Section 2

TYPE TBS-720 MK. 2 TURBO-STARTER

LIST OF CHAPTERS

Note.—*A list of contents appears at the beginning of each chapter*

Chapter 1

DESCRIPTION

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LIST OF ILLUSTRATIONS

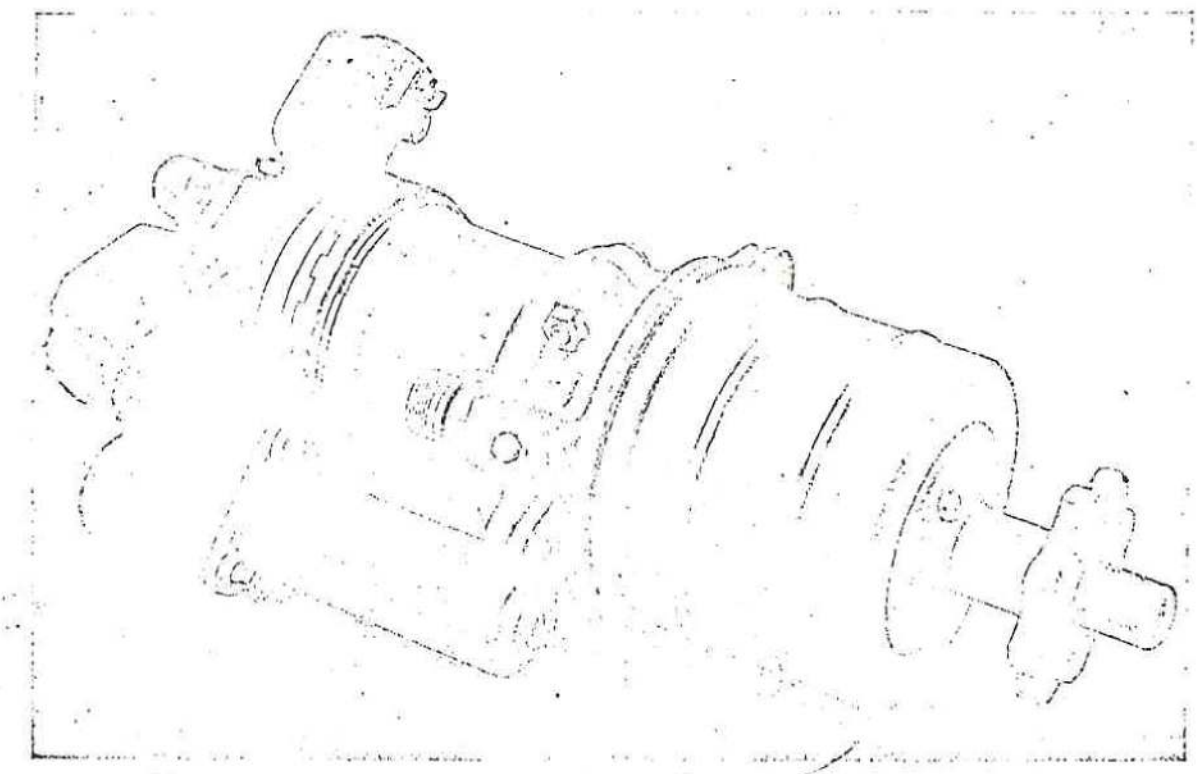

Fig. 1 Breech assembly

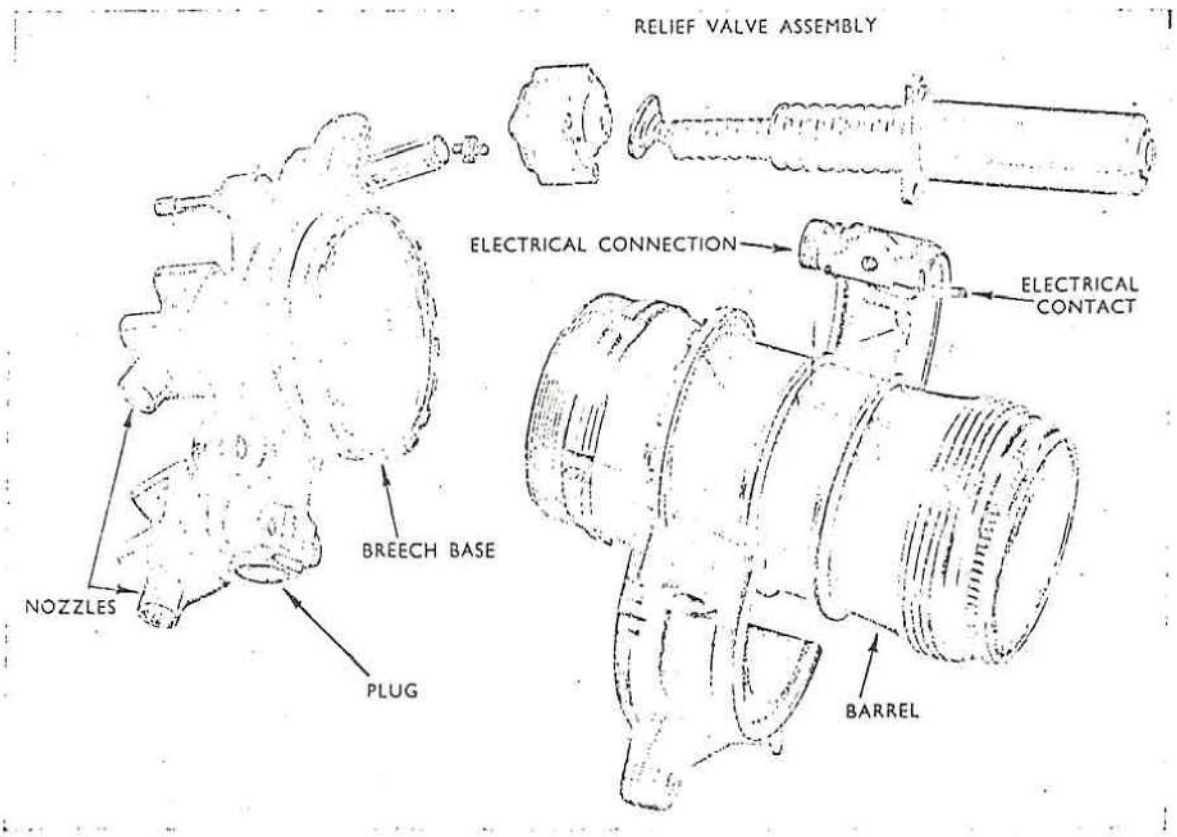

Fig. 2 Main components of breech assembly

BREECH ARRANGEMENT

1. The three breech assemblies are identical and are arranged in clover-leaf formation on the inlet casing with their axes in line with the axis of the starter.

2. The main component is the barrel, which is screwed into a heat-resisting steel breech base shown in fig. 1 and 2. Mounted on the base are the two nozzles for each breech and there is also a duct leading to the pressure relief valve. The three breech bases are in turn mounted on a heat-resisting steel inlet casing, in which the nozzles are inserted.

3. There is no tendency for gas from a burning charge to blow back and affect the remaining live cartridges since the nozzles of each breech are only open to each other in the region of low pressure where the gases discharge against the turbine.

BREECH DETAILS

4. A two-piece muff clamped with four bolts to the breech barrel carries the electrical connection to the detachable breech cap in which the pin for firing the cartridge is located (*fig.* 3). The muff carries the single-pin and socket type connector for the cable and this is bonded to a spring blade which makes contact with an insulated slip ring on the breech cap when this is screwed in place. From the slip ring the circuit is taken to the spring-loaded firing pin through an insulated metal strip which is bonded to the ring during manufacture.

5. The cap screws on to a two-start thread on the breech barrel and seats down on a hard rubber ring against the breech muff. The rubber ring provides a water-tight seal and also minimises any tendency for the cap to lock on the threads.

LOCKING CLAWS

6. In the breech cap are two pairs of spring-loaded claws; one pair forms a positive locking device to prevent the cap from loosening under vibration, and until pressure is applied to a plunger in the centre of the hand grip on the cap these claws lock in serrations formed on the barrel. The other pair of claws hold the rim of the cartridge and provide a means of extracting this when the breech cap is removed. Two smaller plungers projecting through the base of the cap serve to release these extractor claws.

ARRANGEMENT OF NOZZLES

7. Each breech is provided with two convergent-divergent nozzles which have a throat diameter of 6·5 mm. These are inserted tangentially in the heat-resisting steel inlet casing and the roots are welded into elbows which are bolted at four points to the breech bases. At the point where each nozzle enters the inlet casing a piston-ring seal, held by a circlip, provides a gas-tight seal.

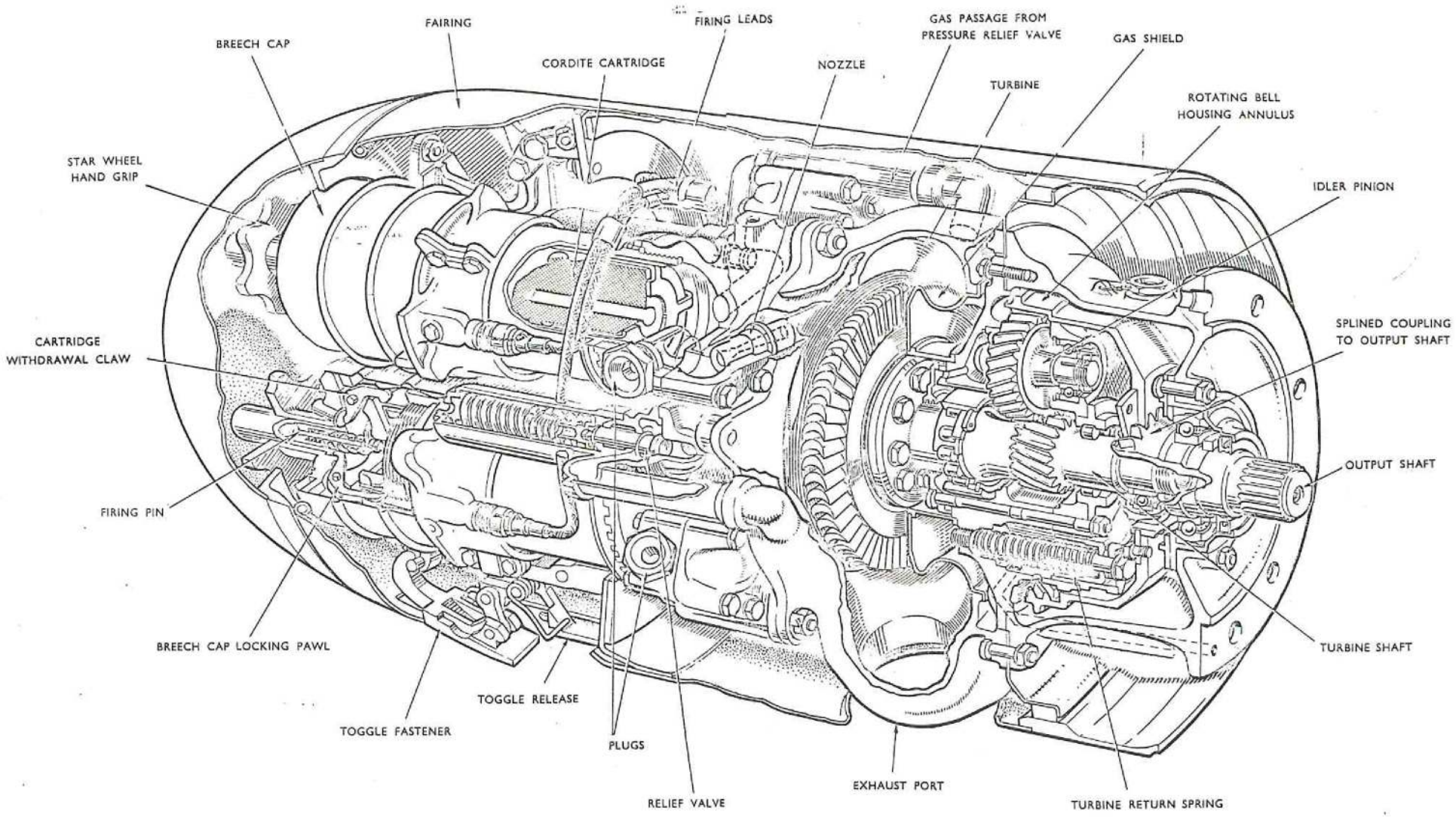

Fig. 9. Sectional perspective view of T B S-720 Mk.2 turbo-starter

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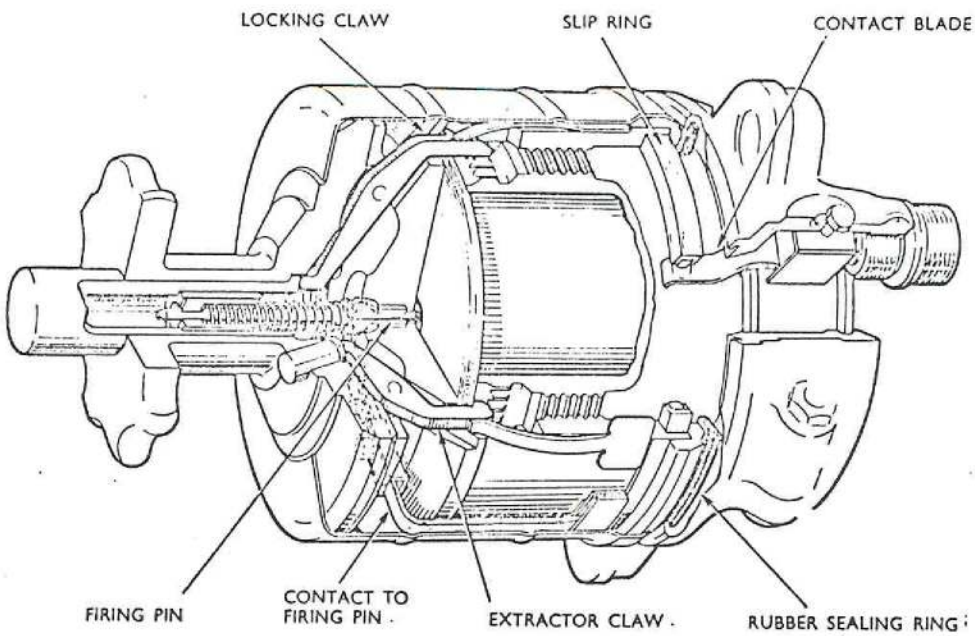


Fig. 3 Sectional perspective view of breech cap

8. Screwed into the outer face of each nozzle base is a hexagon-headed plug which seals a passage for inserting one of two replaceable heat-resistant liners in the gas passage leading to the nozzle. The passage bends at an angle to lead the gases into the nozzle and the two liners are shaped to dovetail together at the apex of the angle where the plug and a support piece lock them securely against movement.

EXHAUST CASING

9. The breech mechanism is separated from the turbine and reduction gearing by the exhaust

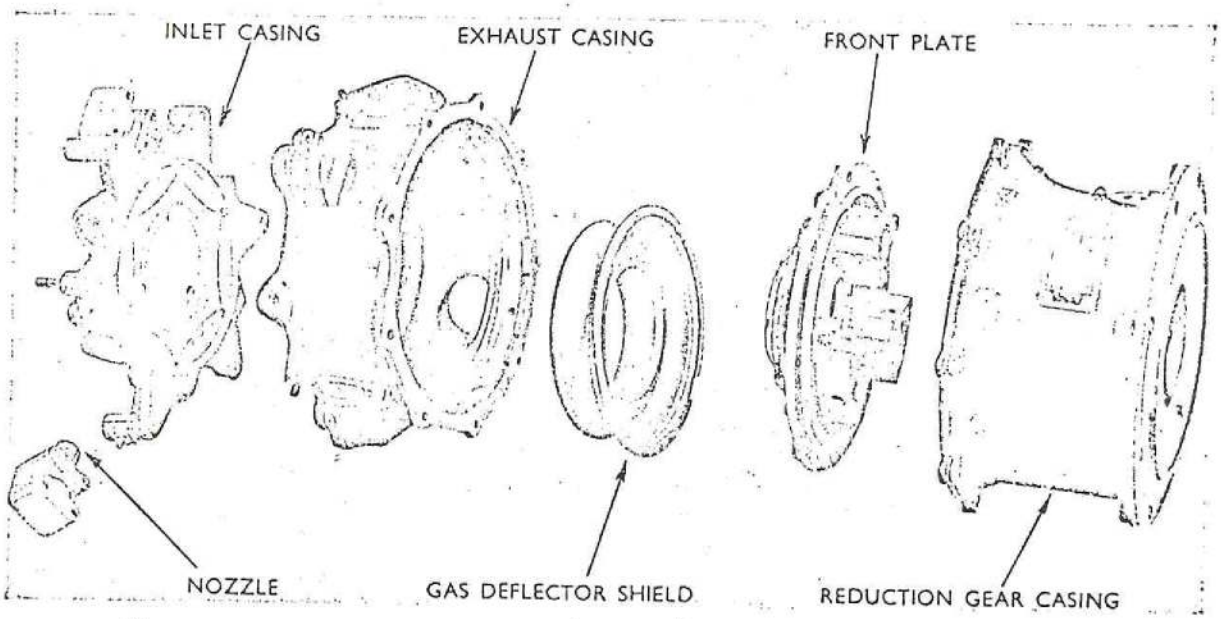


Fig. 4 Turbine and reduction gear casings

casing, illustrated in fig. 4. This is a heat-resistant steel casting and has three equally-spaced exhaust outlets. Projecting into the exhaust casing from the rear face is the deflector shield, which is also of special heat-resistant material, built up by welding into the desired shape to direct the gases towards the exhaust ports. To assist in dissipating heat from this shield the interior is exposed to atmosphere by means of holes drilled in the rear circumference of the exhaust casing.

