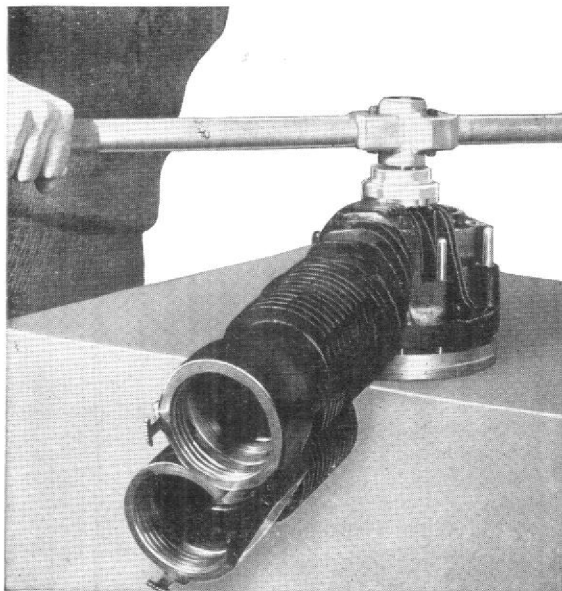


Fig. 66. Fitting cap nut.

REASSEMBLY

Note: All tab washers removed when dismantling must be renewed.

Replace the inlet bush dowels into the casting and check to ensure that the inlet bush slides home fully without fouling them, Fig. 65. Should the bush foul the dowels proceed in the following manner.

- (a) With the bush in position, use a $\frac{3}{16}$ in. reamer to clear out one of the dowel holes.
- (b) Remove reamer and insert dowel.
- (c) Ream out other hole.
- (d) Insert second dowel to check clearance of hole.

After this lining up operation remove bush and dowels, then proceed as follows:—

Lightly smear the bore and face of the casting with which the inlet bush mates with "Heldite" compound and insert both bush and dowels into the breech housing. Only a very small quantity of compound should be used.

Note: If the breech faces have been turned the inlet bush should be lapped to its seating, using H.500 O.P. compound to ensure that no leakage occurs. Do not allow the compound to come in contact with the other faces or diameters.

Fit a new lockwasher and the cap nut, using carrier NT.4431, adapter NT.4107 and a torque spanner loaded to 1,250 lb. in., tighten the cap nut until spanner "breaks," Fig. 66. The threads of the cap nut must be smeared with graphite grease D.T.D.582.

If it is found that when the torque spanner "breaks", a slot in the nut does not line up with the tab on the washer, the nut should be **tightened and not** slackened with a suitable "T" wrench to line up with the next tab.

This operation is preparatory to the hydraulic test which must be undertaken at this stage, and tool NT.4036 will be required. This comprises a set of four small plugs with conical nuts and a clamping ring all of which bear the same tool number.

Insert plugs into the four nozzles of the nozzle ring as shown in Fig. 67, the conical nuts are now put on from the reverse side, both parts being drawn together by screwing in the plug. A sufficient degree of tightness must be attained to effectively plug the nozzles, to prevent the leakage of oil under pressure during the hydraulic test.

It should, however, be noted that the plugs when fitted to an old nozzle ring, may not prove an effective seal. If this is the case a new nozzle ring should be drawn from stores and used for the high pressure test, being returned on completion.

Second operation preparatory to hydraulic test, Fig. 68:—

Fit nozzle ring assembly to the breech housing and secure in position by means of the clamping

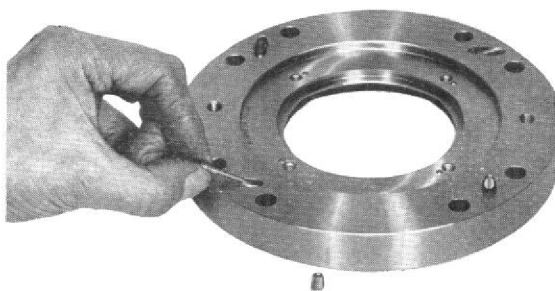


Fig. 67. Inserting nozzle plugs.

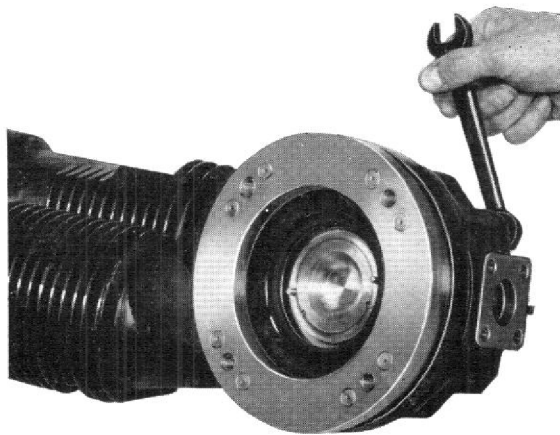


Fig. 68. Nozzle ring assembly fitted to breech housing.

ring which forms the second part of tool NT.4036; using a suitable spanner, tighten the nuts.

Third operation preparatory to hydraulic test, Fig. 69:—

Select a bursting disc $0.010 \pm .0005$ in. thick and fit this to the valve nut. Continue turning the valve seat until it is free of the thread of the valve nut.

Fourth operation preparatory to hydraulic test:—

Assemble the breech housing to the test rig NT.4036 shown in Fig. 70 and 71 but do not connect the oil feed line to the plug hole in the cap nut.

Invert the housing, and with the hole in the cap nut plugged, fill the casting with oil to specification D.T.D.2472 to the level of the "Clupet" seal recesses.

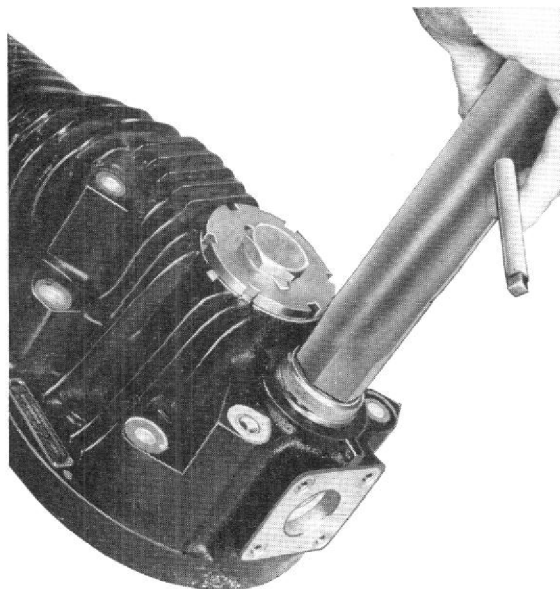


Fig. 69. Fitting safety disc assembly.

Fit the breech caps, invert the casting and connect the oil feed line to the $\frac{1}{2}$ in. gas tapped hole in the cap nut. Slacken the bursting disc nut and operate pump to expel all air from the casting.

Continue pumping until oil issues freely from the bursting disc valve. Tighten the bursting disc and proceed with the hydraulic test as follows.

HYDRAULIC TEST

(a) Assembly and bursting disc to be subjected to 1500 lb. per sq. in. for a period of one minute.

(b) On raising the pressure the bursting disc is to rupture before 2000 lb. per sq. in. is reached.

(c) Ruptured disc to be replaced by a test disc 0.020 in. thick and the pressure raised to 3000 lb. per sq. in. for a period of 20 seconds. No per-



Fig. 70. Hydraulic test pump.

manent distortion shall appear and no leakage is permissible at the following points:—

- (1) Bush to casting seating.
- (2) Bush dowel holes.
- (3) Nozzle ring to casting seating.
- (4) Centre contact assembly of breech caps.

(d) At the satisfactory completion of this test the tool NT.4036 together with the nozzle ring plugs should be removed and the complete casting thoroughly cleaned in benzene to remove all traces of oil.

REASSEMBLY MAY NOW BE CONTINUED

Fit new bursting disc into the valve nut and secure in position with the valve seat; continue turning the valve seat until it is free of the thread of the valve nut. Insert and fit the bursting disc assembly into the breech housing using graphite grease. Fit and tighten the lock nut.

Refit the 4-pin plug which must be so positioned that the large pin is at the bottom as illustrated (Fig. 72).

When refitting the safety switches, it is necessary to fit and tighten in position No. 2 breech switch first. This will allow ready application of a screwdriver and ensures that the fixing screws will be tightened securely. No. 1 breech can then be fitted and secured.

Refit the safety switches ensuring that they are reconnected to agree with the wiring diagram. (See Fig. 73.)

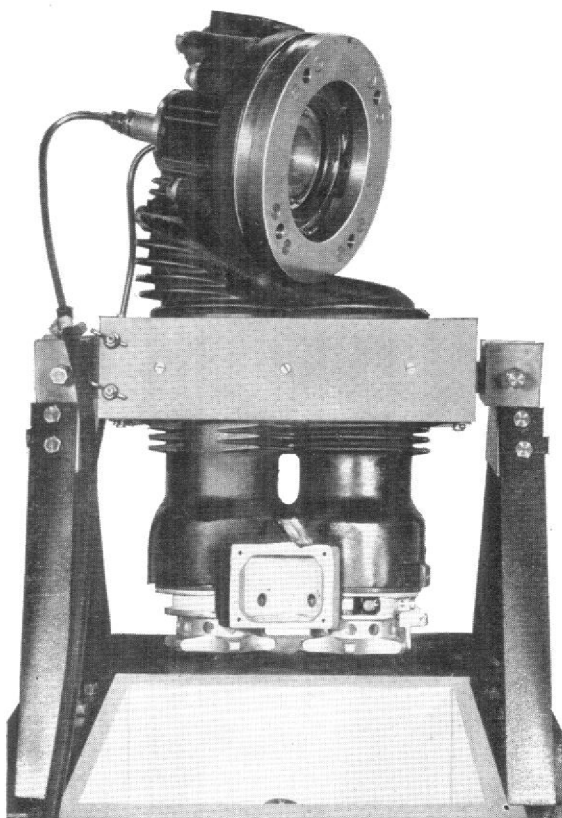


Fig. 71. Hydraulic test rig.

Adjust the position of the switches so that the plungers bear fully on the contact strips on the breech caps when they are fully home.

The following electrical tests should now be carried out:—

- (a) Check firing circuit for continuity.
- (b) Check operation of safety switches to see that they "throw" when caps are screwed home.

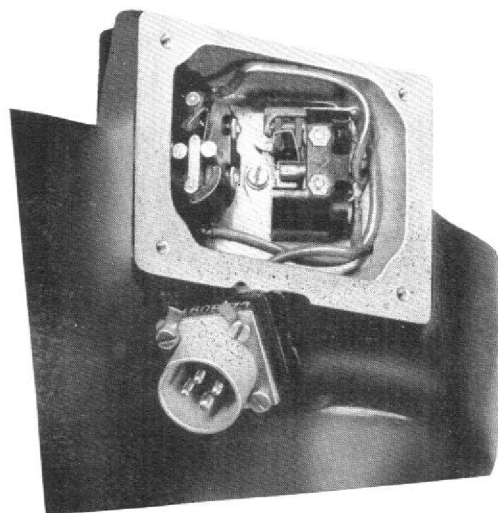


Fig. 72. Correct position of four pin plug.

(c) Insulation tests:—

- (1) 250 volt "Megger" to show not less than 2 megohms between live parts and earth.
- (2) 250 volt A.C. flash test for one minute.

Fit cover plate, gasket, screws and locking strips.

Fit "Clupet" seals and circlips into breech bore.

REASSEMBLY OF CLUTCH

Place the main housing on bench block NT.4005 and ensuring that all components are scrupulously clean, commence reassembly by inserting the rear end plate, Fig. 74. Note the position of the two splines which are marked "X."

Place the annulus gear in such a position that the "XX" marked on the annulus gear is uppermost, Fig. 75.

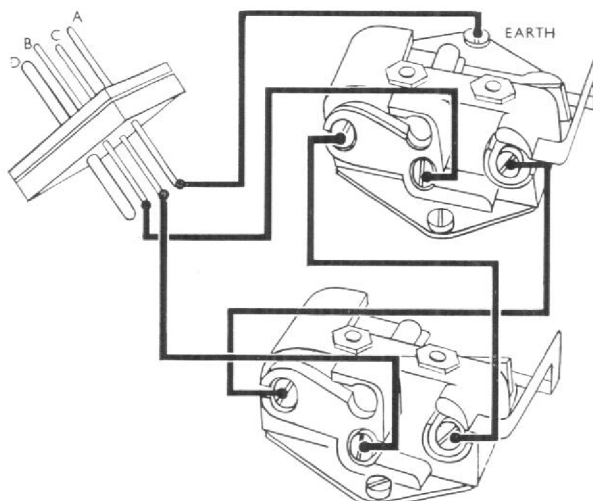


Fig. 73. Safety switch wiring diagram.

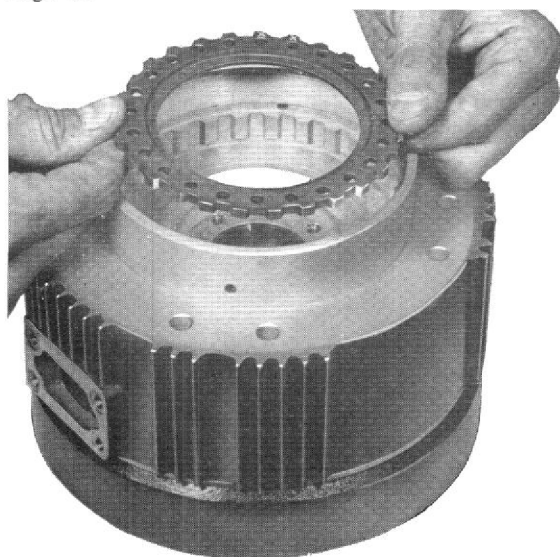


Fig. 74. Inserting rear end plate, showing marked splines.

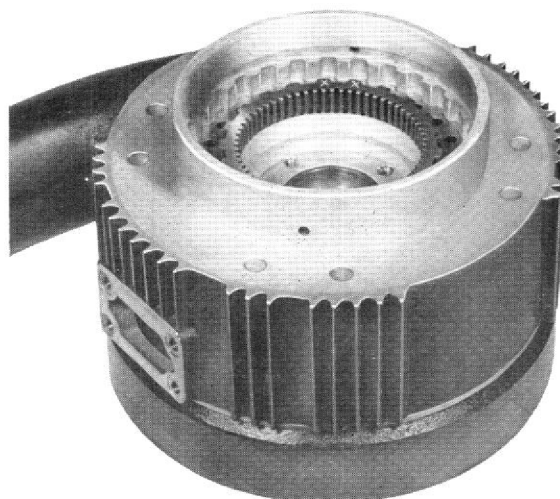


Fig. 75. Correct positioning of marked annulus gear.

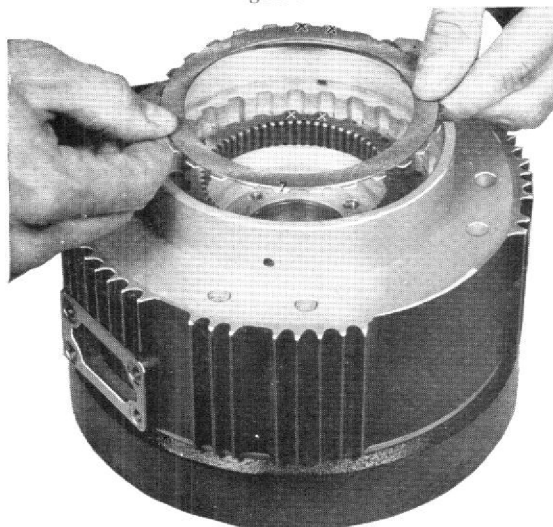


Fig. 76. Inserting marked outer clutch plate.

Insert the outer clutch plate which is marked with a 7 so that the two splines marked with an "X" line up with the "XX" of the rear end plate, Fig. 76, and supply a covering of oil as specified on starter front housing.

Insert inner clutch plate number 6, ensuring that the "X" lines up with the "XX" on the annulus, Fig. 77.

Fit remainder of the clutch pack plates, 5, 4, 3, 2, 9, 1.

Fit the clutch end ring (front) and washer.

Fit the clutch pack clamp NT.4014 into position, Fig. 78.

Insert the 20 clutch springs into their recesses in clutch adjusting nut, and, tilting the main hous-

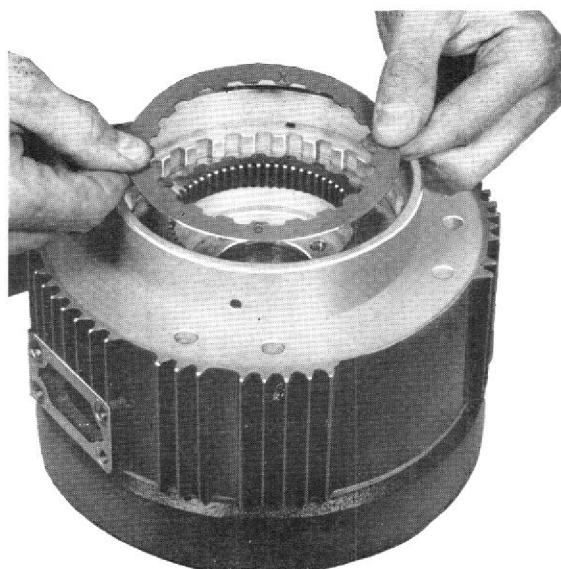


Fig. 77. Inserting marked inner clutch plate.

ing, Fig. 79, oil the threads of the nut and screw in until the springs bear on the clutch spring washer. Take care not to displace the springs during this operation.

Remove clamp NT.4014.

Using tool NT.4006 rotate the clutch adjusting nut through 360 deg., Fig. 80.

Fit slave race into main housing; lightly oil the race and secure in position by means of the clamp plate and four screws.

Fit the test rig drive shaft through the slave race and assemble the rig sun gear and secure in position with a nut which may be the rotor nut or one of $\frac{3}{8}$ in. dia. 26 T.P.I. Fig. 81.

Assemble the complete main housing to the clutch setting rig NT.4106.

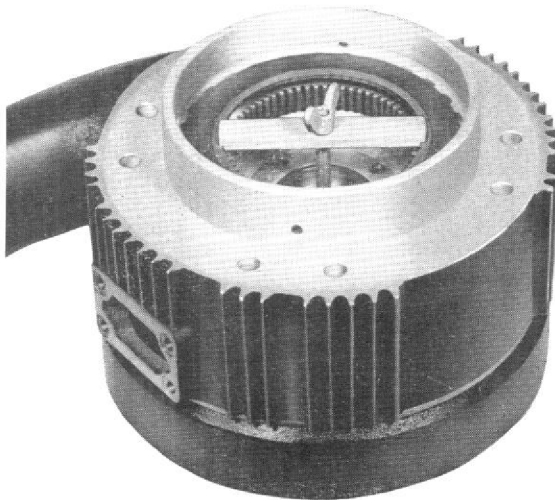


Fig. 78. Clutch pack clamp N.T.4014 in position.

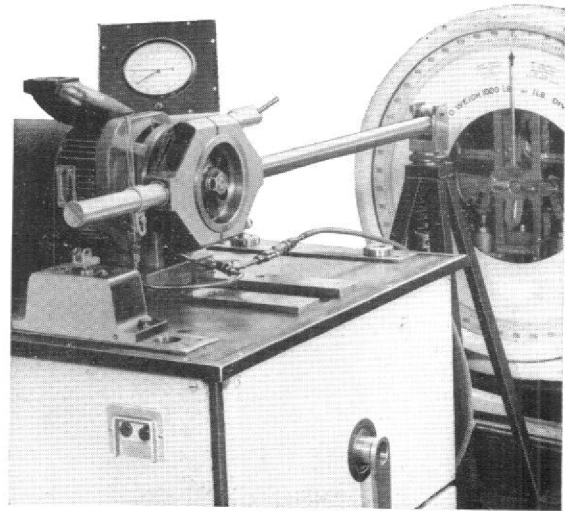


Fig. 81. Main housing assembled to clutch setting rig.

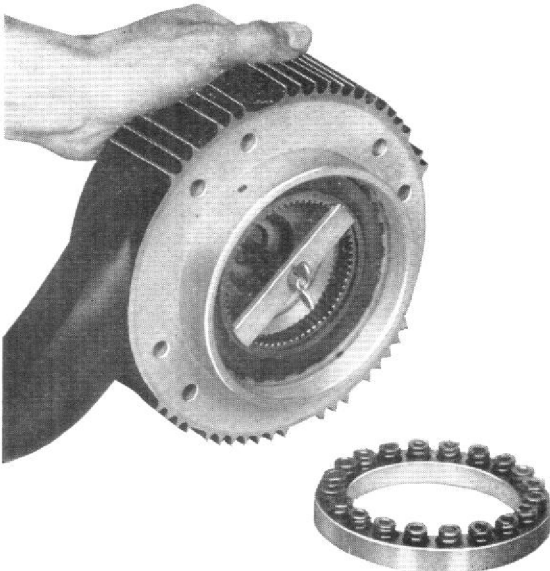


Fig. 79. Fitting main housing to clutch springs and adjusting nut.



Fig. 80. Rotating clutch adjusting nut.

CLUTCH SETTING

Final clutch setting shall be carried out in three stages increasing the spring load in equal increments until final setting is obtained, namely, 160-180 lb. ft.

Slipping torque with clutch rotating at a steady speed of 30 ± 5 r.p.m. and break-away torque of 50 lb. ft should be measured by rotating the clutch from 0-5 r.p.m. by means of a detachable handle on the motor drive.

Each stage shall consist of 25 slipping operations of 10 seconds motor run for each slip, allowing approximately 20 seconds interval between each operation for cooling.

When final setting is obtained allow rig to run for a further 25 operations of 5 seconds each slip with 20 seconds interval between each slip for cooling in order to finally stabilise clutch.

Check and inspect clutch setting immediately after completing final 25 operations when clutch is hot.

Afterwards check clutch setting when clutch is cold (artificial cooling may be applied with fan or compressed air).

Remove the slave race used for clutch setting.

Replace the asbestos lined shroud.

Fit and lock its four screws and tab washers.