PRESSURE RELIEF VALVES

10. An important feature of the starter is the spring-loaded pressure relief valves which are shown in fig. 1 and 2. There are three of these, one for each breech, and they are provided with double loading springs set to give the required controlled breech pressure of 1200 lb/in^2. The valves are set to operate at this pressure on assembly and there is no provision for external adjustment as special equipment is required to retain the highly preloaded springs before they may be dismantled. The valve is a plunger with a 45 deg. seat and its guide is formed integral with the valve body. In the base of the plunger a ball-ended peg is inserted which has a flange beneath which packing shims can be removed or inserted to set the spring pressure during assembly.

11. The passage through which the gases released by the valve are ducted to the exhaust casing for release to atmosphere consists of a short, straight length of stainless steel tubing which passes outside the inlet casing to an extension leading into the exhaust chamber. Piston-ring type seals at each end of the tube ensure a gas-tight seal where it is joined to the pressure valve and the exhaust casing.

TURBINE WHEEL

12. The sliding turbine shaft passes through the centre of the heat shield where a labyrinth-type seal is fitted to ensure a gas-tight joint. A flanged extension on the shaft provides for an eight-bolt attachment of the turbine disc, which is an austenitic steel component with welded-in turbine blades.

TURBINE SHAFT ASSEMBLY

13. The whole of the turbine shaft assembly, including the sun wheel, is carried on two roller bearings. The bearing adjacent to the turbine wheel is located on the shaft and the complete bearing, including the outer race, slides with the shaft in a sleeve formed in the front plate of the reduction gear casting.

14. The bearing which supports the tail of the shaft is fixed relative to the casing, and the inner race, which is formed on the shaft itself, slides through the rollers. Integral with the shaft is the sun-wheel pinion which engages the three planet gears of the epicyclic reduction gear. The sun-wheel pinion is of wider section than the three planet gears to ensure that it is fully in mesh throughout the axial movement of the shaft. Each planet gear has an integral shaft which rotates in ball and roller bearings.

RETURN SPRINGS

15. Housed in the front plate are the three return springs (*fig.* 7) which bias the axial position of the turbine to that of minimum gas torque. To ensure an equal distribution of the load on each spring a three-legged spider plate is spherically mounted on a ball bearing at the tail end of the turbine shaft and is arranged so that each leg bears on the plunger of one of the return springs; the end of each leg is supported in a thrust plate and bears against a cup washer seated on the plunger. Each return spring assembly is held in position by a set-screw which passes through the thrust plate, cup washer, plunger and spring, and screws into the front plate; the spring is located in a sleeve fitted into a cast alloy barrel inserted in the front plate.

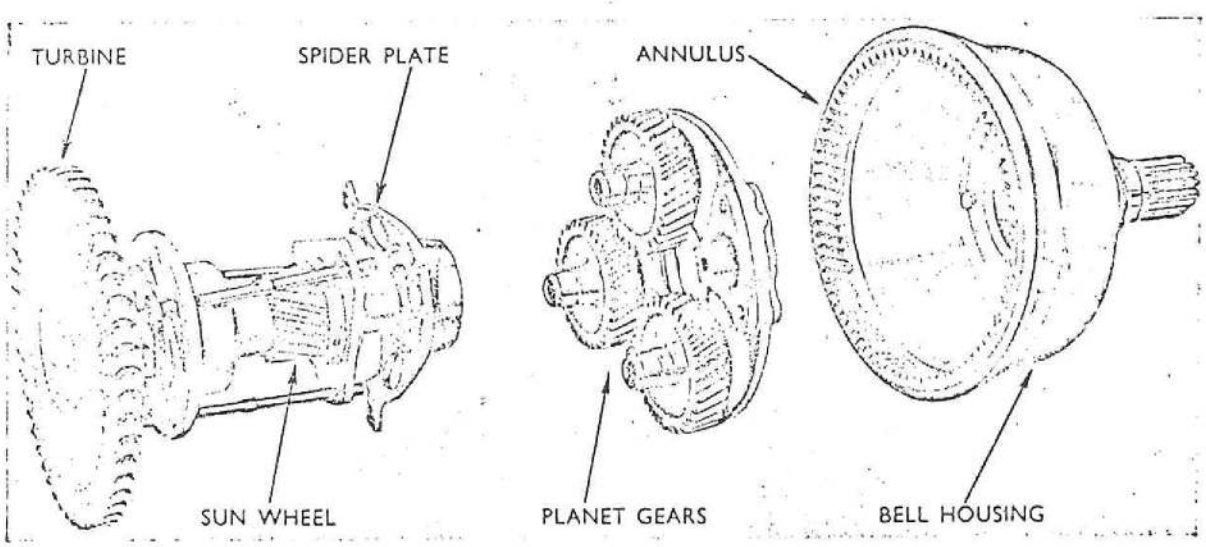


Fig. 5 Reduction gearing

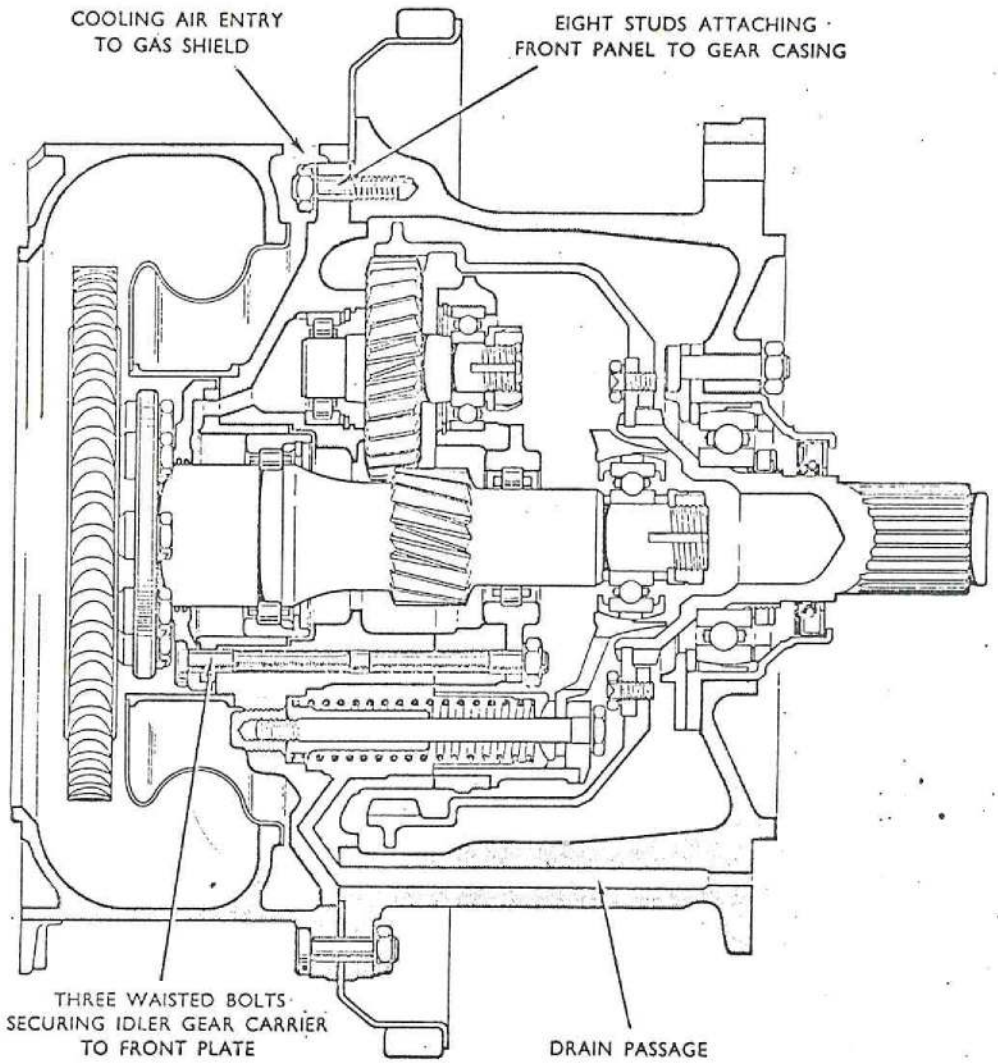


Fig. 6 Gear train assembly

REDUCTION GEAR

16. The sun-wheel on the turbine shaft meshes with the planet gears which rotate an annulus carried inside a bell housing, the whole of which revolves round the turbine shaft pinion. The carrier plate for the planet gears is a light alloy casting and is secured by three waisted bolts to the front plate of the reduction gear casting.

17. The starter gear train provides a step down of 4·5 : 1 between the turbine wheel and the output shaft; a further reduction is obtained through the gears incorporated in the engine to which the starter is connected. The drive to the output shaft is taken from the annulus bell housing through a variation of the usual type of splined coupling. A short series of helically-formed splines is cut in the rear face of the bell housing and these engage with similarly shaped splines on the output shaft. This arrangement allows limited radial movement of the annulus bell gear to ensure equal distribution of the load through the planet gears.

TORQUE CONTROL

18. To prevent overspeeding provision is made for varying the gas torque on the turbine according

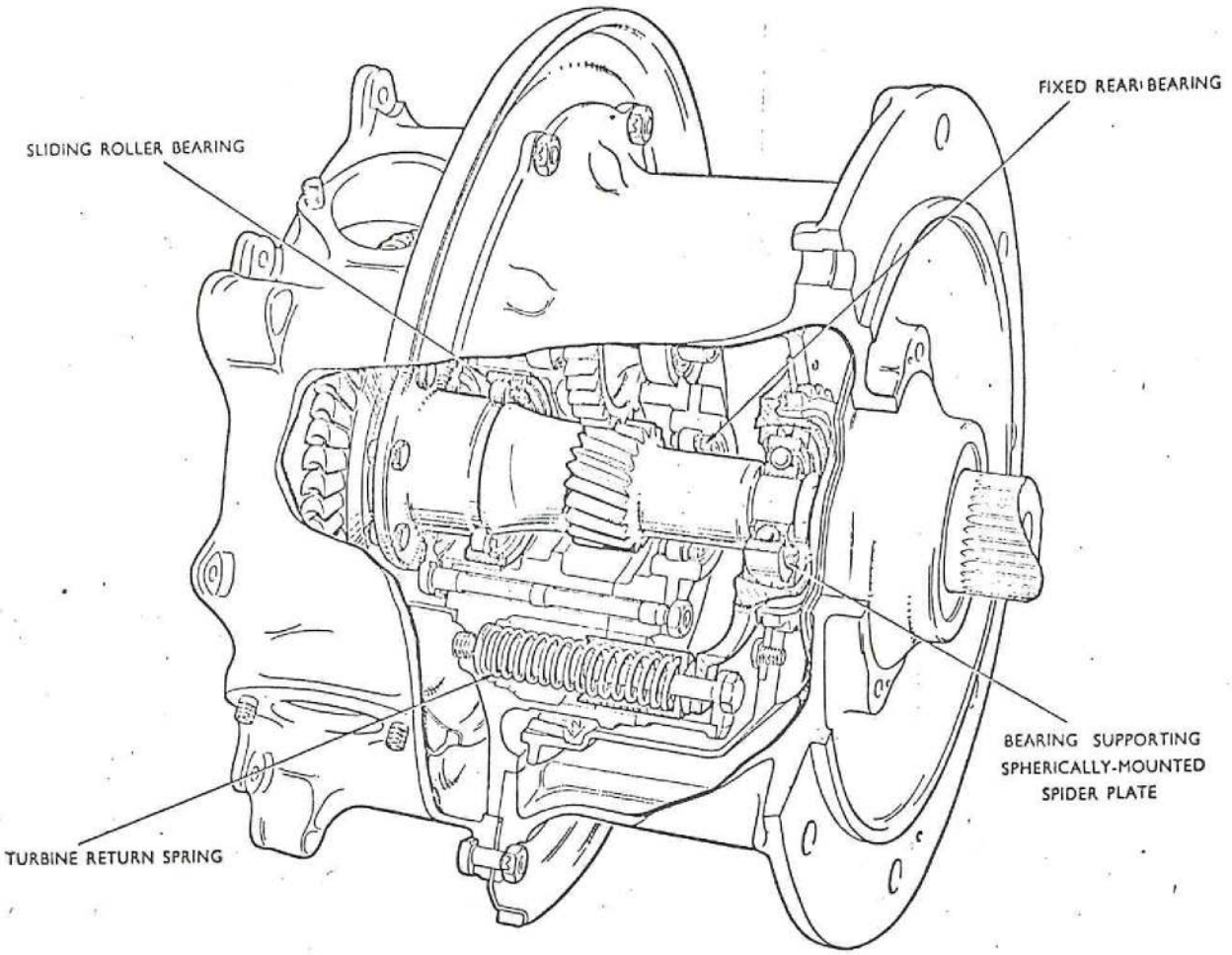


Fig. 7 Sliding turbine shaft and return spring

to the external load. This is achieved by an axial displacement of the turbine wheel on a sliding shaft to ensure that the blades receive the full force of the gases from the burning cartridge *only* when the load imposed calls for the maximum amount of torque.

19. The drive is taken from the sun-wheel, which is integral with the turbine shaft, through the three planet gears to the rotating annulus. Helically-cut gearing is used, the effect of which is to make the sun-wheel move axially when any resistance to turning is being overcome. In overcoming this resistance the turbine slides progressively nearer to the full gas stream, the limit of travel being where maximum torque is obtained (*fig.* 8).

20. When sliding to the position of maximum torque the turbine shaft compresses springs, which return the turbine shaft to the starting position as the torque decreases.

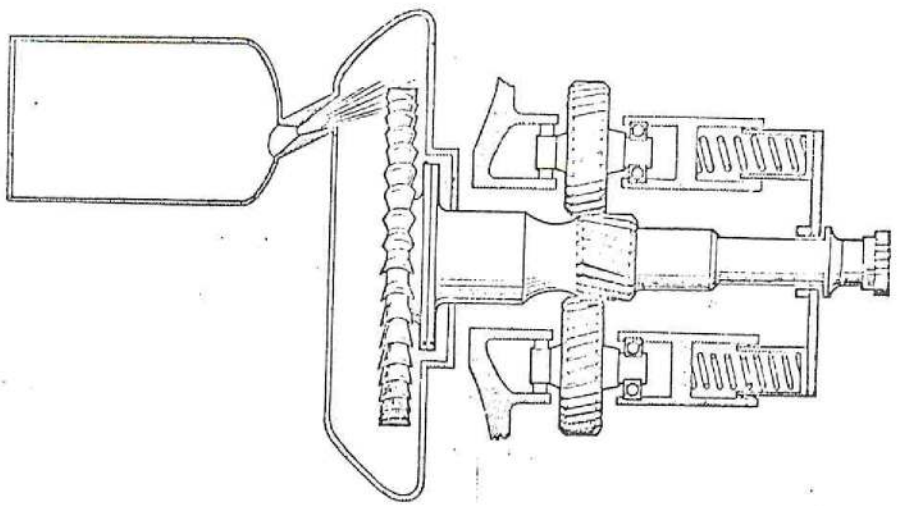
OVERSPEED PREVENTION

21. With this provision for axial movement of the turbine between positions ranging from minimum to maximum gas torque the starter becomes in effect 'load conscious' and is safeguarded against over-speeding. If a cartridge is fired to start the unit against an already running engine, the turbine remains in the low gas torque position until it is actually called upon to drive the engine. Only when the starter is driving under load is sufficient reaction exerted through the helical gears to compress the return springs.

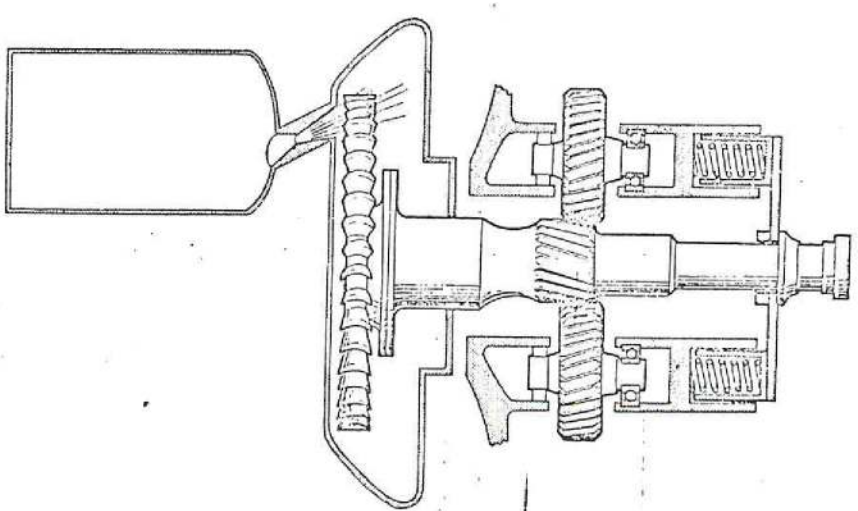
22. The time taken by the starter to overtake the speed of the engine is the same as would be required to accelerate the engine to this speed from rest. This means that there is still sufficient energy in the remaining gases to enable the turbine to accelerate the engine up to its normal starting speed.

GAS PRESSURE CONTROL

23. Any increase in gas pressure will also create a rise in torque, therefore provision must be made to limit this to a suitable maximum under any conditions. The burning characteristics of cordite vary considerably under differences of temperature resulting from climatic conditions and any increase in temperature causes a rise in gas pressure with a corresponding increase in the torque. This is kept within pre-determined limits by the setting of the springs used in the pressure control valves. By limiting the gas pressure to 1200 lb/in^2 the maximum speed of the starter is governed even



A. TURBINE UNDER NO-LOAD CONDITIONS



B. SPRINGS COMPRESSED AND TURBINE RECEIVING FULL TORQUE

Fig. 8. Diagrammatic illustration of torque control

under tropical conditions of operation where the burning time of the cartridges may be accelerated.