Use alignment gauge NT.4430 to obtain correct relationship between the holes in the clutch adjust-

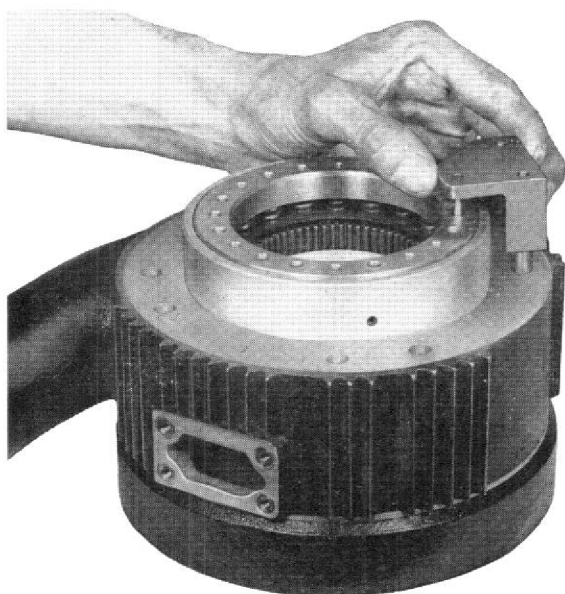


Fig. 82. Use of alignment gauge.

ing nut and the eight holes in the main housing assembly, Fig. 82.

CHECKING THE ROTOR BALL BEARING, Fig. 83.

Note: Scrupulous cleanliness of all the equipment used in these tests is of the utmost importance. Thoroughly clean the bearing with benzine before attempting to test.

For this test, the following equipment is required. Test fixture NT.4013, mandrels NT.4113, NT.4114 and NT.4115, and end nut NT.4013 and also a "Mercer" No. 83 dial test indicator.

Select the mandrel NT.4113 and slide into race as illustrated. If the mandrel (which is a close fit without forcing) has been selected, fit and tighten

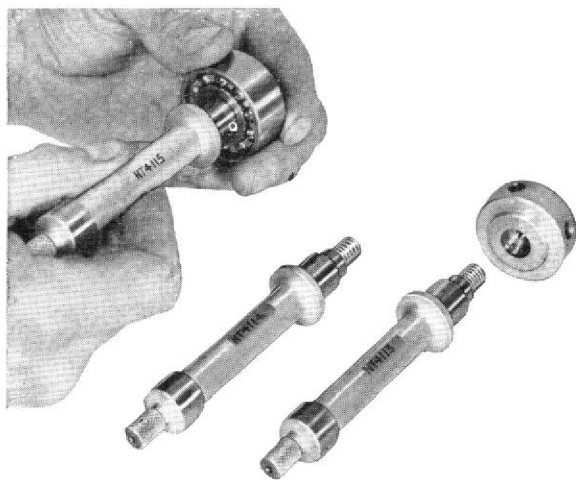


Fig. 83. Mandrels for checking rotor ball bearing.

the end nut NT.4013 shown in the illustration, to lock the bearing to the mandrel.

Fit bearing and mandrel assembly into NT.4013 fixture and using the "Mercer" 83 dial indicator turn the mandrel, Fig. 84. The total indicator reading when the mandrel is turned must not exceed 0.001 in.

If a greater reading is shown recheck after inspecting the race, mandrel, and fixture for cleanliness.

If still outside the permissible limits the bearing must be rejected and a new one used which should be of the same grading as housing and rotor, i.e., both outer and inner.

The new bearing is to be subjected to the same tests as above. If mandrel NT.4113 is not a close fit in the race without forcing, try NT.4114 or NT.4115.

CHECKING OVERSPEED CLUTCH RING

If the rotor has passed the inspection detailed on page 28, the overspeed clutch ring must be checked dimensionally and conform to the limits shown in Fig. 85.

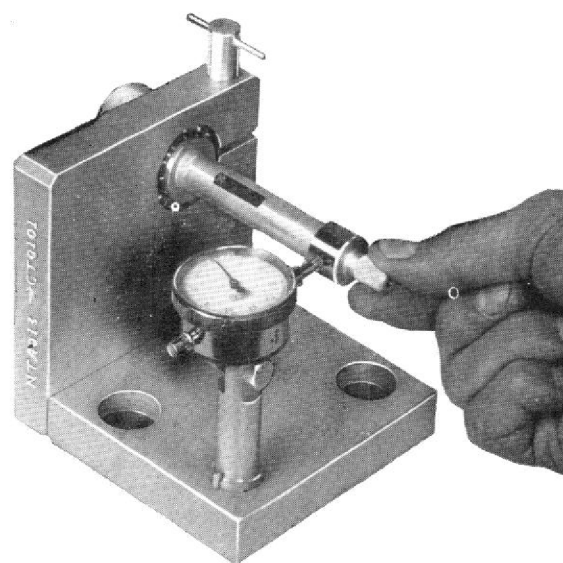


Fig. 84. Fixture for checking rotor ball bearing.

It is very probable, however, that after a short period of service the diameter will be found to have increased by about 0.002 in. due to certain influences which occur at high speeds. This increase is permissible.

The checking of the diameter (which it will be seen is a taper) is accomplished by means of a special gauge R.548 for new rings, and NT.5170 for those which are being inspected after a period of service.

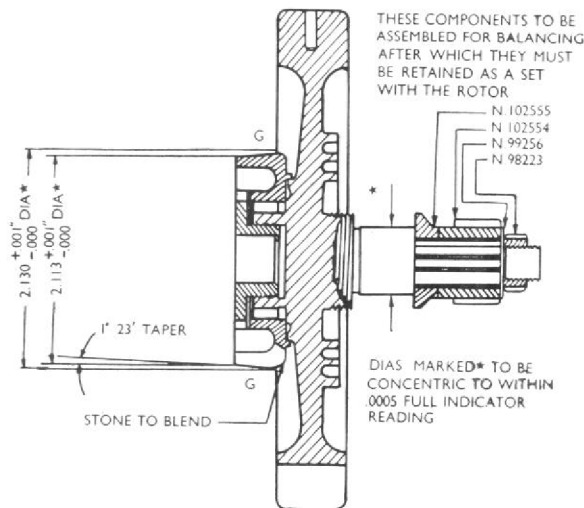


Fig. 85. Overspeed clutch ring dimensions.

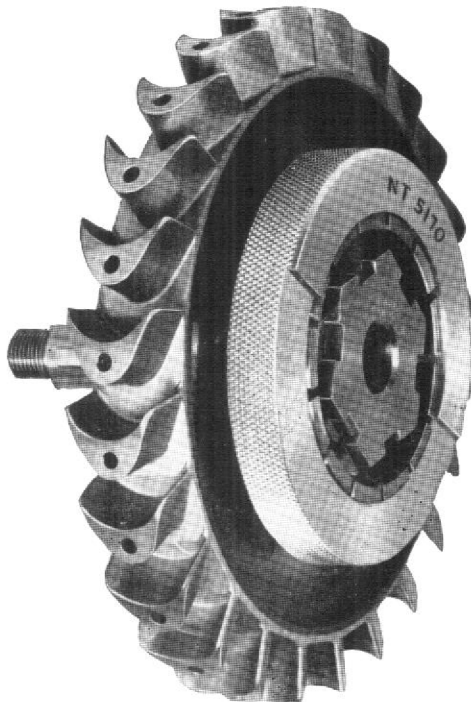


Fig. 86. Use of overspeed clutch ring gauge.

Gauge NT.5170, Fig. 86, is for checking overspeed clutch rings that have been in service and may have expanded as explained in Fig. 85.

It takes the form of a tapered and stepped ring and should be placed over the clutch ring with the stepped side outwards.

If the clutch ring is within acceptable limits its edge will appear within the step as shown in the illustration. If level with the lower or higher edges its maximum or minimum limits respectively are indicated.

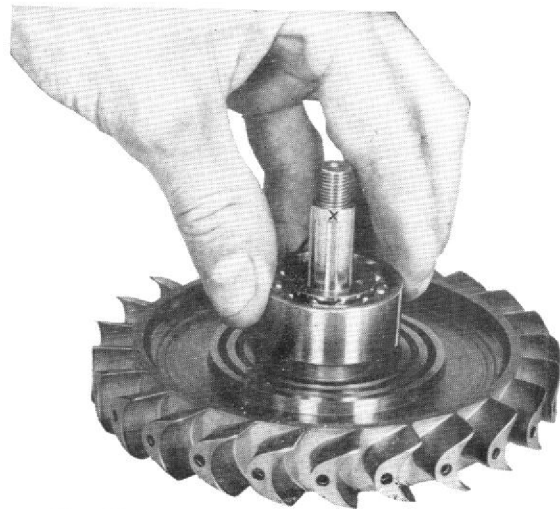


Fig. 87. Fitting bearing to rotor assembly.

Should the edge fail to come up to the lower step edge or exceed the upper one the clutch ring is outside limits. Complete assembly should be renewed.

PROCEED WITH ASSEMBLY AS FOLLOWS:

Before any attempt is made to assemble as detailed in the following paragraphs, each part must be thoroughly cleaned in benzine.

Fit the rotor bearing on to the rotor assembly, Fig. 87.

Fit the sun gear spacer, Fig. 88.

Fit the sun gear, lining up so that the sun gear spline marked with an "X" mates with the similarly marked spline of the rotor.

Fit the locking tab so that it enters one of the three positions on the rotor spline which have been machined for this purpose.

Fit and tighten the nut.

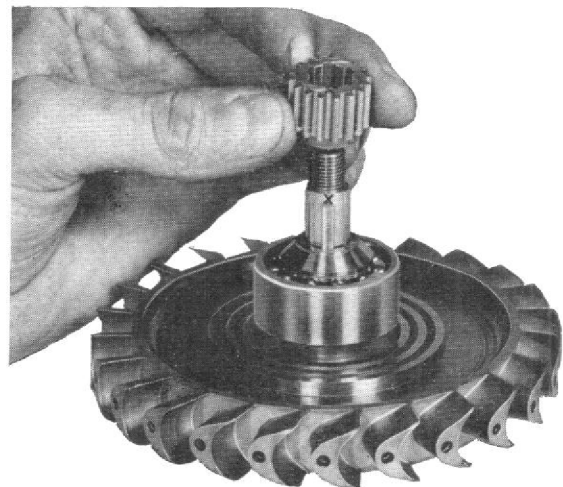


Fig. 88. Fitting sun gear to rotor assembly.

CHECKING SUN GEAR, Fig. 89

Place the assembled rotor into fixture NT.4015 ensuring that the recess for the bearing is perfectly clean, and place a suitable roller between two of the teeth of the sun gear.

A needle roller from the dismantled planet carrier has been used in the rig illustrated and will be found to be suitable for this test.

Carefully turn the rotor so that the dial test indicator bears on the highest point of the roller and note the reading. Move the roller so that it takes up a similar position between the next two teeth on the sun gear and again note the reading at the highest point of the roller. Continue in this manner around the gear and note any difference in the readings so obtained. The maximum difference permissible must not exceed 0.001 in.

If this tolerance is exceeded the sun gear should be removed and turned through one spline and the test repeated. Continue turning the gear on the rotor splines, rechecking the readings. If, however, the 0.001 in. tolerance is exceeded in all six positions fit a new sun gear and repeat the tests.