LUBRICATION

24. The starter is arranged for oil lubrication from the engine supply, the internal distribution of the oil being purely by splash.

25. The method employed on the Rolls-Royce 'Avon' for maintaining the oil level in the starter consists of a dashpot in the form of a small cylinder, mounted in the engine engagement gear casing, in which there is a spring-loaded plunger operated by engine oil pressure. The cylinder is provided with two drillings one of which leads to the starter and the other to a hopper which collects oil splash from the engine front bearing housing. The drillings are so arranged that as the plunger moves against its spring under the increasing engine oil pressure during a start the hopper feed is first of all cut off and the remaining oil is delivered into the starter casing. A reservoir is arranged to maintain a pool of oil into which the bell gear dips.

26. This system ensures that on every start of the engine a shot of approximately 6 c.cs. of oil is delivered to the starter. This is in excess of the starter requirement and surplus oil is allowed to drain back into the plunger cylinder when the engine is shut down. On installation on an engine, the starter must be primed with oil; during priming oil is poured over the bell housing and forms a small reservoir which is kept replenished from the engine supply system each time the starter is used.

Chapter 2

TYPE TBS-720 MK. 2

LEADING PARTICULARS

Type	*Cartridge operated turbo-starter with integral triple breech*
Cartridge	
Type	*Electrically fired, stick type, cordite*
Summer	*No.* 10
Winter	*No.* 10
Turbine	
Type	*Single stage impulse*
Speed	
Maximum	40000 *rev/min.*
Overspeed	42000 *rev/min.*
Reduction gear	
Type	*Epicyclic, helical spur, single stage*
Ratio	4·5 : 1
Direction of rotation (output shaft)	*Anti-clockwise (viewed from drive end)*
Performance	
Output	250 *h.p. at* 40000 *rev/min.*
Duration	3 *secs. at* 15°*C.*
Weight (less cartridges)	60 *lb.*
Oil	*Approved engine oil*
	(Refer to appropriate engine change unit A.P.)

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INTRODUCTION

1. The type TBS-720 Mk. 2 triple breech turbo-starter consists of a single stage impulse turbine which is rotated by the energy of gases liberated from a burning cordite charge. The burning time of the cartridge is approximately two seconds and during this time the turbine rotor attains a speed of approximately 40000 rev/min. and develops about 250 b.h.p.

2. The drive from the turbine is transmitted through an epicylic reduction gear to the output shaft which drives a second reduction gear in the aero-engine, thus giving the required overall starter rotor to engine gear ratio.

3. The pressure generated by the burning cartridge is limited to 1200 lb/in^2 by pressure relief valves and this in conjunction with the

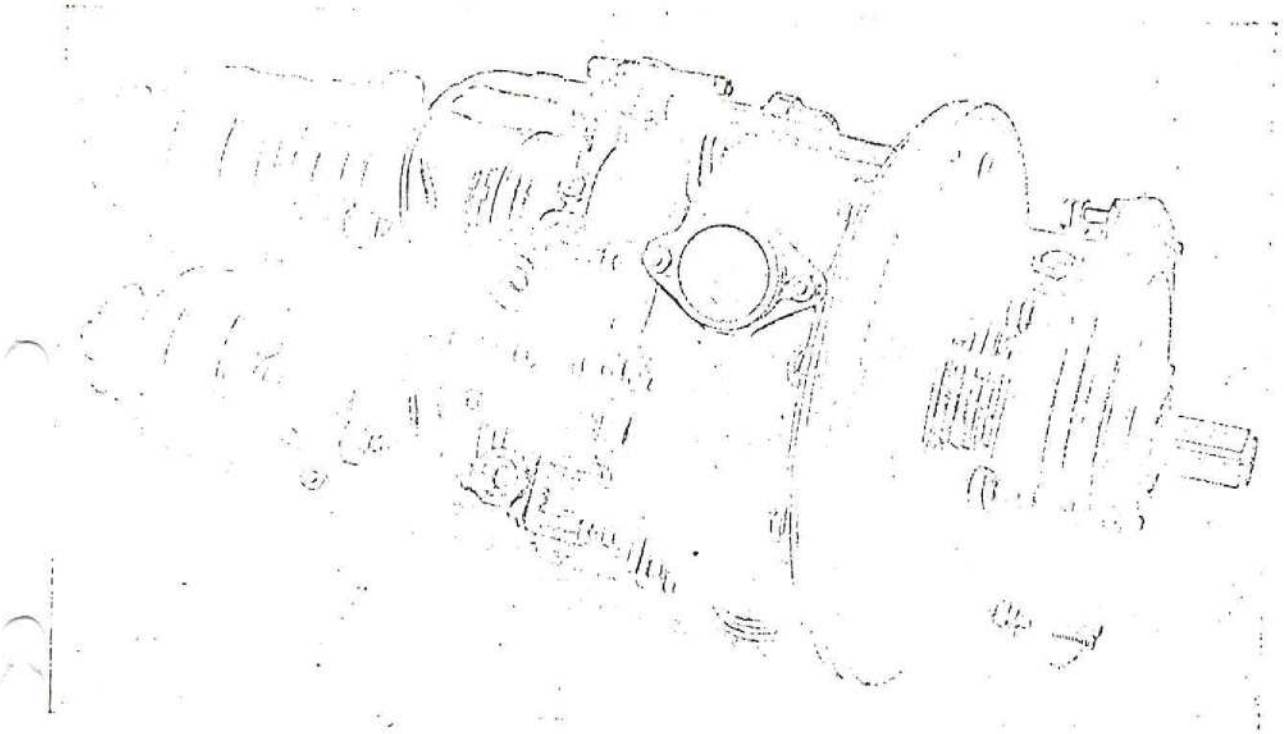

Fig. 1 Type TBS-720 Mk. 2 turbo-starter

sliding shaft arrangement of the rotor, provides an overspeed prevention device.

STARTER SYSTEM

4. The TBS-720 Mk. 2 turbo-starter is a self-contained unit which is bolted to the front casing of the aero-engine. The output shaft is splined to engage with the drive shaft of the engine starter reduction gear, and with the reduction gear on the starter, an overall ratio of 27 : 1 is obtained. The maximum speed of the starter is 40000 rev/min which raises the speed of the engine rotating assembly to 1500 rev/min.

5. The electrical circuit of the starter is fed from aircraft supply by a bonded lead which plugs ...o the socket on the casting of the starter. A 10 ohm resistor is placed in parallel with the firing circuit to prevent electrical leakage firing the starter.

The whole starter unit is enclosed in a fairing the design and arrangement of which will vary :cording to the design of the aircraft and engine .o which the starter is fitted: mounting lugs and studs on the exhaust casings are provided for this purpose. A detachable panel in the fairing is provided to enable the starter to be loaded and unloaded through suitable access panels in the aircraft structure.

7. To convey the exhaust gases to atmosphere exhaust pipes are secured to centre casing of the starter, pass through suitable ducts in the engine air intake body and terminate at the outer skin of the aircraft structure.

8. The description, servicing and minor repair of the starter is contained in Section 2 and information on the application of the starter to aircraft and engine combinations is given in Chapter 1 of this section.

OPERATING CYCLE

Cartridges

9. The cartridge designed for use in the triple-breech starter consists of approximately 720 gm. of cordite composition contained in a thin brass cylinder which has a flanged base: inserted in the centre of this is the primer. To ensure constant pressure of gases the cartridge is hollowed out in the centre. The charge becomes plastic while burning and to prevent any creeping into the breech base with a possibility of blocking the gas passages an expendable grid plate is inserted which forms an end location in the mouth of the cartridge case.

Method of ignition

10. The primer, which is spun riveted into the centre of the base of the cartridge case, consists of a small container filled with a gunpowder mixture. This container is in electrical contact with the cartridge case, and has an insulated centre contact connected to a fuze wire running through the gunpowder mixture to 'earth' on the primer body.

11. The passage of an electric current through this wire heats it sufficiently to ignite the gunpowder and thus fire the igniter charge. As a flash of longer duration than that provided by this small primer cap is required for igniting the cordite cartridge, a separate igniter charge is interposed between the primer and the cartridge. It consists

of a larger-grained gunpowder mixture which is held in a gauze bag.

Sequence of ignition

12. With this arrangement the firing sequence is as follows:—

(1) Fuze wire is heated electrically to fire primer charge.

(2) Quick flash from small primer charge ignites larger and longer burning charge in gauze bag.

(3) Cordite cartridge ignites.

WARNING . . .

In practice this sequence is an almost spontaneous cycle, but under arctic conditions delay, or 'hang-fire', may occur.

Gas flow

13. The cartridges are fired electrically from a selector switch in the pilot's cockpit and the resultant gases pass to nozzles which discharge into the turbine wheel casing. Each breech barrel is connected with two convergent-divergent nozzles from which the gases discharge against the impulse turbine at supersonic velocity. In reaching this high velocity the gas pressure drops from 1000 lb/in^2 at the cartridge to atmospheric level at the discharge orifice of the nozzle. This conversion from high pressure to high velocity is effected through the convergent-divergent shape of the nozzles, the initial acceleration up to sonic velocity taking place in the convergent passages. After escaping through the narrow throat orifice the gases expand in the divergent section of the nozzle and in doing so gain supersonic velocity.

14. After passing through the turbine blades, the gases are deflected by a specially-shaped shield towards three equally-spaced exhaust ports, an arrangement which also prevents the gases from swirling back against the turbine to impair its efficiency by exerting a counter-thrust.

Circuit layout

15. The wiring layout is designed to ensure that whilst the selected cartridge is being fired no other cartridge may be brought into use through a short circuit. That part of the engine starting circuit which affects the turbo-starter is shown in simplified form in fig. 2 where it will be noticed that 10 ohm limiting resistances are incorporated in the lead to each breech. This resister is incorporated in the connector on each breech muff and its purpose is to ensure that in the event of a short circuit the current takes a low resistance path to earth. To ensure this, adequate earthing points are established on the starter button, the selector switch and at each breech.

PREPARING FOR SERVICE

16. The turbo-starter assembly is attached to the engine by twelve bolts fitted through the mounting flange on the starter gear casing. The electrical connection from the engine to the three individual cables leading to the breeches is made through a quick-release plug connector mounted above the reduction gear casing.

17. Stub connections are fitted to the exhaust ports to which pipes are secured to carry exhaust gases away from the engine air intakes.

Oil priming

18. Before installing a new starter or refitting one after long term storage, the starter reduction gear must be drained and reprimed with the grade of engine oil detailed in the Leading Particulars of the appropriate aero-engine Air Publication. To do this proceed as follows:—

(1) Remove the drain and priming plugs and allow the old oil to drain off.

(2) Refit the drain plug and inject approximately one third of a pint of clean engine oil into the reduction gear; when doing this rotate the starter drive shaft to circulate the oil throughout the reduction gear.

(3) Refit the priming plug and lock it and the drain plug.

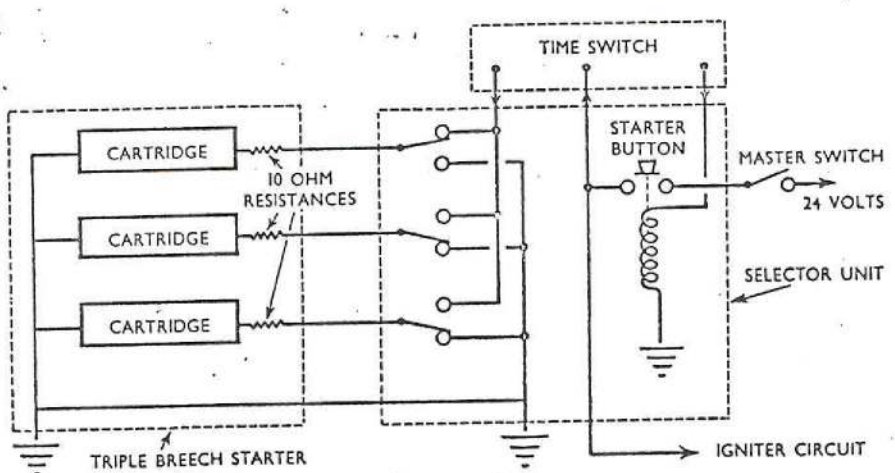

Fig. 2. Simplified electrical circuit

OPERATION

19. Instructions for starting any engine will be found in the relevant engine Air Publication. A start should normally be obtained with one cartridge if the engine is in good running order. When difficulty in starting is experienced a check should be made of possible engine faults.

Loading

20. To load the starter, depress the large central plunger in each breech cap and unscrew the cap from the barrel. Remove the external transportation cover from the cartridge mouth. Fit a cartridge into the breech cap, pushing the cartridge right home so that the two extractor claws clip over the cartridge base, then insert the assembly into the breech barrel. Screw the breech cap fully home by hand, finger tight only; this is important as overtightening may cause jamming and subsequent difficulty in removal after firing.

Unloading

21. Before attempting to reload the breeches refer to Warning 2, para. 22.

To unload, depress the central plunger and unscrew the breech cap from the barrel, then depress the two small plungers in the breech cap to lift the two spring-loaded extractor claws which grip the rim of the cartridge case so that this can be withdrawn from the breech cap. A check should be made to ensure that no loose residue is left in the breech barrel.

Firing

22. The cartridges are fired electrically from a push button which selects the cartridge and energises a time switch in the pilot's cockpit. Once the start button has been pressed the time switch will complete a cycle of 30 seconds before any further attempt to fire another cartridge can be made. This allows the starter to run down to a safe speed before the starting sequence can be repeated.

WARNING . . .

1. **All personnel must keep clear of the engine intake starter and exhaust outlets when an engine is about to be started.**

2. **If a cartridge fails to fire, the next cartridge may be fired immediately after the completion of the 30-second starting cycle. After the three cartridges have been fired in quick succession allowed by the time switch, an interval 10 minutes must be allowed for the breeches to cool before reloading. If the three new cartridges are then immediately fired, the next interval before reloading must be extended to 20 minutes to ensure adequate cooling of the breeches.**

3. **If, at any time, it is necessary to work or make adjustments on the engine or starter, or to check electrical circuits, ensure that none of the breeches contains a live cartridge.**

4. **If a cartridge which has failed to fire, or the remnant of a partly burned cartridge has to be removed from any of the breeches, this must be disposed of in accordance with the safety precautions laid down for the handling of explosives.**

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FAULT DIAGNOSIS CHART

Fault	Possible cause	Correction
(1) Cartridge does not fire.	Defective cartridge or possible delayed action ignition.	Allow the time switch to complete the 30-second starting cycle and then press the starting button again to fire the next cartridge.
(2) Second or third cartridge fails to fire.	Electrical circuit defect.	Wait at least 30 seconds and then unload all three breeches. Check that current reaches spring blade contacts. Check electrical continuity from slip rings to firing pins.
(3) Engine does not light up.	Engine defect.	Refer to engine change unit Air Publication, Vol. 1.

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Chapter 2

SERVICING AND MINOR REPAIRS

Very little servicing is required to keep the starter efficient; while the starter is attached to the engine, it is automatically supplied with oil from the engine oil pressure system. After approximately every 50 shots, the breech caps and contacts should be wiped clean and a light smear of graphite-grease XG–285 (Stores Ref. 34B/233) should be applied to the threads.

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Chapter 1

(This chapter supersedes that issued with A.L. No. 2)

GENERAL INFORMATION

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APPENDIX

INTRODUCTION

1. The operations described in this section are normally undertaken by a base repair unit or approved firm which is equipped with the necessary test rigs, tools and stocks of spare parts. A description of this starter, together with illustrations, notes on installation, operation, servicing and minor repairs will be found in Volume 1 and Volume 6, Part 1 of this Air Publication.

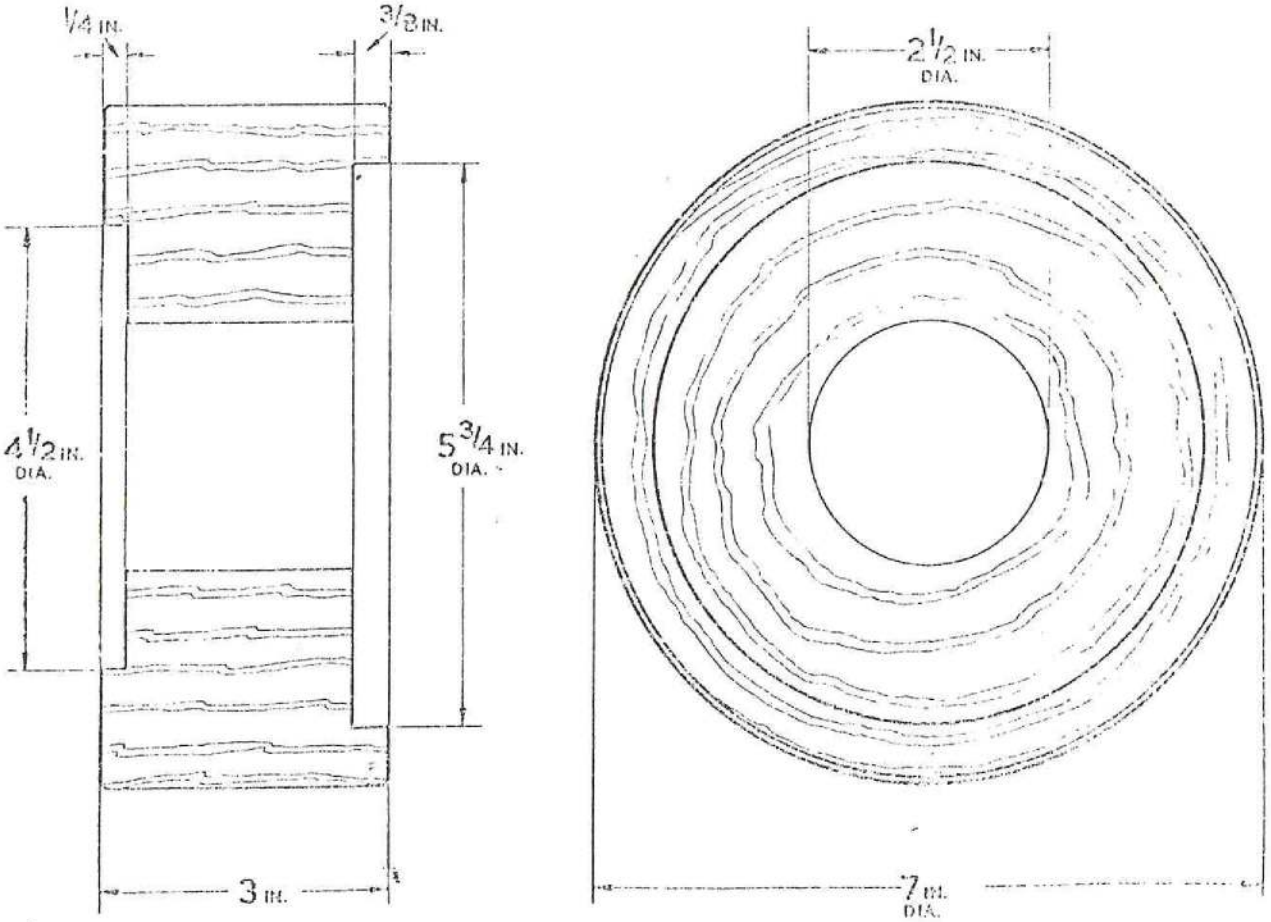

Fig. 1. Hardwood dismantling and assembling stand (Type 71-5272)

SPECIAL TOOLS AND EQUIPMENT

2. The special tools and equipment required to recondition the Type TBS.720 Mk. 2 turbo-starters are listed below. In addition the following equipment will be required :—

(1) A supply of dry compressed air.

(2) The following cleaning equipment :—

(a) Kerosene wash.

(b) Trichlorethylene de-greasing bath.

(c) Cresol—soap wash.

(d) Power driven rotary brushes of wire, bristle, fibre or linen.

(3) Suitable containers for storing the parts of the starter.

(4) A stand, locally made up, to be used for dismantling and assembling the starter (*fig.* 1).

3. In addition to the foregoing, a schedule of the modifications to be embodied and their classification, a Schedule of Fits, Clearances and Repair Tolerances and any approved Repair Schemes are also required.

TOOL LIST

4. The following list of tools, together with a number of standard tools, completes the Repair Base Tool kit.

Part No.	*Description*	*Application*
CX.135287	Stand, support	Check rotor clearance
CX.135288	Tool, contractor	Assembly and dismantling of control valve
CX.135289	Spanner dog	Idler gear nuts
CX.135290	Plug	Assembly of oil seal
CX.135291	Sleeve, guide	Assembly of oil seal
CX.135292	Plate, holding	Holds end of driving shaft so that nut can be tightened
CX.135293	Spanner dog	Driving shaft castellated nut
CX.135294	Plate, holding	For tightening idler gear nuts
CX.135295	Plate, assembly	For breech base
CX.135526	Clamp	Assembling circlip on starter fixing screws
CX.136534	Fixture checking	Bearing in housing (driving shaft)
CX.139349	Spanner ring	Breech barrel
CX.139350	Fixture checking	Rotor return spring loads
CX.139351	Extractor	Return mechanism thrust plate
CX.153012	Extractor	Bearings in bearing panel
CX.153067	Extractor	Bearing on drive shaft
CX.153068	Fixture	For checking the endfloat of the rotor front sliding bearing assembly
CX.153111	Peening block and tool	Assembly of breech cap
CX.153112	Swaging tool and block	Spinning over the shroud on the breech cap
CX.153273	Clamp	Dismantling front roller bearing
CX.153274	Block assembly	Positions breech barrels in correct numerical order prior to assembly of inlet casting
CX.153322	Fixture testing	Testing the setting of safety relief valve
CX.133280 –13 and –17	Drift extractor	Removing bearings from castings
CX.136456 –2 and –8	Sleeve assembly	Used with press for assembly of bearings in castings and on shafts
CX.154186	Fixture assembly	Used with press for assembly of dowel and bearings in bearing panel

and the following standard tools :—

Seeger Circlip pliers Type S.I.B.

Abingdon " King Dick " double-ended ring spanners DDW207 and DDW208.

Abingdon " King Dick " Ignition spanner OIB203.

Stud drivers (2 B.A. $\frac{5}{16}$ in. B.S.F.)

Arbor bond press.

RECONDITIONING PROCEDURE

5. For all starters, whether requiring replacement of major parts or not, the sequence of reconditioning is as follows :—

External examination
|
Dismantle, examine and report
|
Repair
|
Re-assemble
|
Rig test
|
Proof test (as necessary)
|
Quality test (as called for in paragraph 9)
|
Inhibiting for despatch (*A.P.*4171A)

6. Upon the receipt of a starter, it is to be externally examined, dismantled and cleaned and the parts assessed for general condition and compliance with the Schedule of Fits, Clearances and Repair Tolerances, and the specified modification standard, and classed accordingly.

7. Where the reconditioning of the starter is undertaken by a repair base or firm without previous or recent experience of starter reconditioning to official requirements, the first 50 starters reconditioned may be required to be completely dismantled for examination after conclusion of the Acceptance Proof Test at the discretion of the Chief Inspecting Officer A.I.S., the Chief Inspector, N.A.I., or the Inspector-in-Charge A.I.D.

8. Similarly, when reconditioning of a new type of engine starter is commenced, or repair of existing types is resumed after a long interval, and the personnel are not experienced in the repair of the type concerned, the C.O.I./A.I.S., C.I.O/N.A.I., or the Inspector-in-Charge A.I.D., may at his discretion require the complete dismantling of a number of starters before the minimum requirements set out in para. 9 are introduced.

QUALITY TEST

9. Where any quantity of starters is to be reconditioned by a repair base, firm or other established source, a complete Quality Test must be conducted on one starter in every 500, or once in six months, which ever is the greater frequency. Where reconditioning work is to be undertaken at a new source, or has lapsed during a period of six months or more, a complete Quality Test is to be satisfactorily completed on one of the first starters reconditioned at that source before deliveries are proceeded with. The starter selected is to be truly representative of the normal standard of reconditioning, not to be specially assembled, and to be the first starter to have completed the specified Acceptance Proof Test. Full details of the quality test is given in Appendix 1 at the end of this Chapter.

EXTERNAL EXAMINATION

10. Make a general examination of the starter to assess its suitability for repair. This is essential to prevent any unnecessary work being carried out on a starter which comes within the unrepairable category.

Appendix 1

PRODUCTION QUALITY TEST SCHEDULE FOR RECONDITIONED TYPE TBS.720 Mk. 2 TURBO-STARTERS

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Introduction

1. The production quality test shall be carried out on a starter selected by the Inspector-in-Charge A.I.D., the Chief Inspecting Officer A.I.S., or the Chief Inspecting Officer N.A.I., from starters which have previously passed the normal acceptance test, and shall be applied to one in every 500 starters or once every six months, whichever is the lesser period, whilst production continues. During the tests the starter is not to be serviced in any way excepting normal maintenance lubrication.

2. Should the starter fail during any part of the test, it is to be dismantled for examination and a report made as to the cause. Another starter is to be selected and the tests recommenced.

Production quality test schedule

3. Before commencing a production quality test, the starter must have satisfactorily completed a normal production acceptance test, including a strip examination.

4. The complete starter should be fitted to the test rig which should carry a flywheel corresponding to the inertia load of the engine and a hydraulic brake to simulate the compressor power losses as follows:—

Inertia— 256 lb. ft.² equivalent to a 2 ft. diameter flywheel, 4·0 inches thick

Brake setting— 60 H.P. at 1,500 r.p.m. and left at this setting throughout.

Tachometers and Dobbie McInnes indicators should be calibrated before and after the Quality Test.

5. 69 cartridges are to be fired successively at one minute intervals at the rate of three cartridges each half hour, and except where otherwise stated, all cartridges are to be fired at room temperature and should be of the current 720 gm. No. 10 type. Cartridges should be fired in rotation using each breech in turn.

6. During the test specified in para. 5 the following special test conditions are to be observed:—

(a) Shot 5 and 56 are to be fired with the test rig flywheel removed and the water brake disconnected.

(b) Shots 20, 21, 22 and 23 are to be fired in an elapsed time of five minutes—this period to include the reloading of the breech prior to firing the fourth shot.

(c) Shots 40, 41, 42 and 43 are to be fired in an elapsed time of five minutes as in 6(b) but using cartridges which have been soaked at −45 deg. C. for 12–24 hours immediately prior to firing.

7. (a) The maximum flywheel speed is to be recorded for every shot.

(b) Dobbie McInnes indicator diagrams are to be obtained for shots No. 5, 12, 20, 21, 22, 23, 24, 36, 40, 41, 42, 43, 48, 56 and 69.

(c) The batch numbers of all cartridges used are to be recorded.

8. Immediately on completion of the above tests, the starter is to be stripped and inspected, and a report issued as soon as possible to the Inspector-in-Charge, or Chief-Inspecting-Officer.

9. The starter is to be assembled after reconditioning such parts as may be necessary and re-submitted to the scheduled normal acceptance tests before delivery.

Chapter 2

DISMANTLING AND CLEANING

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LIST OF ILLUSTRATIONS

GENERAL

1. When dismantling more than one starter, care must be taken to prevent the interchange of components. Where they are not supplied, suitable stands, receptacles and bins should be made locally so that the component parts of each starter can be safely stored and identified as a unit. It is important that when dismantling mating components they are suitably marked to ensure that they are assembled in the same relative position.

2. Due to the high operating speed of the rotor and to the small clearances, care must be taken to prevent damage to the rotating components during the reconditioning operations. This applies in particular to the rotor blades, the edges of which are easily damaged, also to bearings, bearing housings and gears.

3. It will be found convenient during dismantling and assembling to deal with the starter in two separate halves, i.e. the breech-end half, which consists of the three breech assemblies and the inlet casing and the starter-end half, consisting of the bearing panel, reduction gear and its casing. These two halves, are attached one on each side of the steel exhaust casing

SAFETY PRECAUTIONS

4. Before commencing work on the starter, remove any cartridges in the breeches. For unloading instructions see A.P.1181D, Vol. 1 and Vol. 6, Part 1, Sect. 1, Chap. 2.

5. Before commencing to dismantle the starter, remove the oil priming plug from the gear casing and drain the oil, then replace the plug.

DISMANTLING THE STARTER-END

Removing firing lead harness

6. (1) Remove the locking wire securing the three knurled connector plug nuts to the breech barrel housing. If these nuts are tight, a light tap with a hammer will ease them ; remove the nuts.

(2) Unlock and remove the nuts securing the lead clips, the conduit clip, earth lead tag and the firing lead plug support bracket.

(3) Draw the conduit towards the output shaft, passing the three connector plugs one at a time through the hole in the fairing, then

Separating the front from rear half

7. To separate the two halves proceed as follows :—

(1) Unlock and remove the seven remaining $\frac{1}{4}$ in. B.S.F. nuts securing the gear casing to the exhaust casing and remove the bolts and tab-washers.

(2) Separate the gear casing from the exhaust casing, taking care not to damage the mating faces.

(3) Remove the fairing ring.

(4) Unlock and remove the three $\frac{1}{4}$ in. B.S.F. nuts and the three $\frac{5}{16}$ in. B.S.F. nuts which retain the inlet casing to the exhaust casing, remove the bolts and tab-washers then separate the casings. During this operation care must be taken to prevent the transfer tubes dropping.

Removal of bearing panel assembly from gear casing

8. (1) Unlock and remove the eight $\frac{1}{4}$ in. B.S.F. nuts, securing the bearing panel to the gear casing; take off the tab-washers and withdraw the panel assembly; care being taken to avoid damaging the mating faces.

Removing rotor shaft nut

9. (1) Assemble the bearing panel assembly to the fixture CX.135287 so that the idler gears mesh with the teeth of the fixture as illustrated in fig. 1. Secure it in position with the two knurled nuts.

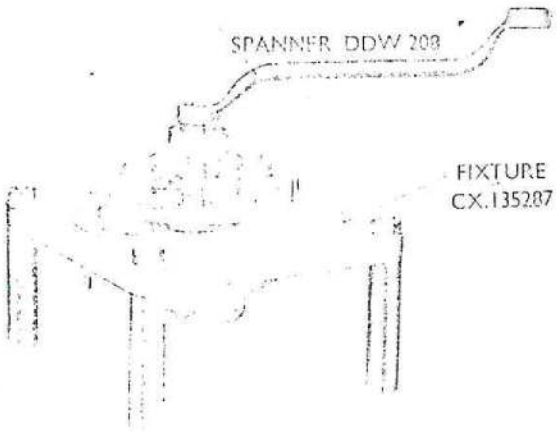

Fig. 1. Removing the rotor shaft nut securing the thrust plate and bearing (rotor removed)

(2) Unlock the rotor shaft nut and using spanner DDW.208 unscrew and remove the nut.

(3) Remove the cupped locking washer and the adjusting washer.

Note . . .

The adjusting washer is selected for a specific starter and must be retained with it.

Dismantling return mechanism thrust plate

10. (1) Unlock and remove the three $\frac{1}{4}$ in. B.S.F. bolts locating the thrust plate and lift off the stop plates.

(2) Fit the extractor CX.139351 and extract the thrust plate complete with the ball bearing as illustrated in fig. 2.

(3) Remove the inner adjusting washer from the rotor shaft.

Note . . .

It is important that the adjusting washers on either side of the ball bearing are not interchanged.

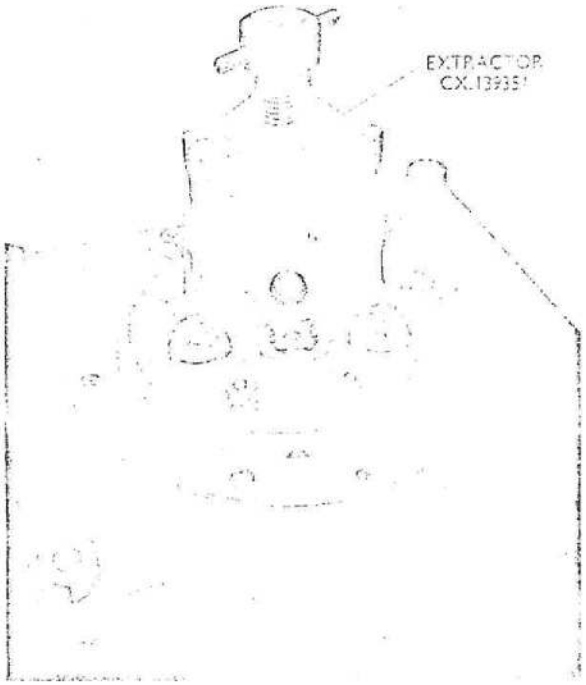

Fig. 2. Removing return mechanism thrust plate

(4) Turn the ball bearing with its two phosphor-bronze seating rings at right angles to its axis and withdraw the bearing and rings through the two slots in the thrust plate, then remove the seating rings from the bearing.

(5) Remove the three spherical washers, the outer spring sleeves, springs, spring guides and the dowelled outer guides.

Note . . .

Care must be taken to ensure that the stop plates and spherical washers are not interchanged either in position or with other starters as they are selected to suit a specific starter.

Dismantling rotor shaft and bearings

11. (1) Unlock and remove the three $\frac{1}{4}$ in. B.S.F. nuts securing the rotor shaft front bearing.

(2) Remove the tab-washers and withdraw the bearing from the shaft, care being taken not to damage the mating faces.

(3) Turn the unit with its stand on one side and carefully draw the shaft and rotor assembly out of the bearing panel.

(4) Remove the exhaust deflector from the bearing panel by a twisting movement.

(5) Withdraw the rear sliding bearing sleeve.

Dismantling the rotor shaft assembly

12. (1) Remove the internal circlip securing the rear turbine shaft bearing using the approved circlip pliers.

(2) Remove the retaining washer.

(3) Slide the outer race rearwards, i.e., towards the rotor, until clear of the rollers.

(4) Remove the rollers from the cage using tool CX.153273.

Note . . .

These rollers are a "snap-in" fit through the outside of the cage.

(5) Withdraw the outer race, the aluminium labyrinth seal and the packing washer from the rotor shaft.

Note . . .

The retaining washer and circlip are selective fits and must be replaced otherwise the bearing assembly will have to be checked as described in Chap. 4.

Removing rotor from rotor shaft

13. Before removing the rotor, the relative position of the shaft and rotor must be marked to ensure correct assembly; then proceed as follows:—

(1) Unlock and remove the eight $\frac{1}{4}$ in. B.S.F. bolts together with the four locking plates and eight special nuts.

(2) Gently tap the rotor away from the shaft flange using a hide faced hammer. Care must be taken to avoid damaging the rotor blades.

Note . . .

Should either the rotor or rotor shaft be replaced the unit must be dynamically balanced as described in Chap. 4.

Idler gears and bearings

14. (1) Unlock and remove the six $\frac{1}{4}$ in. B.S.F. nuts which secure the end-plate to the bearing panel and remove the tab-washers.

(2) Lightly tap out the six bolts using a hide faced hammer or a block of hard wood.

(3) Remove the end-plate from the bearing panel complete with the three planet gears and roller bearings housed in the end-plate.

(4) Assemble the end-plate and gears to the holding fixture CX.135294 as illustrated in fig. 3, locating the gears on the three pegs in the fixture.

(5) Unlock the three gear retaining nuts by punching out the cup type locking-washer.