If the existing sun gear is moved in relation to its original position or if a new one is fitted it must be re-marked with an "X" to mate with the mark on the splines and any other marks removed.

If the permissible tolerance is still exceeded after changing the sun gear, a complete new rotor assembly, consisting of all the items shown in Fig. 85 must be obtained and checked in a similar manner before reassembly to the starter, making sure that the new assembly has been previously balanced.

REASSEMBLY MAY NOW PROCEED

Replace the bearing into its liner in the main housing, Fig. 90. If the bearing which was removed has been found to be satisfactory, and is put back, ensure that it is not inverted on reassembly.

Replace the clamp plate, fitting new tab washers, progressively tightening the screws to ensure that the plate beds evenly on the outer journal of the bearing.

Inspect the labyrinths on the rotor and housing to make certain they are free from foreign particles.

Insert the rotor into the housing.

Replace the spacer.

Replace the sun gear ensuring that the "X" on the gear lines up with the "X" on the splines of the rotor, Fig. 91.

Fit a new lock washer and replace and tighten the nut using a torque spanner loaded to break at 175 lb. in. Should the spanner break so that a slot in the nut is not lined up with one of the tabs of the locking washer, the nut should be further tightened up, using a suitable "T" wrench,

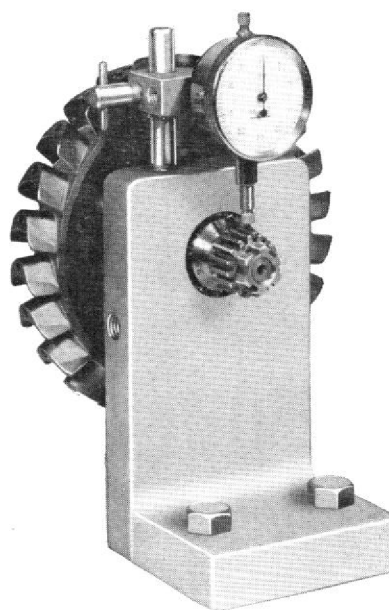


Fig. 89. Checking sun gear.

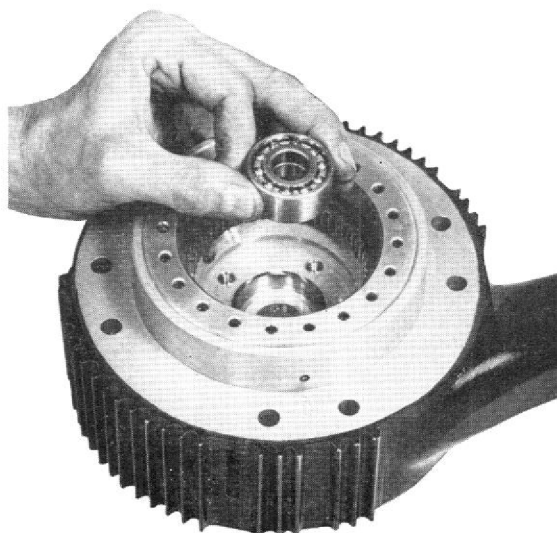


Fig. 90. Replacing rotor bearing in liner.

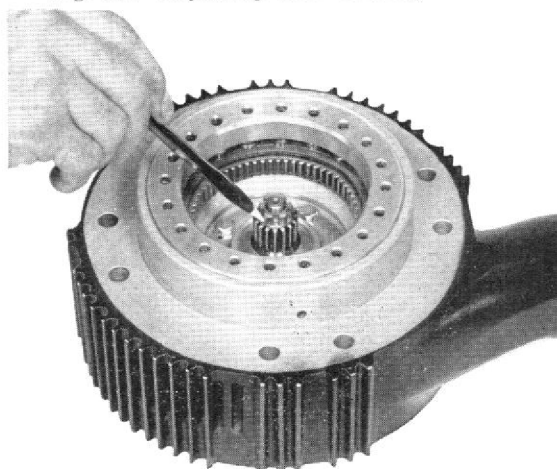


Fig. 91. Checking positioning of sun gear.

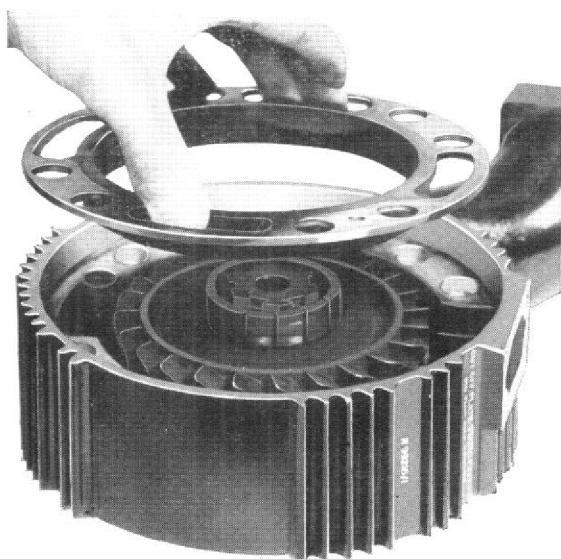


Fig. 92. Replacing shroud.

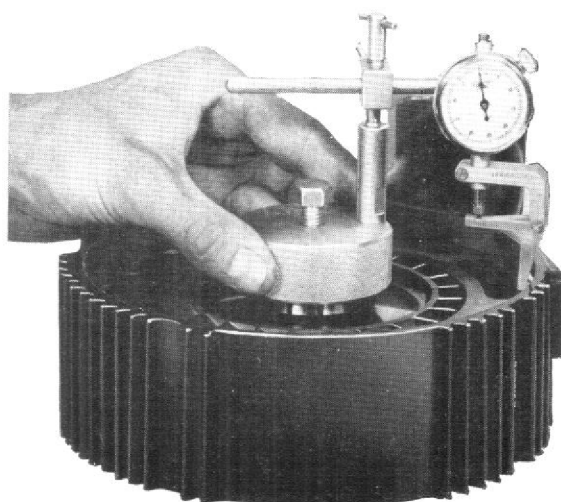


Fig. 93. Checking rotor housing for distortion.

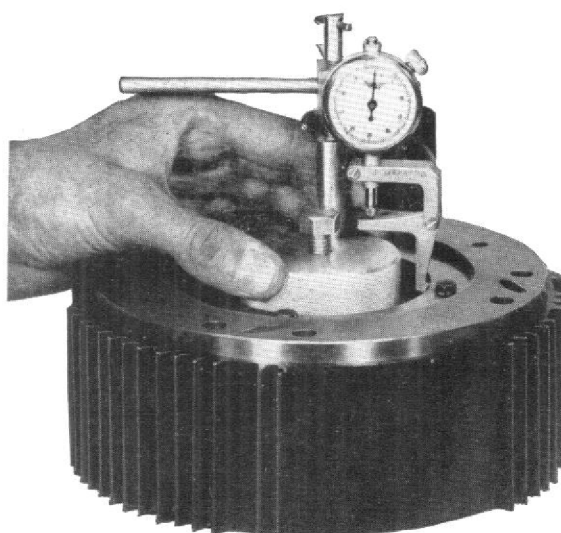


Fig. 94. Testing ball track.

until alignment with the next tab is arrived at. Do not slacken the nut to obtain this line up. **Do not lock the nut** at this stage.

Remove any small particles of the lockwasher which may have been caused by the nut binding on it while tightening.

Replace the 8 dowels.

Replace the shroud noting that all faces are perfectly clean. If the shroud is found to be a close fit in the housing make sure that the housing is not scored when replacing, Fig. 92.

Using NT.4429A and B in conjunction with a No. 83 "Mercer" dial test indicator, check that the reading obtained when the rotor is turned does not vary by more than 0.001 in. if a new casting has been fitted, Fig. 93.

It is permissible to accept a reading of 0.002 in. in cases where the existing housing is used to allow for the slight distortion which occurs during the life of the casting.

If these tolerances are exceeded remove the rotor and ball race and recheck as detailed in Fig. 89, and if found correct reassemble to the main housing, making sure that all mating surfaces of rotor, bearing, sun gear and main housing are quite clean. If tolerance is still exceeded attempt instructions as per Fig. 94. Should the error still persist the main housing must be renewed.

Fit the nozzle ring, checking that the eight holes line up and test the ball track, Fig. 94, in a similar manner to that described under Fig. 93, and note the variation in the readings obtained.

The variation must not exceed 0.001 in. if a new casting and nozzle ring have been fitted.

A variation of 0.002 in. is permissible in cases where a new ring has been fitted to the original casting.

Should the variation be in excess of the permissible limits as it is now set up, further tests may be made in the other three possible positions of the nozzle ring in relation to the casting, where it may be found that a satisfactory reading is obtained by errors cancelling each other.

If this method fails a new main housing must be fitted as stated in Fig. 93.

If the method suggested in Fig. 93 has been employed and the nozzle ring has been given a definite position in relation to the casting, the nozzle ring assembly should be marked with an "X," Fig. 95, adjacent to the trigger inspection window in the housing. The cut-off plate must be assembled with the trigger adjacent to the "X" so that its position with respect to the window is correct.

Place the complete cut-off plate and liner assembly into the nozzle ring and position these on bench block NT.4012. Then, using tool

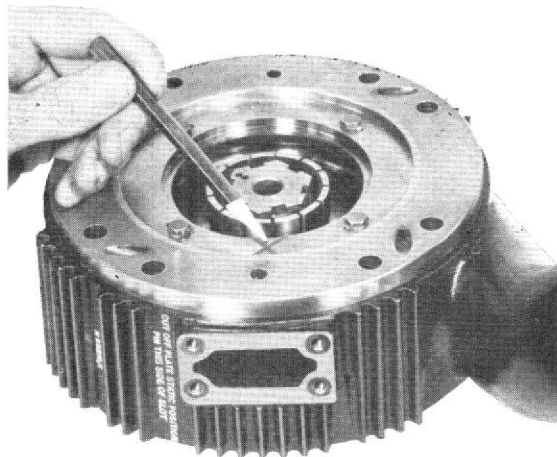
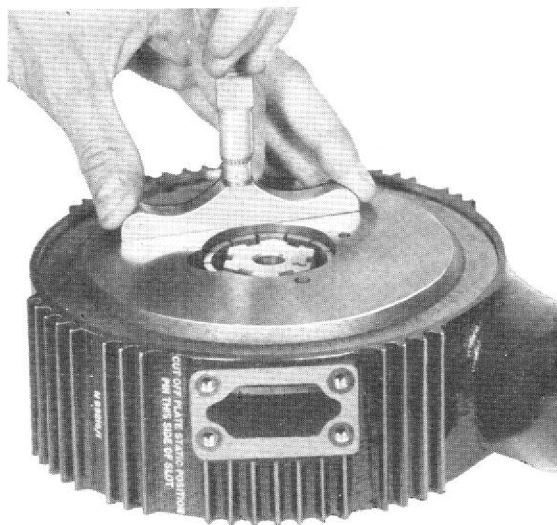


Fig. 95. Marking of nozzle ring assembly.



Fig. 96 and 97. Checking clearance between end of liner and rotor.