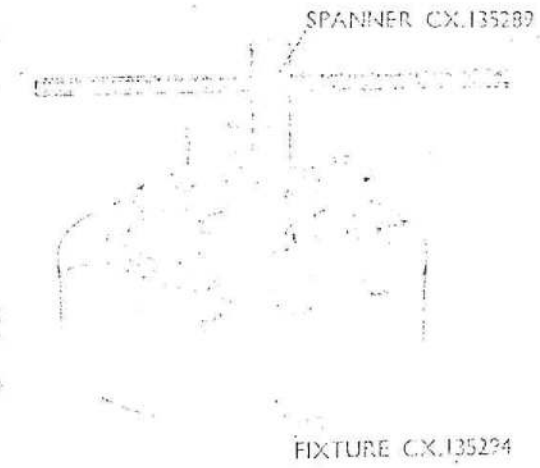

Fig. 3. Removing idler gear nuts

(6) Unscrew and remove the three retaining nuts using spanner CX.135289 (*fig.* 3).

(7) Remove the end-plate from the fixture.

(8) Press out the three planet gears.

(9) Remove the three internal circlips retaining the bearings, using the approved circlip pliers, then take out the bearing washers.

(10) Remove the three ball bearings using tool CX.133280–13.

(11) Remove the three internal circlips retaining the roller bearings using the approved circlip pliers, then take out the bearing washers.

Fig. 4. Removing idler gear roller bearings

(12) Using extractor CX.153012 extract the three roller bearings from the bearing panel, as illustrated in fig. 4.

Note . . .

Do not remove the roller bearings from the bearing panel unless they are to be replaced. Removal is assisted if the bearing panel is first warmed.

Removing the annulus gear

15. (1) Unlock and remove the eight set-screws securing the two annulus gear locating plates, remove the tab-washers.

(2) Remove the two locating plates.

(3) Remove the annulus gear from the driving shaft.

Removing driving shaft assembly

16. (1) Unlock and remove the four nuts which secure the spherical ball bearing locking plate to the gear casing, take off the tab-washers and remove the bolts.

(2) Place the gearcase on a suitable stand and press out the driving shaft complete with the ball bearing assembly, care being taken not to damage the oil seal or the splines of the driving shaft.

(3) Remove the adjusting washer abutting the bearing.

(4) Carefully press out the housing and remove the oil seal.

(5) Assemble the toothed end of the driving shaft in to the fixture CX.135292 (*fig.* 5).

Fig. 5. Removal of self-aligning bearing nut

(6) Unlock the bearing retaining nut and remove the nut, using spanner CX.135293 as illustrated in fig. 5, remove the lockwasher.

(7) Using extractor CX.153067 extract the bearing from the driving shaft (*fig.* 6).

(8) Turn the bearing through 90 deg. relative to the seating ring and draw the bearing out through the slots in the ring.

(9) Remove the adjusting washer and locking plate.

Note . . .

The adjusting washer is made in various thicknesses and is selected to suit a particular starter.

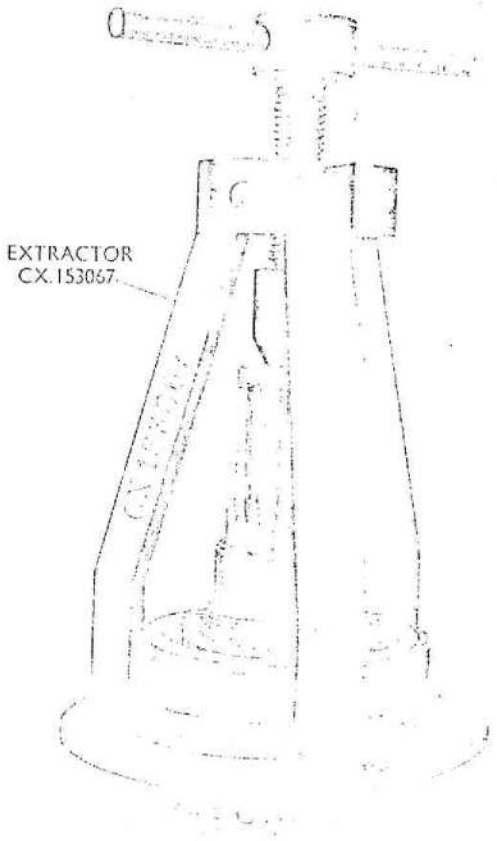

Fig. 6. Removal of bearing from driving shaft

17. Should any of the eight special set-bolts which retain the starter to the aero-engine be damaged, they can be removed by fitting the clamp CX.135526 to the casing as illustrated in fig. 7 and using a suitable tool prising off the spring ring. The bolts may then be withdrawn from the casing.

Fig. 7. Removal of starter set-screws

DISMANTLING THE BREECH-END

Inlet casing and nozzles

18. (1) Unlock and remove the four $\frac{1}{4}$ in. B.S.F. screws and four $\frac{1}{4}$ in. B.S.F. nuts securing each pair of nozzles to its breech case, then remove the tab-washers.

(2) Tap out the twelve bolts, six of which have round heads tapped to receive the cowling support set-screws and six have "D" shaped heads.

(3) Unlock and remove the six $\frac{5}{16}$ in. nuts securing the inlet casing to the breech base; three of these nuts are located in the centre recess of the inlet casing. Remove the tab-washers, and withdraw the inlet casing complete with nozzle units from the breech base.

(4) Remove the bolts and separate the three breech barrel assemblies from the breech base.

(5) Remove the nozzle elbow corrugated joint washers and lift out the nozzle units from the inlet casing.

Breech-base liners

19. (1) Unlock and remove the two hexagon headed plugs from each breech base, remove the tab-washers.

(2) Remove the liner support pieces and the liners from each breech base.

Note . . .

Should either of these components be difficult to remove, they may be eased by inserting a few drops of penetrating oil.

Barrel housings

20. (1) Unlock and remove the six $\frac{1}{4}$ in. B.S.F. nuts which secure the three barrel housings to the three barrels.

(2) Remove the tab-washer and bolts.

(3) Carefully lift out the rubber sealing ring.

Note . . .

The two halves of each barrel housing must be kept together and identified with each barrel and breech from which they are taken.

Firing lead connection

21. Should the firing lead connection, which is fitted to one half of each barrel assembly be suspected of being faulty, bend back the locking tab and remove the 4 B.A. screw, using spanner O1B.203, then remove the connection assembly.

Pressure control valves

22. All components of the pressure control valve must be retained with the specific breech base to which they belong.

Warning . . .

The pressure control valve springs, are very heavily loaded; under no circumstances therefore should any attempt be made to remove these springs without using the contractor tool CX.135288 otherwise personal injury may result.

Fig. 8. Contractor tool for dismantling the control valve

(1) Assemble the valve spring contractor tool CX.135288 (*fig.* 8) through the hole in the spring housing then screw down to compress the two springs.

(2) Unlock and remove the three nuts securing the control valve, then remove the tab-washers.

(3) Lift off the spring housings and remove the bolts.

(4) Slowly release the tension on the contractor tool.

(5) Remove the springs, spring seatings, thrust peg and adjusting washer.

Note . . .

The adjusting washers are provided in a range of thickness and are selected to suit the specific valve assembly.

(6) Remove the control valve casing and the control valve.

(7) Repeat the foregoing procedure on the two remaining control valve assemblies.

Breech barrels

23. (1) Remove the retaining ring and lift off the barrel locking-ring.

(2) Hold the assembly plate CX 135295 in a vice and fit the breech base to it.

(3) Using spanner CX.139349 unscrew the barrel from the breech base as illustrated in fig. 9.

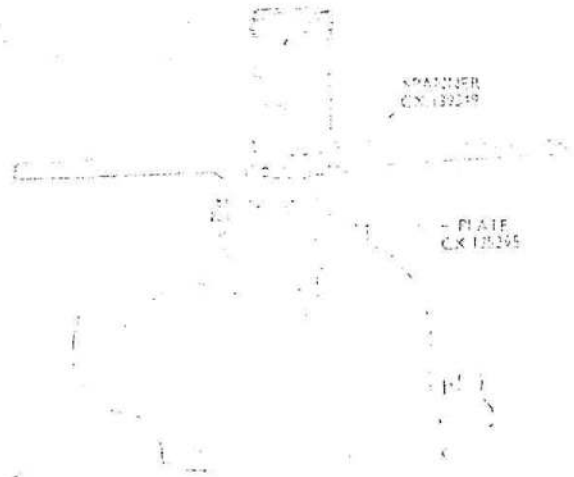

Fig. 9. Removing the breech barrel

(4) Remove the copper joint washer.

Note . . .

Mark each barrel in respect to its breech base to ensure that it is replaced correctly.

(5) Repeat the procedure on the remaining two assemblies.

Breech cap assembly

24. To dismantle the breech cap assembly proceed as follows :—

(1) Using a hacksaw cut round the circumference of the shroud at a distance of half an inch from the top, i.e., the hand-wheel end.

(2) Ease off the large portion of the shroud by lightly tapping it with a hammer, care being taken to hold the locking and extraction lever springs which are held in position by the shroud.

(3) Remove the retaining ring from the large portion of the shroud by cutting the shroud in a longitudinal direction. When the shroud is opened out, the retaining ring can be removed.

(4) Remove the small portion of the shroud.

(5) Unlock and remove the eight 2 B.A. screws which secure the breech cover to the breech cap, then remove the tab-washers.

(6) Invert the two components and using the large portion of the shroud as a stand remove the firing pin spring, guide, washers, plunger, locking lever and extracting lever pins. The latter items may require light tapping to remove them.

(7) Remove the locking and extracting levers and the two operating buttons.

(8) Using a soldering iron, remove the solder locking from the screw which secures the flexible connector from the firing pin to the terminal plate of the electrical connections, then remove the screw and firing pin assembly.

(9) Lift out the firing-pin bush and remove the screw securing the terminal plate and electrical connection to the breech cap.

(10) Remove the spring washer, plain washer, insulation bush and the ' U ' shaped insulation piece.

(11) Remove the insulation strip and guard and withdraw the slip-ring and insulation ring assembly from the breech-cap complete with the electrical connections.

(12) To remove the firing-pin insulation bush in the breech-cap, first prise out the aluminium insert which is peened in position, then press out the bush with a suitable drift.

CLEANING

25. Methylated spirit must be used to remove the accumulated carbon deposits. Hard carbon deposits may be removed by soaking the component in a bath of methylated spirit or in hot water. The removal of carbon deposits from the breech bases, nozzles and exhaust casing should be carried out by the use of blunt scrapers and wire brushes. Steam may be used where carbon deposits are exceptionally difficult to move.

26. Care must be exercised when cleaning machined mating faces, the component should be soaked in methylated spirit until the carbon can be removed by the use of hardwood scrapers. The rotor assembly, with the exception of the rotor blades should be cleaned with fine grade emery cloth soaked in methylated spirit. After initial cleaning, the rotor should be lightly vapour blasted. Alternatively it may be very lightly sand blasted. Great care must be taken not to use a coarse sand or too high a pressure if the latter method is adopted. All ball and roller bearings should be thoroughly cleaned by repeated immersion in clear trichlorethylene or gasoline no-lead followed by blowing out with compressed air until all trace of irregular running is removed. They should then be dipped in Spec. D. Eng. R.D.2487 oil, and wrapped in greaseproof paper to protect them from dirt.

27. Oily components should be cleaned by washing in gasoline, no-lead or trichlorethylene. After cleaning, all these components must be thoroughly dried with compressed air and the surfaces protected by applying a light coating of oil OX–38 (Stores Ref. 34A/266). If it is expected that a number of starters will be regularly handled they should be cleaned in accordance with instructions given in A.P.1464C, Vol. 1, Part 2, Sect. 2, Chap. 4, para. 42 to 49 inclusive.

Chapter 3

INSPECTION

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Modifications

1. During inspection a check must be made to ensure that all essential modifications are embodied. Outstanding modifications should be listed for incorporation during rebuilding of the starter and any redundant parts withdrawn. It is essential that an up-to-date copy of A.P.1181D, Vol. 2, Leaflets, General Orders and Modifications is available for this purpose.

Dimensions

2. The inspection of the starter must be carried out in conjunction with the Schedule of Fits, Clearances and Repair Tolerances given in Vol. 6, Part 3 of this A.P.

Consumable parts

3. The following parts must be discarded during dismantling irrespective of their condition:— Rubber sealing rings, copper and nickel joint washers, locking tab-washers, circlips ("Seeger" Type circlips must be rejected if strained or damaged) and in the case of time-expired starters, the firing lead assembly.

4. When the inspection of the dismantled starter is carried out, it should be borne in mind that all components passed for re-use will be subject to a further life of 500 shots. The life of the starter is generally limited by erosion of the rotor blades, nozzles, breech base liners and breech bases. Make a visual inspection for obvious damage such as scored bearing surfaces, distortion and corrosion. Generally, corrosion which cannot be removed from a mating or bearing surface by normal cleaning methods will entail the rejection of the affected component. Corrosion in other parts may be removed by polishing. Stoning or the use of fine emery cloth is permissible only at the discretion of the inspecting authority. The following specified items need special attention as defined.

Breech cap assembly

5. Check the continuity of the firing pin circuit and check that its insulation resistance is not less than two megohms using a 500-volt insulation resistance tester (*Ref.* 5G/1621).

Firing lead harness

6. Check that the insulation resistance between the individual firing circuits, also between each firing circuit and the casing, with the breech caps removed, is not less than three megohms using a 500-volt insulation resistance tester. Check the continuity of each lead. Visually check for signs of overheating or chafing, of the insulation. Remove the circlips which secure the lead pins. Withdraw the lead pin, bush, spring, resistor cup and resistor from each lead. Check that each resistor is within the limits of 10·0 ohms ± 1·0 ohm, and check the lead pin and resistor cup for freedom of movement with the spring.

Breech base

7. Inspect for thermal cracks particularly where the gas ports blend into the hemispherical bore.

a result of extended tests, the maximum breech base life has been upgraded to 800 starter operations. An inspection standard has been set based on examination of the breech bases after (a), 300 and (b), 800 starter operations. Breech bases which meet the inspection standard after a previous life of 300 starter operations may be accepted for a further life of 500 starter operations. Breech bases which do not meet the inspection standard after 300 starter operations and all breech bases which have completed more than 300 starter operations should be rejected. Inspect the pressure control valve seat for erosion and cracks. A small amount of lapping is permitted to restore the seating face to a good condition. If excessive erosion and cracking is present, the seating face may be re-machined to salvage drawing CX.167841. Check that the mating faces for the nozzle elbows are in good condition and free from distortion. Up to 0·003 in. may be ground off these faces to restore surface flatness.

Pressure control valve

8. Check for signs of erosion and thermal cracks. If the seating face will not clean up by lightly lapping with its own breech base, the valve should be rejected.

Nozzle and elbow assembly

9. Inspect the elbows for erosion and thermal cracks. Deep cracks will necessitate rejection, but light cracking may be accepted at the inspector's discretion. Inspect for diametral collapse of the nozzle bore immediately downstream from the inserts and check for wear in the parallel bore of the insert. The worn dimensions should be within the limits specified in the Schedule of Fits, Clearances and Repair Tolerances given in Vol. 6, Part 3 of this Air Publication. Check that the elbow mating face is in good condition and free from distortion. A degree of collapse in the immediate vicinity of the hole may be permitted provided that a good joint can be guaranteed. A maximum "dishing" of 0·003 in. is permitted, provided this does not extend over the joint face.

Note . . .
The life of the nozzle elbow assembly is not expected to be much in excess of 500 *starter operations.*

Breech base and nozzle elbow liners

10. Check that the liners show no signs of excessive erosion or thermal cracks.

Note . . .
The life of the liners is not expected to be much in excess of 500 *starter operations.*

Nozzle elbow corrugated joint-washer

11. A new washer must be fitted every time the nozzle elbows are disturbed.

Rotor assembly

12. Inspect the rotor blades for excessive erosion, damage or cracks at the blade roots. Check the out-of-balance of the rotor and shaft assembly which should not be more than 0·05 oz. in. at 1,500 r.p.m. When a rotor or shaft is renewed, the rotor and shaft assembly must be dynamically balanced as a unit as illustrated in Chap. 4, fig. 1, using an approved dynamic balancing machine.

Note . . .
The life of the rotor is expected to be in the order of 1,000 *operations.*

Ball and roller bearings

13. The procedure for the inspection of ball and roller bearings is described in A.P.1464B, Vol. 1, Part 2, Sect. 1, and should be applied when inspecting the bearings.

Rotor shaft

14. Check that the roller track dimensions are in accordance with the Schedule of Fits, Clearances and Repair Tolerances. Visually inspect the teeth for signs of chipping, corrosion or "picking-up". Using a pair of steel balls or rollers, whose diameter is within the limits of 0·1252 in. high 0·1250 in. low, measure the diameter over the tops of the balls or rollers. This measurement should not be less than 1·519 in.

Rotor-shaft rear-sliding bearing

15. Check the bearing in accordance with the Schedule of Fits, Clearances and Repair Tolerances. There should be complete freedom from scoring on the roller track and sliding surfaces. Using fixture CX.153068, check the bearing assembly for endfloat which must be within the limits of 0·002 in. maximum 0·001 in. minimum.

Rotor return-mechanism self-aligning bearing

16. Check the bearing in accordance with the Schedule of Fits, Clearances and Repair Tolerances and inspect for general condition and freedom of movement in the spherical seating.

Idler gear

17. Visually inspect the teeth for signs of chipping, corrosion or "picking-up". Using a pair of steel balls, or rollers, whose diameter is within the limits of 0·1252 in. high 0·1250 in. low, measure the diameter over the tops of the balls or rollers. This measurement should not be less than 2·4228 in.

Annulus gear

18. Visually inspect the teeth for signs of chipping, corrosion or "picking-up" and check that there is no fretting on the teeth locating the driving shaft.