NT.4019 in the manner illustrated, Fig. 96, measure the distance from the face of the tool NT.4019 to the end of the liner. Next determine and note the distance from the end of the liner to the face of the nozzle ring by subtracting the micrometer reading from the dimension engraved on the tool, i.e., the thickness of the tool.

Place the tool NT.4019 on to the shroud in the main housing and selecting a hole to suit the spindle diameter of the micrometer, insert the micrometer and read off the depth indicated, Fig. 97.

Subtract dimension engraved on tool, note result. Subtract this from the reading previously noted in Fig. 96, and add 0.020 in. to the result. The dimension so obtained indicates the amount of liner which must be removed from the outer edge to give the necessary clearance between the end of the liner and the rotor which when assembled should be $0.020 \pm \begin{smallmatrix} .002 \\ -.000 \end{smallmatrix}$ in.

Place the cut-off plate and new liner assembly on fixture NT.4021 and using a vertical drilling machine and cutter NT.4116, Fig. 98, remove the amount calculated in Fig. 97.

A new sealing cap should be fitted in the following manner:—

Examine the undercut in the bore of the liner to make sure that it is clean and free from particles of foreign matter.

Select and anneal a cap.

Place the cut-off plate and liner assembly on the base of tool NT.4022 and turn the knurled ring nut so that the liner takes up such a position that the edge of the convex top of the tool lines up with the bottom groove in the liner.

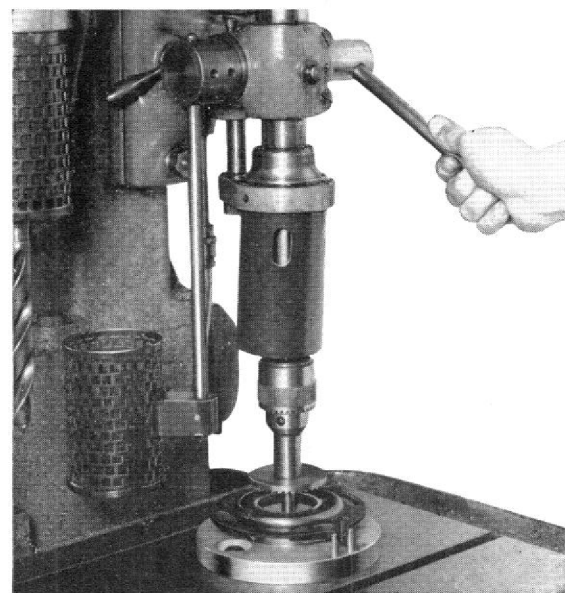


Fig. 98. Use of fixture NT.4021 and cutter NT.4116.

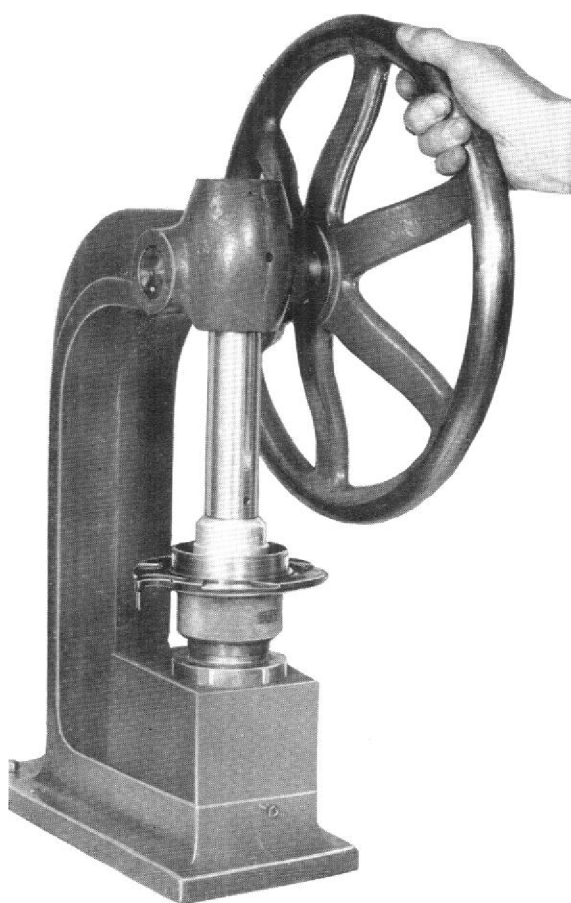


Fig. 99. Fitting sealing cap into liner.

Secure the punch NT.4022 in the rack press NT.864 and placing the base and cut-off plate and liner assembly under the punch, position the base so that the punch will enter the bore without fouling the liner.

Raise the punch and insert the new annealed cap, then press home into the groove of the liner, Fig. 99.

Note: It is essential that the new cap be pressed fully home at the first attempt as if the motion is interrupted resulting in a series of attempts, the effect of annealing the cap will be lost.

Insert the 68 stainless steel balls after inspecting to make sure they are perfectly clean. They must be assembled dry, i.e., free from grease or oil.

Fit bearing washer and circlip over the balls.

Note 1: Although provision is made for 69 balls only 68 are used.

Note 2: If it has been necessary to mark the nozzle ring in relation to the trigger window as described in Fig. 95 check that the trigger pin of the cut-off plate is adjacent to the "X," Fig. 100.

Assemble the cut-off plate and nozzle ring assembly to the special tools NT.4028A, B, and C, using a No. 83 "Mercer" dial test indicator set to zero. Make certain that the surface of tool NT.4028A is perfectly clean to prevent damage occurring to the face of the nozzle ring.

Depress lever fully and read off on the scale. Note the reading which in the case illustrated is 0.033 in. from zero, Fig. 101.

Remove the circlip and fit sufficient shims which, with the wave washer, will reduce the reading to within 0.005 in. to 0.010 in. with lever depressed.

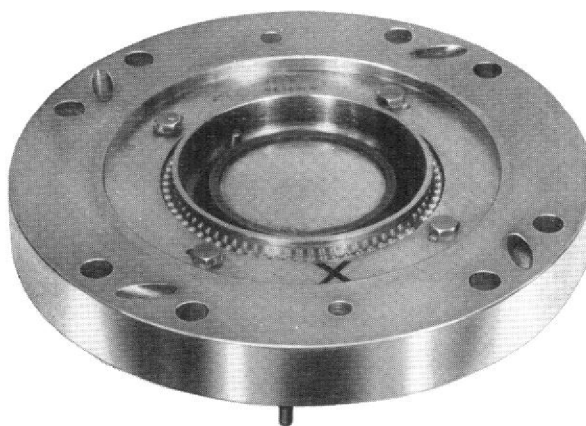


Fig. 100. Position of trigger pin (in relation to "X" on nozzle ring).

In the case illustrated the wave washer checked with the micrometer was found to be 0.018 in. and shims to the thickness of 0.008 in. were added, bringing the original end float reading down to 0.007 in.

Re-check this new reading.

Note: Fit the shims before fitting the wave washer, ensuring that the shims and wave washer are free of the undercut when fitting the circlip which must go fully home in its slot.

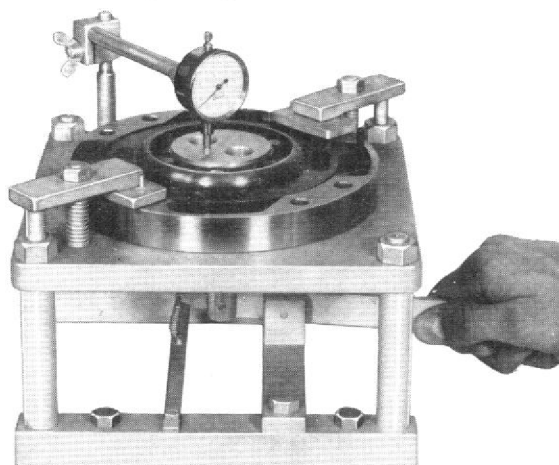


Fig 101. Use of special tools NT.4028 A.B.C.

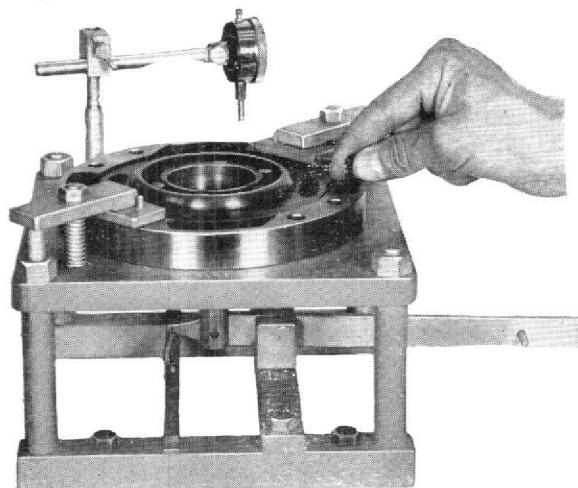


Fig. 102. Operating cut-off plate trigger.

Move the cut-off plate trigger 25 times in each direction to bed the carbon ring, Fig. 102.

Dismantle the cut-off plate and nozzle ring assembly and inspect the carbon ring and see that it is bedded over its full bearing surface.

REASSEMBLE

Assemble cut-off plate and nozzle ring to the tool NT.4028A as previously and apply a spring balance to the trigger, noting the reading at which the trigger begins to move, which should be between 4 lb. and 4½ lb., Fig. 103.

Place the 12½ lb. weight NT.4028D on the arm (equivalent to 50 lb. load on the cut-off plate) as illustrated, and manually turn the cut-off plate by means of the trigger, Fig. 104. The cut-off plate should just drag due to its pressure on the carbon ring.

Add the additional weight NT.4028E, which is 1¼ lb. (the total loading on the cut-off plate is now 55 lb.) and again check the movement, Fig. 105. It should now be quite free.

If this is not the case add or remove shims as necessary keeping the end float maintained within the permissible tolerance of 0.005 in. to 0.010 in. and the radial load 4 to 4½ lb.

If adding or removing shims within the possible limits will not give the required result the wave washer must be renewed and the tests repeated.

REASSEMBLY OF THE FRONT HOUSING

Thoroughly clean all components before re-assembly, noting particularly that the oil inlet hole is clean.

If a new oil seal is to be fitted proceed as follows.

Using rack press NT.864, base NT.4008B, adapter NT.4008A and punch NT.4009, assemble

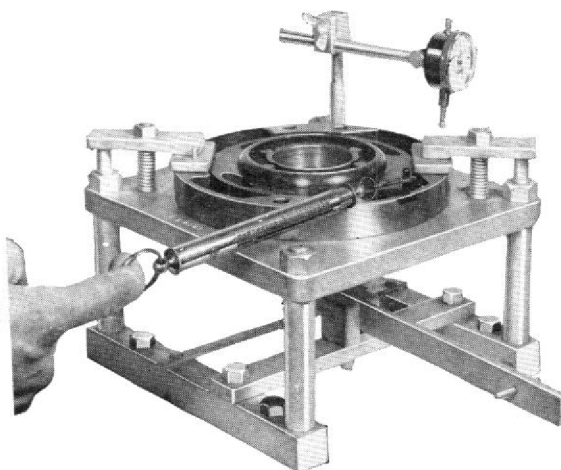


Fig. 103. Checking trigger operating force.

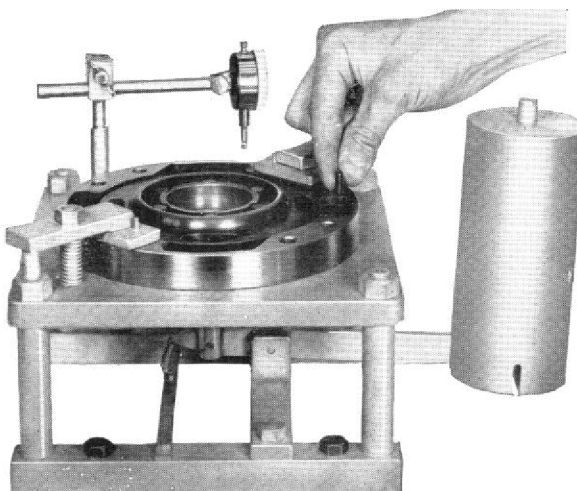


Fig. 104. Checking movement of cut-off plate.

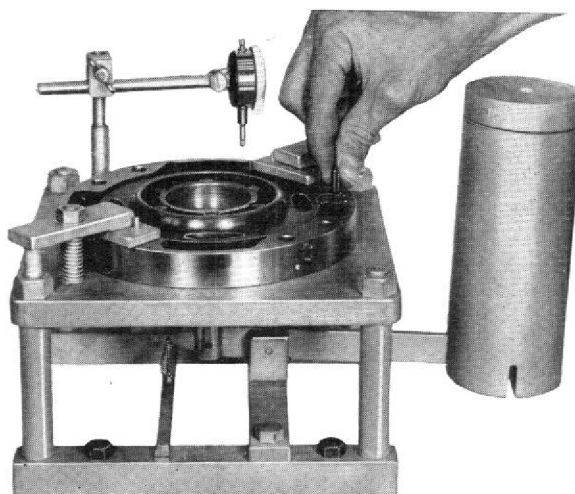


Fig. 105. Checking movement of cut-off plate.

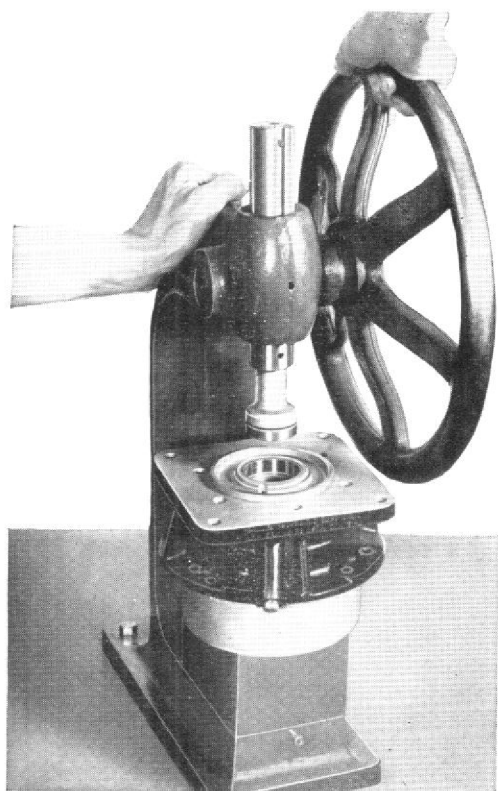


Fig. 106. Assembling front housing.

the front housing in position on the base and adapter. Fitting the punch into the rack press line up the housing to ensure that the punch enters without fouling, Fig. 106.

Fit the new oil seal on to the punch so that the free edge of the rubber enters the housing first, and press home into its housing. See that the rubber of the seal is free to move into its shell.

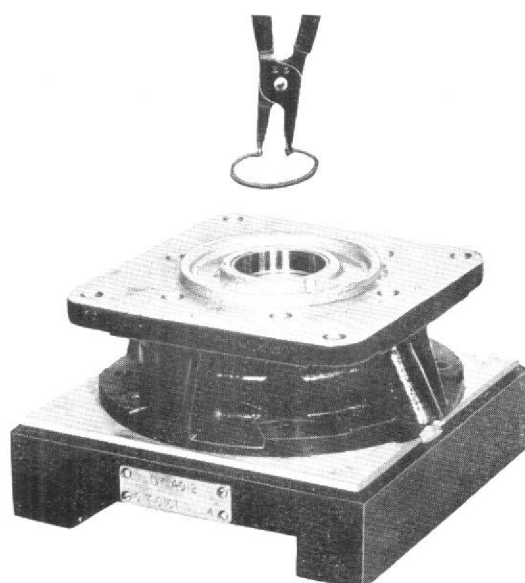


Fig. 107. Refitting circlip.

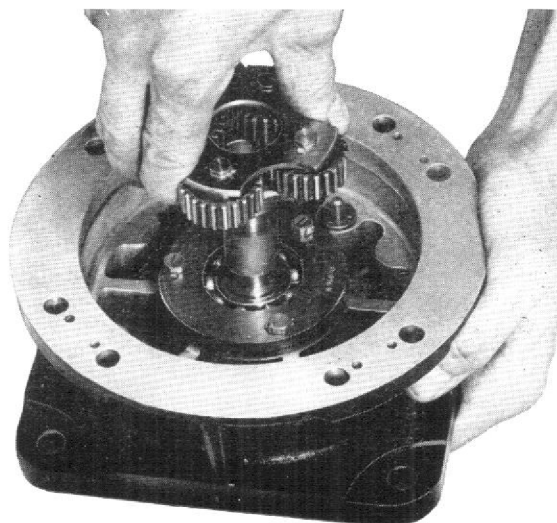


Fig. 108. Refitting planet carrier.

Refit the circlip, Fig. 107, make sure it goes fully home in its recess.

Refit the rear bearing.

Refit the bearing clamp plate. Fit and lock the three securing screws.

Refit planet carrier, Fig. 108.

Note: The dismantling of the planet carrier was dealt with at considerable length on page 24. Its reassembly follows exactly the same procedure in reverse but substituting new parts if inspection showed the necessity, the sequence of assembly being lower washers, pinions, bearing needles, upper washer, retaining plate, screws and tab washers. (See Fig. 53, 54, and 55.)

Replace the spacer, Fig. 109, by passing it over the shaft and through the seal so that it abuts the rear bearings.

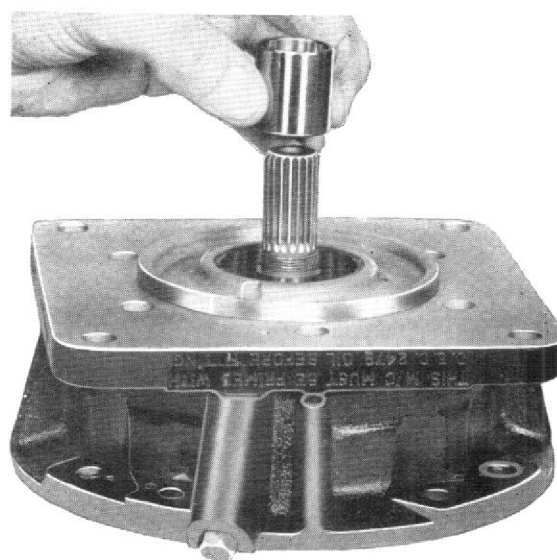


Fig. 109. Replacing spacer.

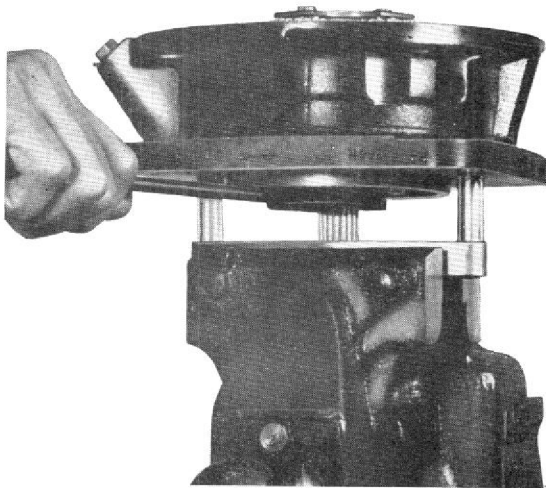


Fig. 110. Tightening planet shaft nut.



Fig. 113. Assembling nozzle ring and cut-off plate to breech housing.



Fig. 111. Checking alignment of clearance holes.

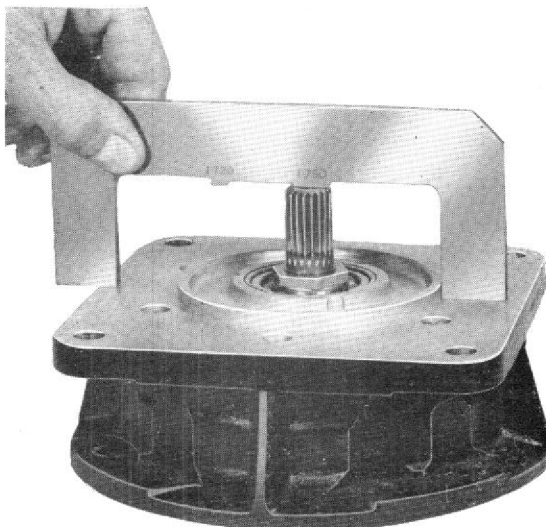


Fig. 112. Checking length of shaft.

Fit the front bearings.

Fit lockwasher, flattening the large tabs before replacing and tightening the nut which is the next operation, using fixture NT.4011, and a $\frac{1}{8}$ in. Whit. spanner for the purpose, Fig. 110.

Check tightness of planet retaining plate screws at this stage.

Fit gauge NT.4004 on to front housing and push home the four studs into the mounting holes.

Using a plug, as illustrated, Fig. 111, check that the six clearance holes are in true alignment with the holes in the gauge.

Insert the spline gauge (not shown in the illustration) to check that the drive shaft is concentric with the mounting spigot. It may be necessary to rotate the planet carrier slightly to line up the splines with the gauge.

Using the gauge NT.4109 (which is virtually a "Go" and "No go" gauge), check the length of the shaft, Fig. 112. With the 1.750 projection over the end of the shaft it should be possible to slide the gauge across the face of the flange but with the 1.720 projection similarly positioned it should not be possible.

At this stage check that the screws of the cut-off plate and nozzle ring are locked with the tab washer and that the dowels in the inlet bush are caulked.

After making sure that the mating faces of the nozzle ring and breech housing are perfectly clean, apply a very thin film of "Heldite" compound.