Exhaust casing

19. Check that the collapse of the seating spigot does not exceed the figure quoted in Modification C.T.S.502.

Bearing panel

20. Check that all the oil holes are unobstructed.

Gear casing

21. Check that the oil hole from the mounting flange to the panel bearing mounting face is unobstructed.

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Chapter 4

ASSEMBLING AND TESTING

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GENERAL

1. Before commencing to assemble the starter make certain that all reconditioning operations, repair schemes and modifications called for in the inspection report have been completed. The components must then be washed and dried with moisture-free compressed air.

2. Except in a few instances, no dimensions will be quoted in these instructions for assembling the starter, reference must be made to the Schedule of Fits, Clearances and Repair Tolerances given in Part 3 of the Air Publication to ascertain the correct dimensions.

3. Where components are marked or have been marked during dismantling, it is important that they are assembled in their correct relative positions. Lightly coat all gears, bearings and shafts with OX–38 (Stores Ref. 34A/266) oil before assembling. Absolute cleanliness must be maintained during the assembling operations, this applies particularly to ball and roller bearings which should not be unwrapped until actually required. Assembly must be effected in accordance with the following procedure.

ASSEMBLING THE STARTER-END

Assembling rotor to rotor shaft

4. (1) Assemble the rotor to the rotor shaft then fit the eight ¼ in. B.S.F. screws, dual locking washers and special nuts.

Note . . .

New screws, special nuts and locking washers must be used whenever the rotor is removed from its shaft.

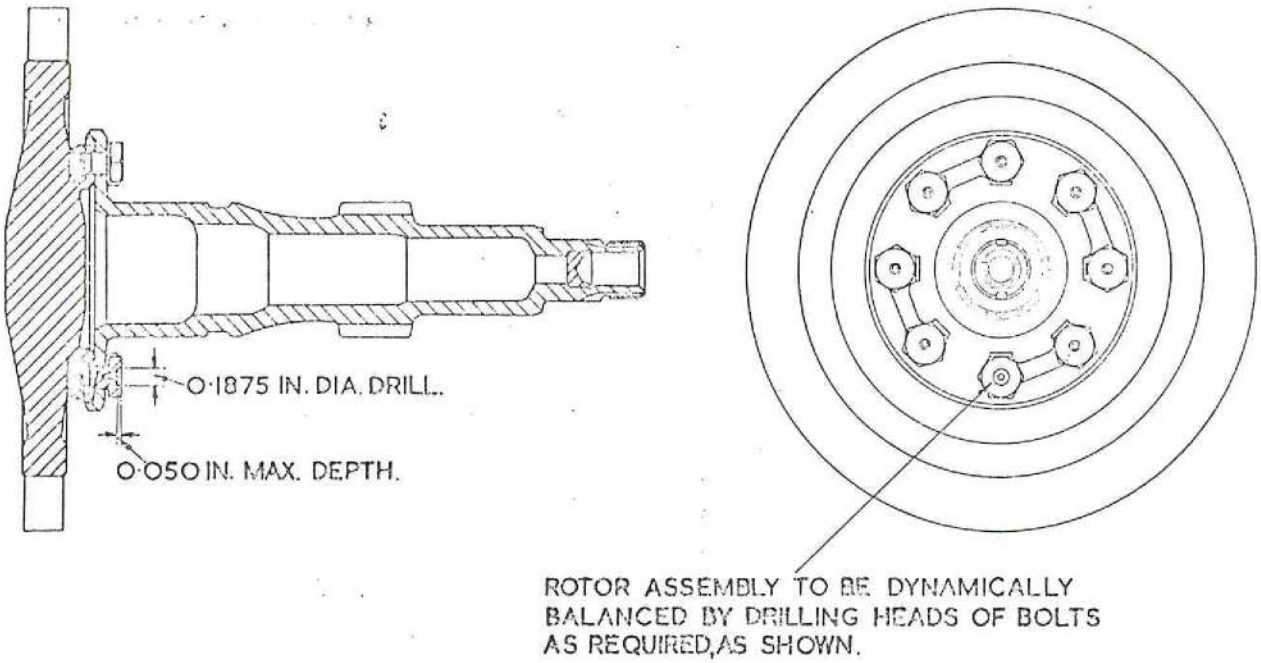


Fig. 1. Method of balancing rotor assembly

(2) Tighten the bolts and bend up the locking tabs against the inside flat of the bolt head in order to counter the effect of centrifugal force on the locking-tabs.

(3) Fit the assembly to an approved dynamic balancing machine and dynamically balance at a speed of 1,500 r.p.m.

Note . . .

The balance must be within the limit of 0·05 *oz. in. Should this not be attained, the appropriate bolt head or heads may be drilled as illustrated in fig.* 1 *to obtain the correct figure.*

(4) Remove the assembly from the balancing machine.

Assembling the idler gears

5. To assemble the idler gears to the end plate, proceed as follows:—

(1) Place the end plate on a suitable support to be made locally.

(2) Ensure that the planet gear ball bearings are perfectly clean and in good condition, then place the bearings into their respective housings.

(3) Fit the bearing washers and circlips.

Note . . .

Should it be necessary to fit a new end plate, the three dowels must be fitted so that they protrude from the face of the end plate within the limits of 0·150 *in. maximum to* 0·125 *in. minimum.*

(4) Press in the three idler gears so that the threaded portion of the gear shaft is fitted from the circlip side of the ball bearing.

(5) Fit a new cup type locking washer to each gear shaft and then the special nuts.

(6) Assemble the end plate to the holding fixture CX.135294 (*fig.* 2) locating the gears on the three pegs in the fixture.

Fig. 2. Tightening idler gear nuts

(7) Tighten the three nuts using spanner CX.135289 as illustrated in fig. 2.

(8) Lock the nuts by punching the cup-washers into two diametrically opposite slots in the nuts.

Note . . .

If a new bearing panel is required a new dowel must be fitted using fixture CX.154186 as illustrated in fig. 3. *In addition and before assembling the roller bearings, three new serrated inserts must be fitted to take the return mechanism set-screws. These inserts must be a tight fit in the bearing panel and the open end of the insert must be at least* 0·005 *in. below the adjacent surface.*

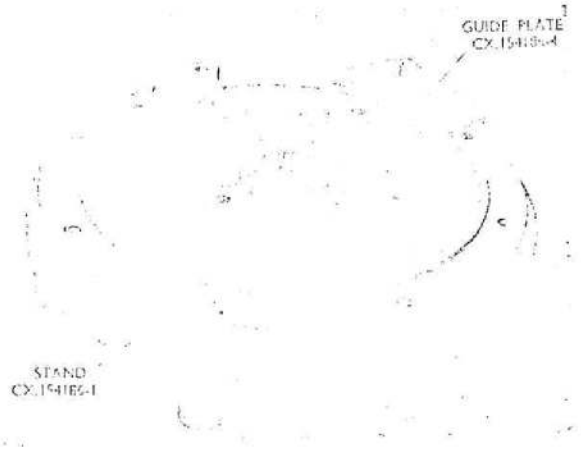


Fig. 3. Fixture for fitting dowel into bearing panel

(9) Support the bearing panel in fixture CX.154186-1.

(10) Ensure that the roller bearings are clean, then press the bearings into their housings using sleeve CX.133456-2.

(11) Fit the three bearing washers and circlips in the respective positions from which they were removed.

(12) Assemble the end plate with its gears to the bearing panel and gently tap together.

(13) Fit the six bolts (approx. $2\frac{3}{4}$ in. long) tab-washers and nuts, tighten the nuts.

(14) Check that the gears rotate freely in their bearings, and if satisfactory, lock the nuts.

(15) If binding is apparent, locate the cause and rectify before proceeding further.

Checking end float of rotor shaft rear sliding bearing

6. (1) Press the rollers into the cage. The rollers are a "snap-in" fit through the outside of the cage.

(2) Fit the cage with its rollers to the outer race, then the retaining washer and circlip.

(3) Using fixture CX.153068 (*fig.* 4) check that the end float on the rollers is within the limits of 0·002 in. maximum and 0·001 in. minimum. Ensure that the circlip is uppermost.

Note . . .

If the end float is outside the limits, select an appropriate thickness of retaining washer in order to obtain the correct end float.

(4) On completion of the test, dismantle the bearing assembly and keep the components together until final assembly.

Assembly of rotor shaft to bearing panel

7. (1) Fit the three long 'D' head bolts for the bearing panel through the holes in the aluminium rotor shaft seal, then place the seal over the rotor shaft and into its normal position.

(2) Assemble the packing washer on to the three bolts and slide into the recess in the shaft seal.

(3) Place the roller bearing cage in position over the rotor shaft track then carefully tap the rollers into the cage using a small copper drift.

(4) Fit the outer race, retaining washer and circlip.

Note . . .

If the rear sliding bearing sleeve has been disturbed, press it into position so that the oil hole corresponds with the oil hole in the bearing panel.

Note . . .

Should it be necessary to fit a new bearing sleeve, it should be selected so as to be a light press fit in the bearing panel.

(5) Assemble the exhaust deflector in position over the rotor shaft assembly so that the rear sliding bearing enters the sleeve and the three D head bolts pass through the holes in the bearing panel.

(6) Fit the rotor shaft front roller bearing to the end plate.

(7) Assemble tab-washers to the three 'D' head bolts, then fit and tighten the $\frac{1}{4}$ in. B.S.F. nuts and finally lock.

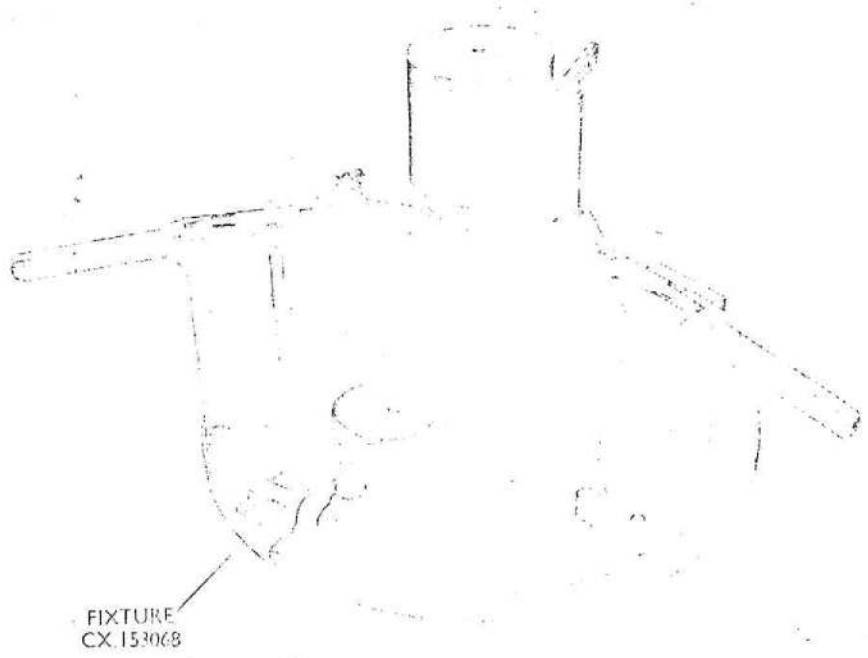


Fig. 4. Fixture for checking end-float on rear sliding bearing

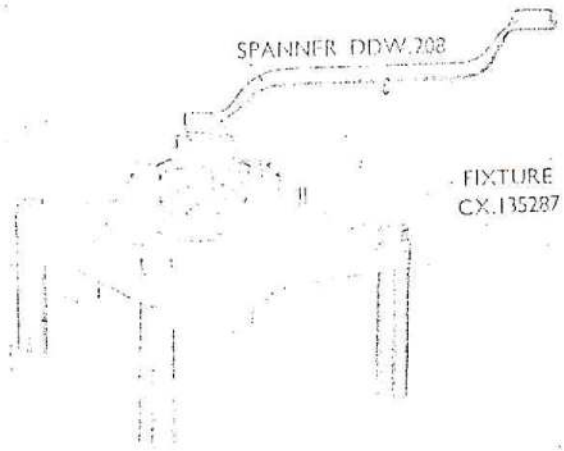


Fig. 5. Fitting the rotor shaft nut securing the thrust plate and bearing (rotor removed)

Assembling the rotor return mechanism

8. (1) Fit a phosphor-bronze seating ring on to each side of the rotor-return ball bearing, then place the assembly in the thrust plate: positioning the seating rings in the two slots in the thrust plate.

(2) Turn the assembly through 90 deg. then check that the assembly moves freely in the thrust plate seating.

(3) Obtain the correct thickness adjusting washer (*see para.* 9) and fit it to the end of the rotor shaft.

Note . . .

Adjusting washers are supplied in a range of thicknesses in order to obtain the correct axial clearance of the rotor to the gas nozzles.

(4) Fit the bearing panel assembly to the support stand CX.135287 (*fig.* 5) so that the idler gears are locked.

(5) Fit the three spring guide sleeves, the three springs, outer sleeves and dowelled guides. The outer sleeves must move quite freely over their whole travel.

(6) Place the correct thickness of spherical washer into the dished part of each of the three outer sleeves.

(7) Press the thrust plate on to the rotor shaft using sleeve CX.136456-2.

(8) Fit the packing-washer, cupped-washer and bearing nut. Tighten the nut using ring spanner DDW-208 (*fig.* 5) but do not lock the nut until the rotor axial clearance has been checked and found correct.

(9) Fit a stop plate on top of each of the three lugs of the thrust plate, then insert the three long bolts complete with their tab-washers through their respective holes in the thrust plate. Tighten the bolts, but do not lock them until the rotor travel and the rotor return mechanism spring loading has been checked as detailed in para. 9.

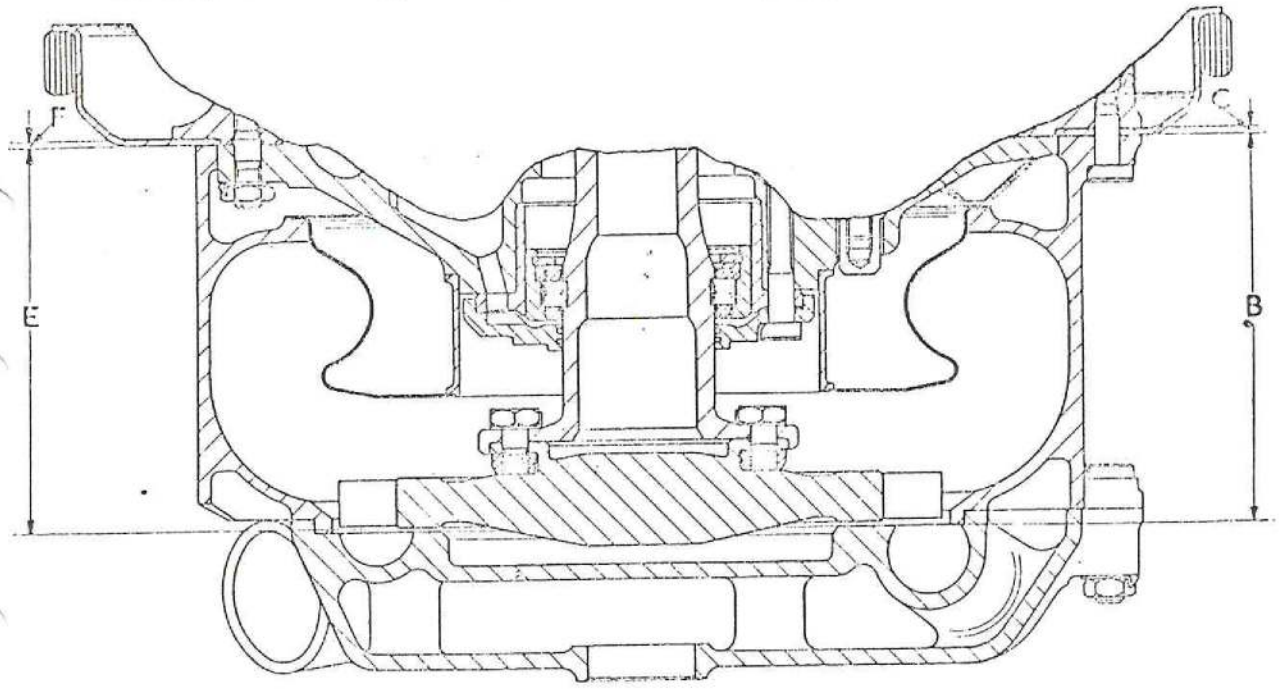
Note . . .

The stop plates are supplied in a range of thicknesses to obtain the correct rotor travel also the spherical washers in order to adjust the rotor return mechanism on spring loading.

Measurement and adjustment of rotor travel

9. Before proceeding with the following adjustment it is advisable to remove the rotor return springs.

(1) Fit the bearing panel to the support stand CX.135287 so that the rotor hangs vertically down.



Rotor shown in 'full-gas' position.

Fig. 6. Measurement of rotor travel (TBS 720, Mk. 2)

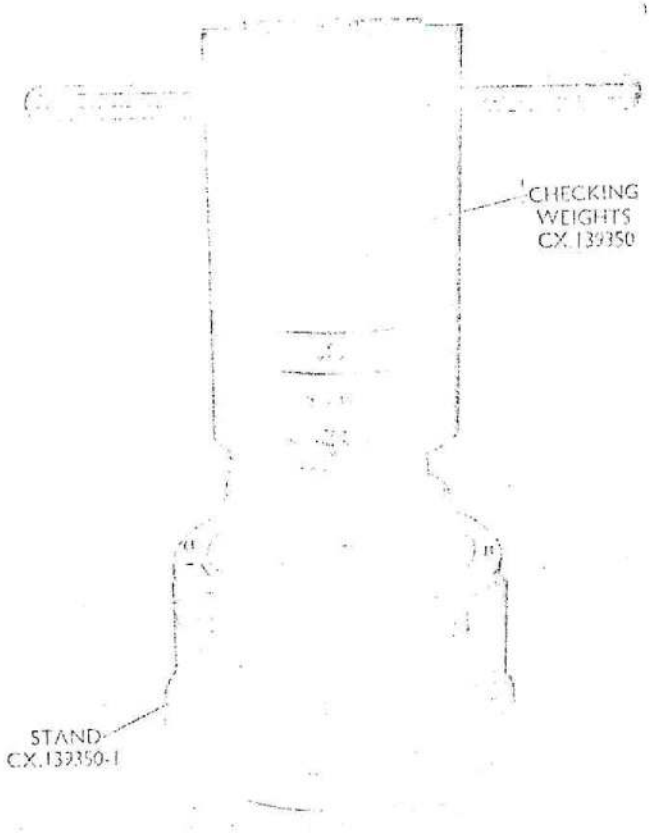


Fig. 7. Checking fixture for rotor mechanism spring loading

(2) Measure the distance from the rear face of the exhaust casing to the nozzle face of the inlet casing as shown in fig. 6 with both casings mated together and call this dimension " B."

(3) Measure the thickness of the fairing support ring flange and call this dimension " C."

(4) Add dimensions " B " and " C " and call it dimension " G."

(5) Measure the distance from the bearing panel clamping face on the support stand to the under face of the rotor adjacent to the blades and call this dimension " E."

(6) Measure the depth of the spigot in the gear casing which takes the fairing support ring and call this dimension " F."

(7) Add dimensions " E " and " F " and call it dimension " H."

(8) Subtract dimension " H " from dimension " G "; the resulting dimension being the axial clearance of the rotor to the inlet casing nozzle face when the rotor is in the " full gas " position.

(9) This clearance must be within the limits of 0·020 in. maximum and 0·010 in. minimum and may be obtained by the selection of suitable adjusting washers and packing washers when required.

(10) To measure the rotor travel, lift the rotor and check the travel by direct measurement. Any figure within the limits of 0·570 in. maximum and 0·520 in. minimum is acceptable. The actual setting on individual starters will vary according to the " no-load " speeds obtained during the acceptance tests.

(11) To adjust the rotor travel, stop plates of varying thickness should be fitted from the range provided.

Measurement and adjustment of rotor mechanism spring loading

10. Fit the assembly to checking fixture CX.139350 as illustrated in fig. 7. The total load which can be applied to the end of the rotor shaft without producing movement from the " out-of-gas " position should be within 28·0 lb. maximum and 22·0 lb. minimum. The rotor should complete its travel with an applied load of 75·0 lb. minimum. The foregoing checks should be repeated after depressing the rotor to its full travel position several times and any change in the results obtained will indicate excessive friction in the assembly. Particular care must be taken to obtain free movement throughout the full travel. The necessary adjustments can be made by fitting a different thickness of spherical washers from the range provided.

Assembling driving shaft, spherical bearing and annulus gear to gear casing

11. If a new gear casing is required proceed as follows :—

(1) Screw in the eight studs so that the longest length of thread is screwed into the casing and the remainder of the stud protrudes 0·550 in.

(2) Press a new ventilating disc into the casing and fit a new dowel which must be driven in as far as possible.

(3) Press the oil seal into the bearing housing using plug CX.135290 (*fig.* 8).

Fig. 8. Pressing the oil seal into the bearing housing

(4) Assemble the phosphor-bronze seating ring to the spherical ball race, then fit the ball race assembly into the seating ring slots and turn the race through 90 deg.

(5) Before pressing this ball race assembly on to the driving shaft, place the bearing housing locking-plate and adjusting washer over the driving shaft, ensuring that the locking-plate is correctly positioned.

(6) Using sleeve CX.136456-8, press the ball race assembly on to the driving shaft, then fit the locking washer and ring nut.

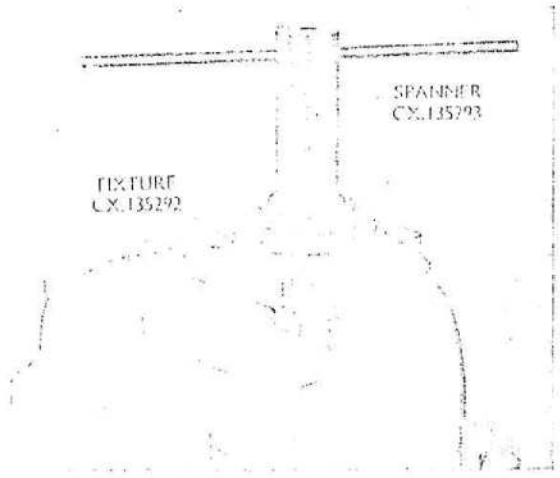


Fig. 9. Fitting self-aligning bearing nut

(7) Position the driving shaft in the holding plate CX.135292 (*fig.* 9) then tighten the bearing nut using spanner CX.135293 as illustrated in fig. 9. Bend up the tab of the locking-washer.

(8) Place the bearing-housing thrust ring in the bearing housing, ensuring that the ring is positioned correctly.

(9) Fit the driving shaft and ball bearing assembly into the bearing housing and press into position using oil seal guide CX.135291 (*fig.* 10) fitted over the end of the driving shaft to prevent damage to the oil seal.

(10) Secure the assembly in position with the four $\frac{1}{4}$ in. B.S.F. bolts which must be inserted from the inside of the gear casing together with tab-washers and nuts. Do not bend the locking tabs until the bearing axial clearance has been checked.

Fig. 10. Driving shaft assembly fitted with oil-seal guide prior to pressing together

Adjusting bearing axial clearance

12. To adjust the bearing axial clearance mount the bearing housing assembly on the fixture CX.136534 (*fig.* 11) and using the oil seal guide CX.136534-5 as described in para. 11 then proceed as follows :—

(1) Check the height between the fixture base and the underside of the bearing housing using slip gauges.

(2) Compare the foregoing figure with the height from the fixture base to the underside of the adjusting washer.

(3) The two figures when compared will enable the correct adjusting washer to be selected to give an axial clearance of 0·002 in. minimum and 0·004 in. maximum between the bearing outer race and the thrust ring.

(4) Place the annulus gear inside the gear casing and fit the gear on to the driving shaft.

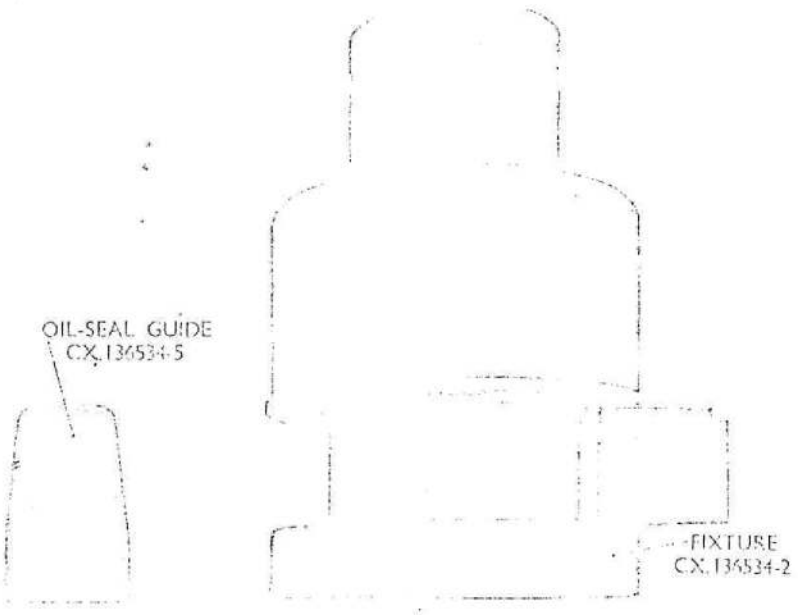


Fig. 11. Checking fixture for end-float of drive shaft bearing

(5) Fit the two semi-circular locating plates into the recess of the driving shaft so that the machined groove in the plates is facing towards the driving shaft.

(6) Secure the plates in position with the eight 2 B.A. screws and tab-washers and tighten them using a long tubular spanner, finally, lock the screws.

Assembling the bearing panel to gear casing

13. Before fitting the bearing panel to the gear casing, ensure that the rotor moves freely up and down, also make sure that the locating dowel is fitted to the gear casing and that the bearing panel is correctly located, then fit the eight tab-washers and $\frac{1}{4}$ in. B.S.F. nuts; finally locking the nuts.

Assembling the exhaust casing and fairing ring

14. Should a new exhaust casing be fitted, first screw in the six studs so that 0·375 in. of the thread length is in the casing then proceed as follows :—

(1) Fit the fairing ring and exhaust casing to the gear casing so that the hole in the fairing is aligned with the " milled out " portion of the exhaust casing.

(2) Secure the assembly in position with the seven short $\frac{1}{4}$ in. B.S.F. bolts tab-washers and nuts. Do not lock the nuts at this stage.

Note . . .

The remaining two holes are provided for longer bolts which also secure the firing lead socket bracket.

ASSEMBLING THE BREECH-END

Assembling breech base and pressure control valve

15. Should a new breech base be required, fit a new breech base stud. This stud must be inserted with the long thread end in the breech base so that its maximum length protruding from the adjacent surface does not exceed 1·375 in.

16. Before commencing to assemble the pressure control unit, check that the bore of the valve casing in which the valve is housed has been reamed to 0·625 in. minimum to 0·626 in. maximum diameter. If the valve has been lapped in its breech base housing, ensure that the valve and housing are perfectly clean and free of lapping compound.

17. Fit the valve into the valve casing then assemble the unit to the breech base so that the seating face of the valve meets the seating face of the breech base. Fit the adjusting washer which should be chosen from the range available in order to obtain the correct relieving pressure then proceed as follows :

(1) Fit the thrust peg, spring seating, inner and outer springs and the spring housing.

(2) Assemble the valve spring contractor tool CX.135288 (*fig.* 12) through the spring housing and screw in to compress the springs.

Fig. 12. Contractor tool for assembling the control valve

(3) For breech base marked No. 1 secure the spring housing to the breech base with the three D head bolts, then fit the tab-washers and nuts and lock the latter.

(4) For breech bases marked 2 and 3, secure each spring housing to its breech base with two D head bolts and one shouldered bolt, the latter being positioned in the hole nearest to the transfer tube seating. Fit tab-washers and nuts and lock the nuts.

(5) Remove the valve spring contractor tool and then test each assembly using fixture CX.153322 (*fig.* 13) as follows.

(i) Each valve must withstand a pressure of 1,000 lb. per sq. in. for a minimum period of one minute without showing any signs of leakage.

(ii) Each valve must be adjusted to open at a pressure within the limits of 1,205 lb. per sq. in. minimum and 1,230 lb. per sq. in. maximum.

Warning . . .

In the event of a valve having to be dismantled for adjustment, the contractor tool CX.135288 must always be used before attempting to remove the spring housing, as the springs are heavily loaded and failure to observe this precaution may result in injury to personnel.

Assembly of breech barrels

18. To assemble the breech barrels proceed as follows :—

(1) Assemble the locking rings and barrel retaining rings over the breech end of the barrel and in that order.

(2) If the firing lead socket connection has been removed assemble, as follows:

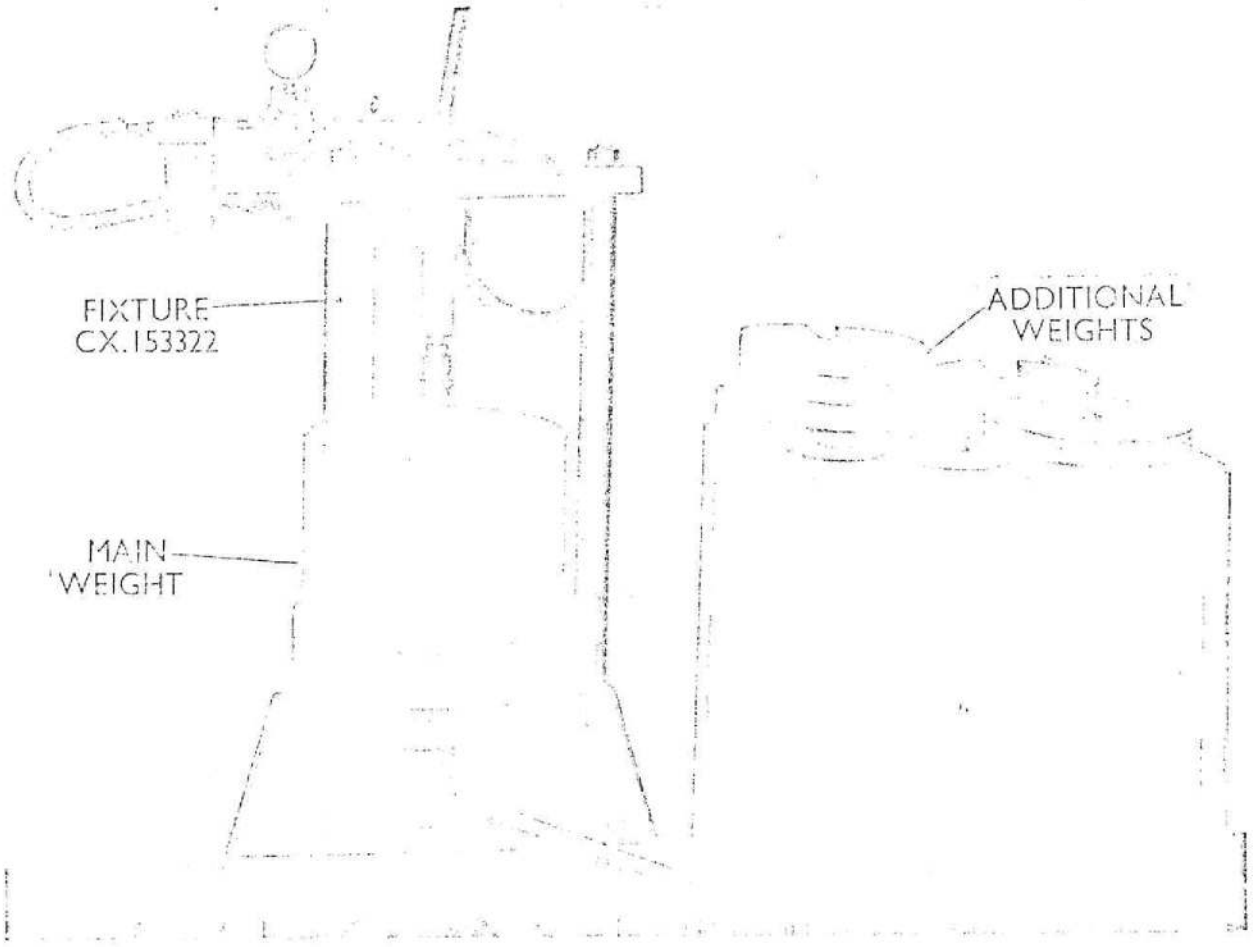


Fig. 13. Fixture for checking setting of control valve

(3) Using the 4 B.A. screw as a guide, fit the insulating channel to the screw and fit the other components in the following order.
  (i) The insulating bush.
  (ii) The contact assembly; such that the contact is opposite the opening in the contact spring support and faces towards the screw head.
  (iii) The contact spring backing spring. This spring must fit the contour of the contact spring assembly.
  (iv) The insulating washer and contact spring clamping pad; the recess in the clamping pad is located on the insulating bush.

(4) Remove the 4 B.A. screw and fit it complete with its tab-washer to the barrel housing, positioning the assembled components on the screw so that the contact is opposite the adapter.

(5) Tighten the 4 B.A. screws with spanner OIB.203 then lock with the tab-washer.

(6) Fit the split housings to the barrels so that the split housing assemblies marked CX.136361/1 are fitted to their original barrels and the split housing assembly marked CX.136362/1 is fitted to the other barrel.

(7) Fit a new rubber sealing ring to each housing.

(8) Secure each pair of split housings in position with two D head bolts, tab washers and nuts. Tighten the nuts and lock them.

Note . . .

When these nuts are tight the split housings can just be moved around the barrel.

(9) Position the breech base on the holding plate CX.135295 (*fig.* 14).

(10) Fit a copper joint washer in the breech base and screw in the appropriate barrel; tighten the barrel using ring spanner CX.139349 as illustrated in fig. 14.

(11) Fit the barrel locking-ring into the slots of the breech base and spring the retaining ring into position.

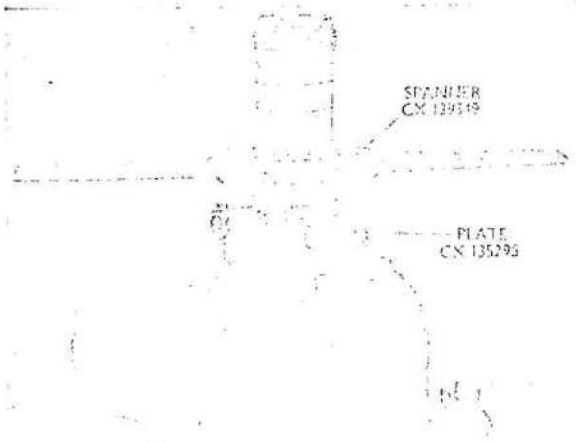


Fig. 14. Tightening the breech barrel

Assembling the breech units and inlet casing

19. If a new casing is to be fitted proceed as follows :—

(1) Fit the 2 B.A. studs with the long thread in the casing so that they stand proud of the adjacent surface by 0·300 in.

(2) Screw in the long thread portion of the three $\frac{5}{16}$ in. B.S.F. studs so that when inserted they stand proud of the adjacent surface by 0·950 in.

(3) Fit the twelve nozzle split sealing rings. There are two per nozzle and must be positioned so that the slots in the rings are opposite to each other.

(4) Fit the six retaining washers and circlips to the inlet casing and roughly position the six nozzle units.

(5) Fit the liners, care being taken to position the liners marked " A " in the " A " marked part of the breech base and the liners marked " B " in the " B " marked part of the breech base.