Assemble the nozzle ring and cut-off plate assembly to the breech housing so that the free ends of the springs pick up with the pins of the inlet bush, Fig. 113. The cut-off springs must be located so that by revolving the trigger pin in a clockwise direction the springs are expanded and

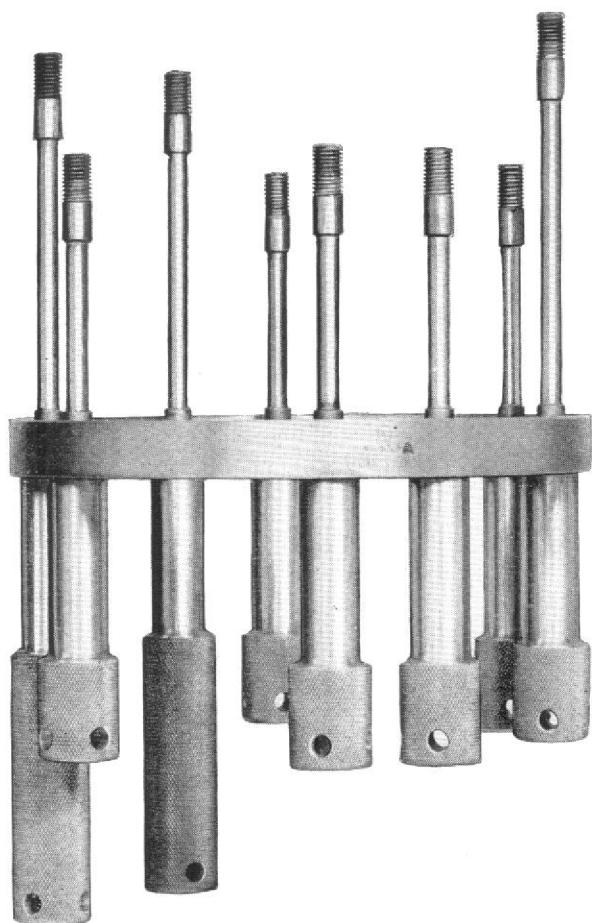


Fig. 114. Stud assembly ring NT.4039A.

tend to return the plate in an anti-clockwise direction when released.

Extend the springs by turning the nozzle ring assembly in a clockwise rotation until the eight holes line up.

Holding the nozzle ring in position operate the cut-off plate manually to ensure that both springs have been engaged. If correct, the cut-off plate will return rapidly to its original position.

If it is found that only one spring has been engaged it will be necessary to repeat the operations, if necessary, removing the nozzle ring and cut-off plate assembly from the breech, by use of the extractor NT.4100, as illustrated in Fig. 28.

Thoroughly clean the eight studs and see that the nuts run freely on the threads, assemble the studs into the assembly ring NT.4039A and fit the plugs NT.4039B and C in the manner illustrated, Fig. 114.

Invert the breech housing and fit eight new tab washers, apply a small quantity of thin oil to the thread, fit and moderately tighten each nut in turn, Fig. 115. Remove the plugs NT.4039B and C and the ring NT.4039A.

It will be noted that the studs are in such a position that the slots in their shoulders line up

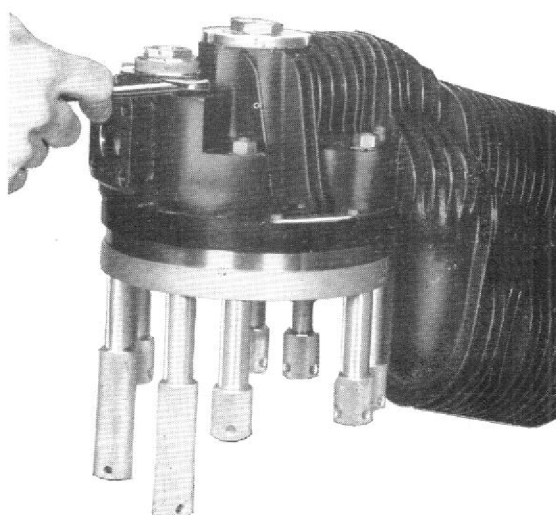


Fig. 115. Studs fitted to main housing.

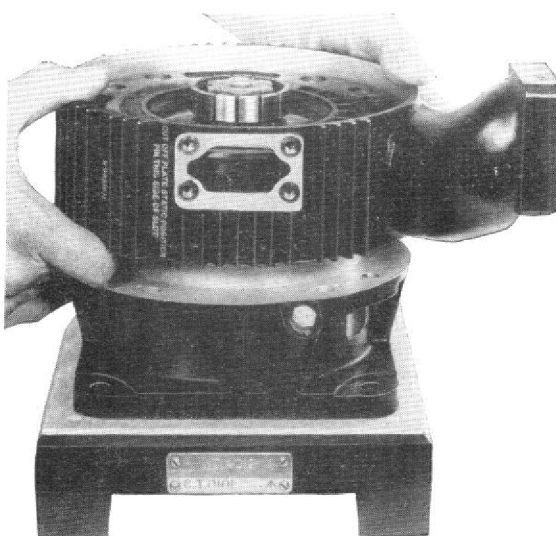


Fig. 116. Main housing being assembled on to front bearing.

with the dowels in the main housing.

ASSEMBLY OF MAIN HOUSING TO FRONT HOUSING

Before proceeding with assembly, check that the tab washers fitted to bearing clamp plate, sun gear, planet pinion retaining plate, bearing clamp plate, and under the output shaft nut are all securely locked.

Adequately lubricate the planet carrier assembly, the sun gear, the annulus and the bearings, with the correct engine oil.

Using bench block NT.4012, assemble the main housing to the front housing, Fig. 116, positioning the castings so that the oil priming plug on the front housing is adjacent to the overspeed inspection window in the main housing.

Upon assembly spin the output shaft to see that it is quite free. If this is not the case separate

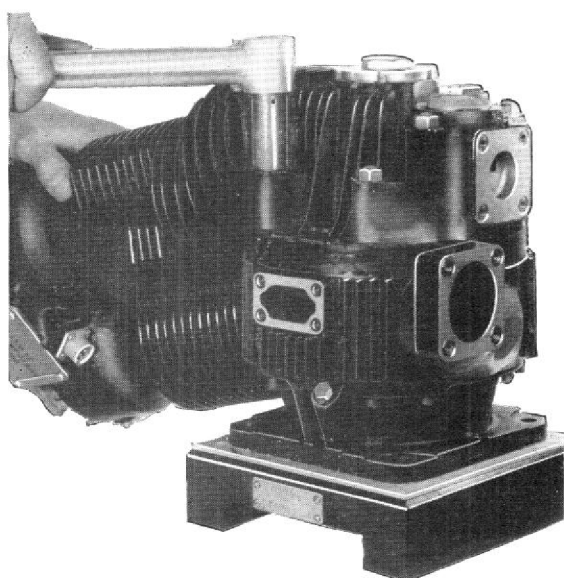


Fig. 117. Tightening breech nuts.

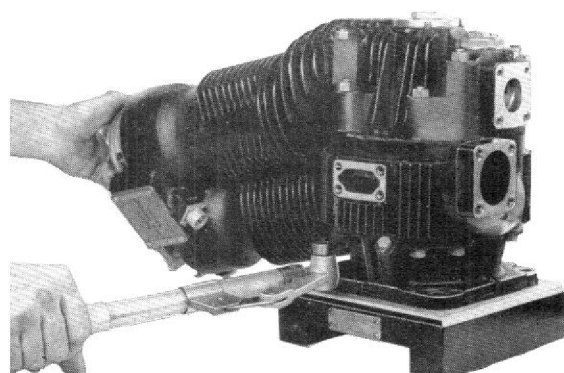


Fig. 118. Tightening front housing nuts.

the castings and inspect to ascertain the reason.

Note: Before proceeding to assemble main housing to breech casting, check that clearance between cut-off plate and shroud is $0.060 \pm .002$ in. by use of suitable micrometer. If this is not so either cut-off plate or shroud is distorted and must be replaced.

Lower the breech housing into position on the main housing. Tighten the breech nuts, using a torque spanner loaded to 170 lb. in. in conjunction with adapter NT.4030, until the spanner "breaks," Fig. 117.

Do not bend up the locking tabs.

It is essential that the nuts at the breech end are fully tightened before attempting to tighten the nuts at the front housing end.

Using a torque spanner and adapter NT.4033, fit the nuts to the front housing, Fig. 118, seeing that all new tab washers are first fitted. A special tab washer, Part No. N.83287, must be used for the stud adjacent to the oil priming plug.

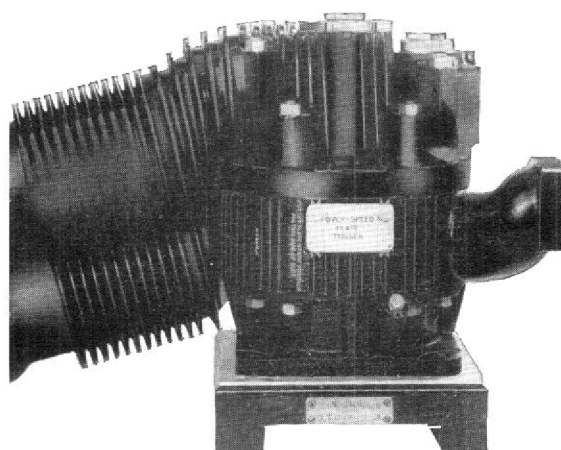


Fig. 119. Position of overspeed trigger cover plate.

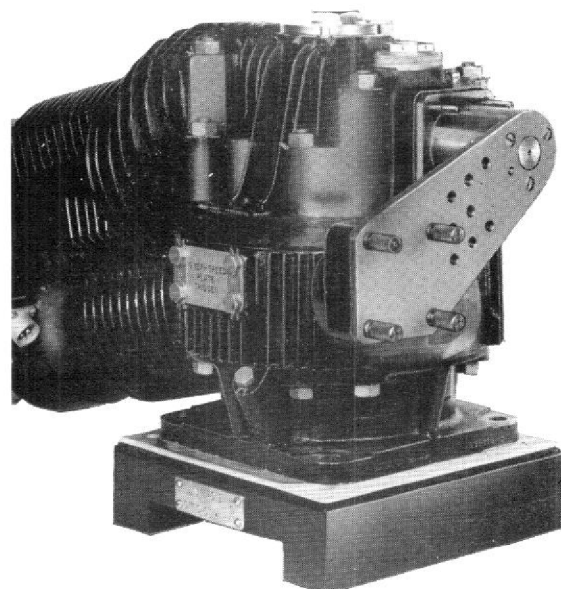


Fig. 120. Use of acceptance gauge NT.4035.

A torque of 70 to 80 lb. in. must be applied to the nuts and this is obtained by loading the torque spanner to 4 lb. ft. (used with the adapter this produces 72 lb. in. torque).

Do not bend up the locking tabs.

Turn the output shaft to make sure that it is free.

Fit a new lockwasher to the inlet bush cap nut plug and tighten the plug.

Refit the overspeed trigger cover plate complete with its copper gasket and new tab washers, Fig. 119.

Using the threaded studs provided, assemble the acceptance gauge NT.4035 as shown, Fig. 120, to check that the exhaust flanges are aligned correctly.

Remove gauge. Starter may now be considered ready for test.

Note: Where instructions have been given not to bend up tabs, i.e., Fig. 117, 118, these are left until after testing, which involves partial dismantling after shots are fired.

TESTING

This section is introduced for the general information and instruction of test personnel, who will in all matters be subject to the test requirements of the Air Ministry and Ministry of Civil Aviation in the United Kingdom or other appropriate authorities.

Note: Some of the tests described in this section have already been dealt with in page 29 to 44 since they are carried out during the process of assembly. These are repeated here in order that speedy reference to them can be made in cases where test information only is required.

(1) THE HYDRAULIC TEST

(See also page 30, Fig. 67—71, for preparation, etc.)

Breech, bush, cap nut, nozzle ring (with suitable nozzle plugs), bursting disc assembly, and breech caps, to be assembled. Casting to be filled with oil to specification D.T.D.2472. Care must be taken to see that no air pockets are left.

The assembly is now mounted in the test rig NT.4036 or similar (see Fig. 70 and 71) and the pump connected.

The following tests should now be carried out.

- (a) Assembly and bursting disc to be subjected to 1500 lb. per sq. in. for a period of one minute.
- (b) Pressure to be raised, bursting disc is to rupture before 2000 lb. per sq. in. is reached.
- (c) Ruptured disc to be replaced by a test disc 0.020 in. thick and the pressure raised to 3000 lb. per sq. in. for a period of 20 seconds.

No permanent distortion is permissible and there must be no leakage at the following points.

- (1) Bush to casting seating.
- (2) Bush dowel holes.
- (3) Nozzle ring to casting seating.
- (4) Centre contact assembly of breech caps.

During the high-pressure test the casting should be examined for cracks whose presence will be revealed by excessive "sweating" of oil.

Note: Some leakage at the breech caps via their threads is bound to take place during this test. Provided items 1 to 4 are tight, this leakage can be disregarded.

(2) ELECTRICAL TESTS

- (a) Check firing circuit for continuity.
- (b) Check operation of safety switches.
- (c) Insulation test.

A reading of not less than 2 megohms must be obtained between the live parts and earth, on the application of a 250 volt "Megger."

As an alternative to (c) a flash test may be given by connecting a 15 watt lamp in series with the test lead and connecting to a 250 volt, 50 cycle, supply.

(3) CLUTCH TEST

(Full details of clutch setting procedure and test rig are given on page 33, Fig. 81 and 82).

- (a) Clutch to be set up so that breakaway does not exceed 262 lb. ft. Running setting to be within 180 to 160 lb. ft. minimum.
- (b) Clutch to be slipped five times over 90 deg. rotation.
- (c) Setting to remain within the above limits.

(4) FUNCTIONAL TESTS

TEST RIG. To carry out these tests a suitable rig is necessary which is made up along the lines shown in Fig. 121, which illustrates test rig NT.4437.

Here all the characteristics of the inert engine are reproduced and must comply with the following specification.

Engine inertia to be 262 lb. ft.² and compressor loading 40 h.p. at 1750 r.p.m. or equivalent loading at the starter spline. Engine gear ratio 5.7 : 1.

This is given in the test rig illustrated by a 262 lb. ft.² disc when coupled to the starter by bevel gear NT.4420 and rig gearbox NT.4421 which has a ratio of 5.5 : 1.

Means are provided for the attachment of a tachometer drive, the dial being installed together with the firing equipment at a control point remote from the test rig.

Suitable precautions must be taken to see that during the actual test, no personnel are in the immediate vicinity of the rig which should be installed in a separate compartment.

PREPARATION

Prior to mounting the starter on the test rig it is to be primed with engine oil specification D.E.D.2479 through the filler plug until it emerges from the planet carrier.

TESTS

The following tests must now be carried out.

(a) Performance tests

Six cartridges are to be fired at 10-minute intervals; two of these cartridges to have been previously soaked at + 45 deg. C. for 12 to 24 hours.

(b) Rapid firing sequence

Three cartridges to be fired, the second after one minute and the third after a total elapsed time of four minutes. The flywheel may be arrested between cranks.

(c) No load, overspeed tests

Two cartridges are to be fired while the starter is disconnected from any load.

(d) Recordings

Recordings of cartridge burning time and pressure and starter speed to be taken for two cartridges (para. 4a) one each cold and heated.

(e) Acceptance limits

- (1) Starter speed at 4 (a) not to be less than 1500 r.p.m.
- (2) Burning time at 4 (a) to be 3.3 ± 0.1 seconds.
- (3) Average pressure at 4 (a) to be $1,000 \pm 100$ lb. per sq. in.
- (4) Cut-off speed as at 4 (c) to be $50,500 \pm \frac{5000}{0}$ r.p.m.

Mod. S.5132 introduces a new rotor wheel assembly N.116682. It is recommended that this modification be embodied during the next overhaul, when the test procedure will be as follows:

(a) Performance tests

Four cartridges are to be fired at ten minute intervals.

(b) Rapid firing sequence

N.B. The starter is to be allowed to cool to room temperature before commencing this sequence. Three cartridges are to be fired, the second after one minute and the third after a total elapsed time of four minutes. The flywheel is to be arrested between cranks.

(c) No load, overspeed tests

Two cartridges are to be fired with the starter disconnected from any load.

(d) Tight load tests

With the test rig inertia reduced to 189 lb. ft. two cartridges must be fired, both cartridges having been previously soaked at + 45 deg. C. for 12-24 hours.

(e) Recordings

Recordings of cartridge burning time and pressure and starter speed are to be taken for cartridges 3 and 4 in test 4 (a).

(f) Acceptance limits

- (1) Starter speed at 4 (a) must not be less than 1,500 r.p.m.
- (2) Burning time at 4 (a) to be $3.2 \pm .2$ seconds. Variations from these limits may be acceptable, subject to the approval of the Inspector in Charge.
- (3) Average pressure at 4 (a) to be $1,000 \pm 100$ lb. per sq. in.
- (4) Cut-off speed at 4 (c) to be 58,000-63,000 r.p.m.
- (5) Starter speed at 4 (d) must not be less than 10,200 r.p.m. at output shaft and the cut-off plate must not operate.

(5) EXAMINATIONS

On completion of the above tests the starter is to be partially or completely dismantled as required by the local governing airworthiness authority, and examined for wear or defects.

Radial clearance between shroud and rotor to be not less than 0.006 in. when both parts are clean and at room temperature.

(6) PROOF TESTS

The starter is to be reassembled, the gearbox primed with oil as in para. 4, and the following tests carried out:—

- (a) If para. 5 involved upsetting the clutch tests as at para. 3 (clutch test) apply in entirety.
- (b) Starter to be refitted on rig and a proof of assembly test of two cartridges carried out with a 10-minute interval, a visual speed reading only need be recorded.

Note: At the conclusion of the test if starter is proved satisfactory the locking tabs left unsecured in Fig. 117 and 118 should now be bent up.

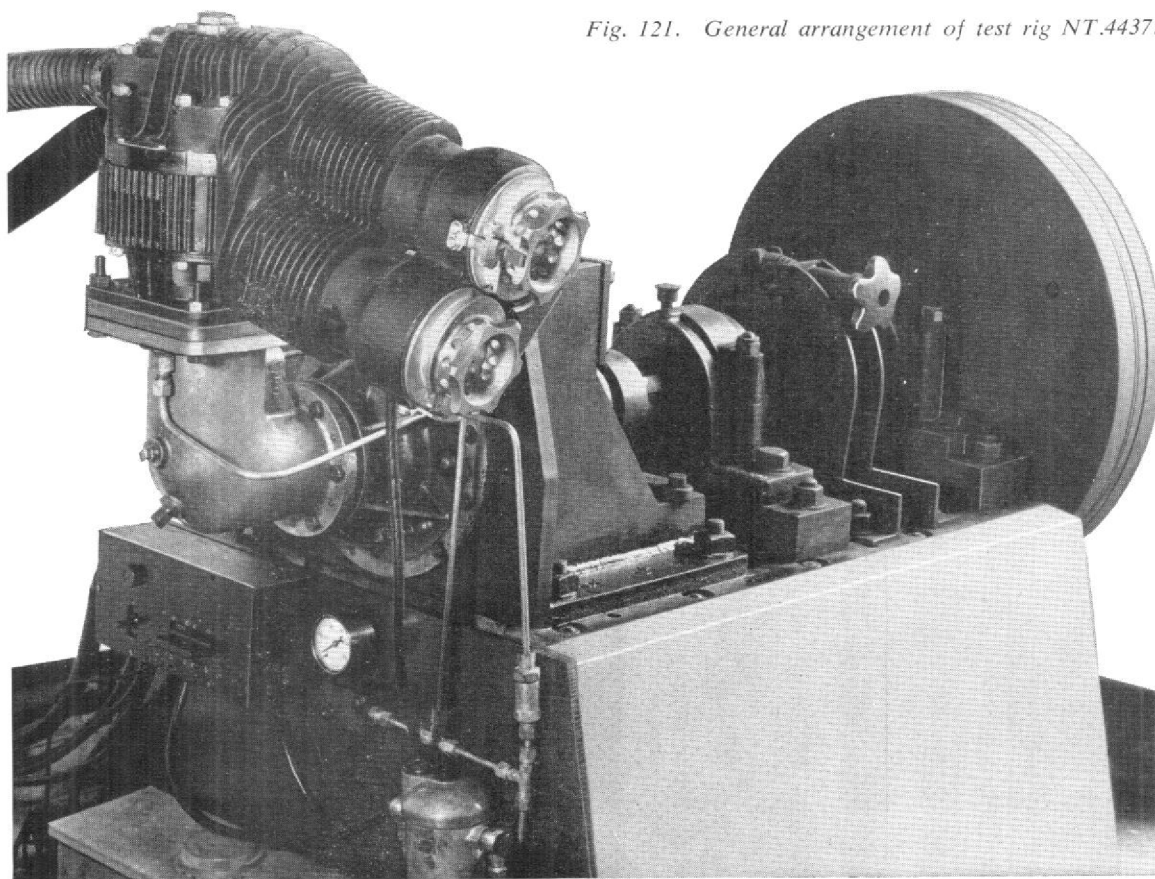


Fig. 121. General arrangement of test rig NT.4437.

(7) REPLACEMENT OF MAJOR PARTS

In the event of para. 5 disclosing defects involving the replacement of parts, further tests will be applicable as follows:—

	Para.
(1) Breech casting and/or breech caps	2, 4, 5, 6
(2) Breech safety switches	2
(3) Nozzle ring assembly	4, 5, 6
(4) Cut-off plate and/or overspeed clutch barrel	4, 5, 6
(5) Rotor and/or overspeed clutch ring	4, 5, 6
(6) Clutch assembly, part or complete, including springs	3, 4, 5, 6
(7) Main housing assembly	4, 5, 6
(8) Front housing assembly	4, 5, 6
(9) Planet carrier and/or planet gears and needle rollers	4, 5, 6

(8) PREPARATION FOR DISPATCH

- (a) Starter to be cleaned externally and in breech bores and caps. Breech cap threads to be re-greased with D.T.D.582 graphite grease.

- (b) All external lockings to be secured.
(c) Suitable cover to be secured to front housing to protect spline and ball race. Blanks to be fitted to exhaust and bursting disc flanges.
(d) Turbo-starter log book to be completed with all relevant details and kept with starter.

SPARE PARTS

All service parts are made interchangeable as far as is possible, but in some cases it is necessary to furnish a complete assembly because the parts are either permanently fastened together or are dynamically balanced after assembly. Complete assemblies are obtainable for use where service equipment does not provide for balancing.

Ball bearings are specially made for the heavy service demanded of them, inferior ones will not prove satisfactory and it is essential that replacements should be of an approved type.

Experience has indicated that it is preferable to return to our nearest Service Department, or to an authorised service station, any apparatus that cannot be easily and satisfactorily repaired by following the instructions contained in this chapter.

When ordering please give complete information including part name, part number, and serial numbers and details of the apparatus. This will ensure positive identification and prompt service.



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