(6) Fit the correct liner support piece and secure in position with a breech base plug and tab-washer ; do not tighten the plug at this stage.

Fitting inlet casing to breech and barrel units

20. The sequence for fitting the inlet casing to the breech and barrel units is as follows :—

(1) Place the assembly block CX.153274 on the bench so that the boss marked with the fig. 3 is towards the front of the bench and the zero mark is on the left side.

(2) On the boss marked 3, place the barrel of No. 3 breech and barrel unit.

(3) Also place No. 1 and 2 breech barrel units on No. 1 and 2 bosses respectively.

(4) When assembled correctly, the view from the breech end of the assembly should be as shown in fig. 15.

Note . . .

Care must be taken to ensure that the split housing assemblies fit together in the correct sequence.

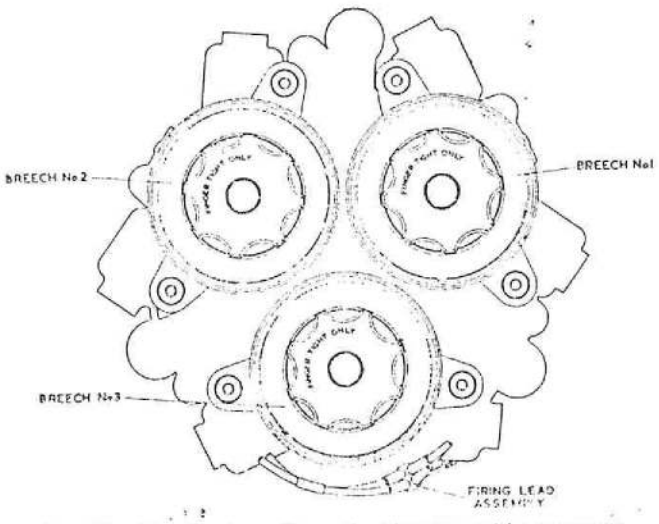


Fig. 15. Numbering of breeches for assembly purposes

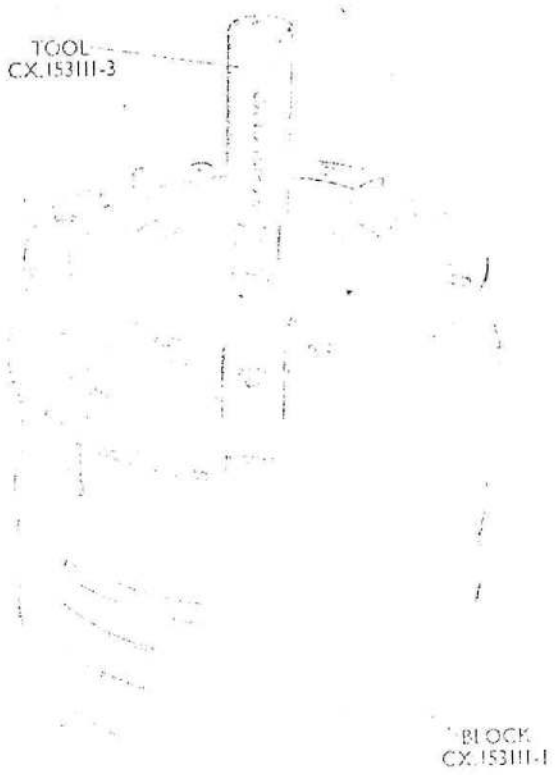


Fig. 16. Peening tool and block for breech-cap

(5) Fit a new nickel corrugated joint washer to each of the six breech base faces. It should be noted that these washers can only be positioned one way.

(6) Fit the inlet casing complete with the nozzles to the three breech units so that the 2 B.A. stud on the inlet casing is facing towards the zero mark on the assembly block.

(7) To each nozzle elbow, fit two $\frac{1}{4}$ in. B.S.F. set-screws together with the common locking plate.

(8) Through the breech base and the nozzle elbow, fit a 'D' head bolt also a tapered head bolt. The former bolt being nearer to the starter centre line in each case.

(9) Fit the common locking plate and nuts.

(10) Before tightening the nuts and set-screws, fit the six $\frac{5}{16}$ in. tab-washers and nuts to the studs, three of which project through the centre recess in the inlet casing.

(11) Tighten all the nuts and set screws and lock by bending up the locking tabs. It is important that these nuts and set-screws are tightened evenly to ensure a gas-tight joint.

(12) Finally tighten the breech base plugs and lock with the tab-washers.

Assembling the breech-caps

21. To assemble the breech-caps proceed as follows :—

(1) Anneal the aluminium inserts for two hours at 200 deg. C. this procedure will prevent the possibility of them cracking when the insulation bush is inserted.

(2) Fit the breech-cap to the peening block CX.153111-1 and press in the $\frac{3}{4}$ in. B. insulation bush using a suitable drift.

(3) Using tool CX.153111–3 peen the insert over the bush (*fig.* 16).

(4) Fit the insulated slip-ring and connection strip assembly to the open end of the breech-cap.

(5) Position the guard and the insulation strip where the connection strip passes through the slot in the breech-cap.

(6) Fit the channel shaped portion of the insulation in the breech cap slot which is situated at the bush and insert end of the breech-cap.

(7) Fit the headed bush through the connection block on the end of the connection strip assembly and secure it in position with the 5 B.A. screw, locking washer and plain washer.

(8) Place the firing pin bush in position and then insert the firing pin through the bush and into the breech-cap.

(9) Secure the firing pin connection strip to the connection block with the 7 B.A. screw and plain washer.

(10) Check that the firing pin connection strip is clear of the raised centre boss.

(11) Lock the connection strip by a spot of approved soft solder on the side of the 7 B.A. screw head.

(12) Using the barrel shroud as a stand, place the breech-cover with the handle downward through the smaller hole in the shroud.

(13) Fit the plunger, checking for freedom of movement.

(14) Fit the two operating buttons.

(15) Place the shorter pair of levers in the slots which are aligned with the buttons.

(16) Secure each lever in position with a fulcrum pin.

(17) Fit the second pair of levers and insert their fulcrum pins, then check that all four levers move freely.

(18) Assemble the following items in to the bore of the plunger. First the large washer then the guide. Place the small washer in the bottom of the bore of the guide and insert the firing pin spring.

(19) Position the breech cap on the breech cover which is supported by the shroud, then invert all the components and remove the shroud.

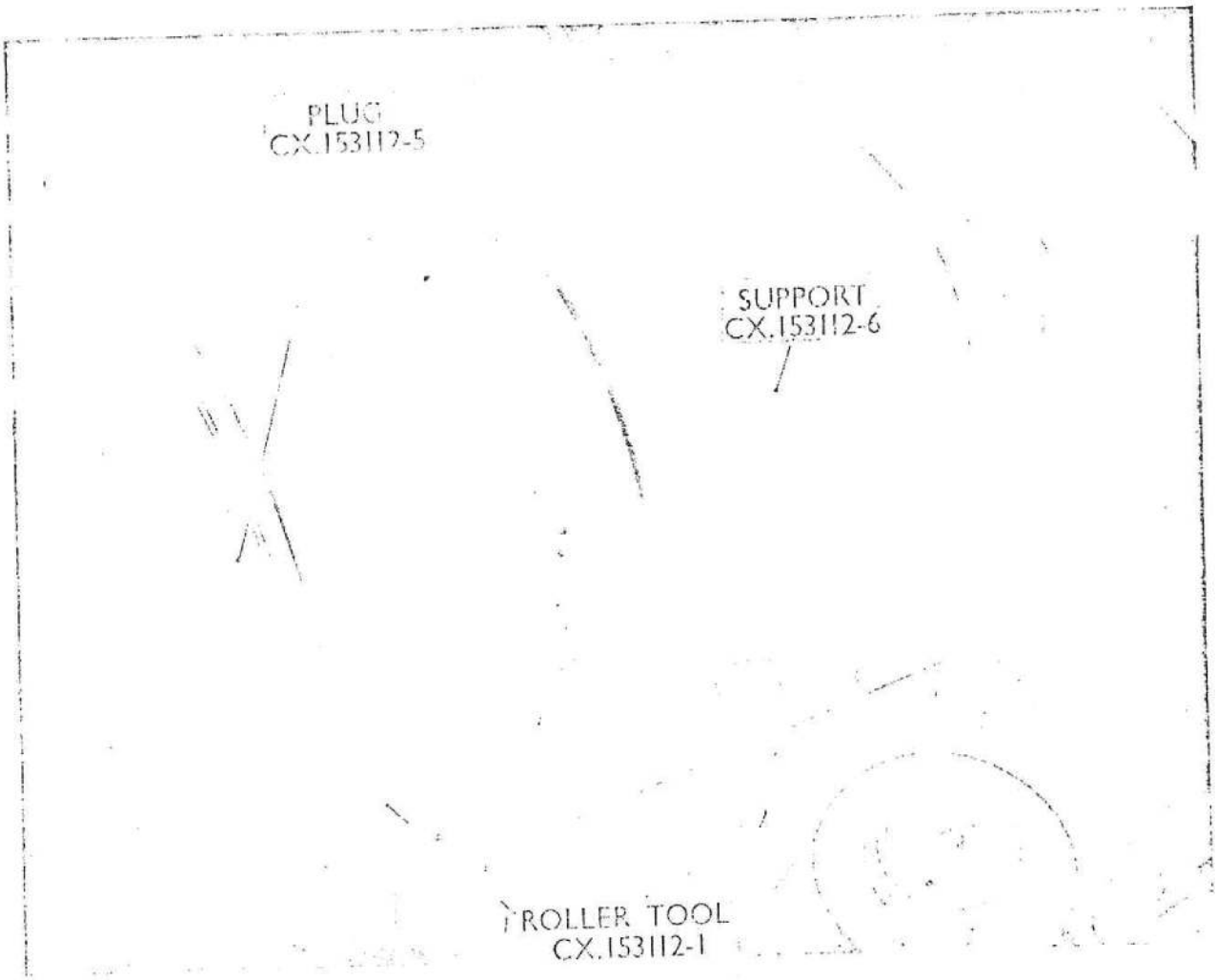


Fig. 17. Swaging fixture set up in lathe

(20) Secure the breech cover to the breech-cap with eight 2 B.A. screws which must be tightened and locked with tab-washers.

(21) Provision must now be made to retain the four lever springs in position while the shroud is fitted. Using a piece of $\frac{1}{2}$ in. wide feeler steel, bend it round so that it will slide over the breech cap and trap the four lever springs. After obtaining the correct diameter of the clip braze the two ends together to form a permanent tool.

(22) With the tool in position retaining the springs, push the shroud over the breech cap and over the lever springs thus pushing the tool off the springs. Remove the tool.

(23) Fit the retaining ring to the open end of the shroud ready for swaging the rim of the shroud over the ring.

(24) Check that all levers operate satisfactorily and check the insulation resistance between the slip ring and the cap body with a 500-volt insulation resistance tester (Stores Ref. 5G/1621). The insulation resistance must not be less than three megohms.

(25) Screw the breech-cap on to the appropriate part of the fixture CX.153112 (*fig.* 17), then place the fixture in a lathe. The assembly must then be rotated at approximately 200 r.p.m. the shroud being firmly held to the breech-cap by the outer portion of the fixture which is mounted on a rotating centre in the tail-stock. The roller tool CX.153112-1 which is mounted in the tool post is then applied to the rim of the shroud. This tool is designed so that with careful manipulation of the lathe feeds, a longitudinal as well as a radial pressure can be applied, thus allowing the shroud to be clenched tightly to the cap without buckling. The rotation of the lathe should be reversed during this operation otherwise the resistance resulting from the swaging tool may tighten the breech-cap on the threads of the fixture, resulting in difficulty in removing the finished breech-cap from the fixture. When a new shroud or other component has been fitted to the breech-cap assembly the insulation resistance between the slip ring and cap body must be checked using a 500-volt insulation resistance tester. The insulation resistance must not be less than three megohms.

FINAL ASSEMBLY OF THE STARTER

22. The final assembly of the starter is to be completed as follows :—

(1) Fit the three transfer tube assemblies into the breech-end unit and the exhaust casing assembly to this unit.

(2) Secure the two units together with the three $\frac{1}{4}$ in. B.S.F. and the three $\frac{5}{16}$ in. B.S.F. bolts and tab-washers.

(3) Ensure that the 2 B.A. stud in the inlet casing is approximately in line with the opening in the fairing ring, then check that the transfer tubes are free to rotate. Tighten the nuts, but do not lock at this stage.

(4) Fit the firing lead assembly by passing the three connector plugs, one at a time through the hole in the fairing ring and position the socket end of the harness to the two remaining holes.

(5) Secure the firing lead support bracket with the two long 'D' head bolts, fit the tab-washers and fit and tighten the nuts.

(6) Fit the three connector plugs to their respective sockets and then fit the lead clips, the conduit clip and the earth lead tag, under one of the lead clips. Fit the tab-washers and nuts to secure these components.

(7) Fit a breech cap to each barrel.

23. Should any of the starter supporting set-screws have been removed, due to damage, new screws may be fitted by clamping them with fixture CX.135526 as illustrated in fig. 18. These screws are assembled with plain and locking washers and secured in position in the starter flange with a spring ring.

Fig. 18. Fitting starter set-screws

Note . . .

External locking tabs must not be bent up or locking wire fitted until the starter has been assembled subsequent to stripping after acceptance tests.

ACCEPTANCE TESTS

General

24. The completed starter should be mounted on the test rig and primed with 200 cc's of engine lubricant (OX-38). The rig should consist of a flywheel, coupled in tandem with a 'Heenan and Froude' hydraulic dynamometer Type DPX2. The inertia load of the flywheel must be 256 lb. ft.^{2} and the brake sluices are set to absorb 60 H.P. The two loads, inertia and brake, simulate the engine inertia and compressor characteristics respectively during starting. A mounting flange for the starter reproduces the engine mounting and incorporates

the complete ratchet drive unit and spring drive assembly as fitted on the engine. Recordings are taken of the starter speed by means of a tachometer generator which is driven off the test stand. The gas pressures existing in the breech during the starting cycle are recorded by means of the Dobbie-McInnes type of indicator. The spent gases are ducted outside the test cell by exhaust pipes.

25. Make the necessary electrical connections and check the following :—

(1) The insulation resistance between the separate firing circuits and between each firing circuit and the casing must not be less than three megohms using a 500-volt insulation resistance tester.

(2) The continuity of each of the firing circuits and of the earth lead must be checked.

26. Cartridges of the current 720 grammes No. 10 type should be used and fired at the day temperature existing except where otherwise stated.

27. The interval between successive shots of the test should not be less than one minute.

Acceptance test

28. Six shots should be fired in rotation from the three breeches at the rate of three cartridges each half hour. The last three of these six cartridges are to be soaked at a temperature of +45 deg. C. for 12–24 hours immediately before firing.

29. Fire four cartridges in five minutes, the period to include reloading of the breech prior to the firing of the fourth shot.

Overspeed safety test

30. Fire three cartridges, one in each breech, with the test rig flywheels disconnected.

31. The maximum test rig speed for every cartridge fired and the pressure/time characteristics for cartridges No. 1, 4, 5, 6, 7, 10, 11, 12, and 13 must be recorded.

32. For cartridges No. 7 to 10 inclusive, the speed should not be less than 1,500 r.p.m.

33. For cartridges No. 11, 12 and 13, the speed should not be greater than 1,750 r.p.m. nor less than 1,250 r.p.m. If the lower speed condition is not met, the tests should not be stopped but adjustment should be made as in para. 37.38,

34. The maximum breech pressure observed for cartridges No. 4, 5 and 6 should be within the limits 4,125 lb. per sq. in. minimum and 1,250 lb. per sq. in. maximum, as a check on the operation of the pressure control valves.

35. If the pressure stipulated in para. 33 is not met, the original pressure settings are to be re-checked.

INSPECTION

36. The starter should be partially stripped for examination and if satisfactory should be assembled and submitted to a final test as detailed in para. 39 and 40.

37. If major parts have been replaced after the acceptance test as described in para. 28 to 35, the acceptance test must be repeated and the replacement parts examined before proceeding with the tests in para. 39 and 40.

38. Any adjustments required to meet the conditions of para. 32/33 should be made at this point.

Final test

39. If adjustment was carried out at para. 38 stage the overspeed test (*para.* 30) should be repeated and the conditions of para. 33 satisfied before proceeding as described in para. 40.

40. The test rig should then be loaded as described in para. 24 and one cartridge fired from each breech in rotation. The rig speed should not be less than 1,500 r.p.m. on each of these shots.

Note . . .

In the event of a speed of less than 1,500 *r.p.m. occurring during one of the three final test shots, provided that previous cartridges in this breech produced a speed in excess of* 1,500 *r.p.m., it is permissible to fire one additional cartridge through this breech. If the resultant speed is in excess of* 1,500 *r.p.m., the starter may be accepted.*

41. Where major parts, as listed below, have not been renewed, a relaxation of the acceptance tests is permissible and the number of shots to clear a starter reconditioned to this standard is reduced to nine ; and comprises three normal shots, three hot shots and three no-load shots, as follows :—

(1) Six shots to be fired as detailed in para. 28.

(2) Three shots to be fired as detailed in para. 30.

(3) The four shots as detailed in para. 29 are not required.

(4) The dismantling of the starter as detailed in para. 36, 37 and 38 and the final test of three shots after re-assembly, are not required.

LIST OF MAJOR COMPONENTS

Gear casing	CX.136797
Bearing panel	CX.122228
End-plate	CX.122231
Rotor shaft bearings ..	CX.122271 CX.122266 and CX.132180
Rotor	CX.136062 or CX.132958
Exhaust casing	CX.132095
Idler gear bearings	CX.122233 and CX.122236

Idler gear	CX.122235
Annulus gear	CX.122272
Driving shaft	CX.122274
Driving shaft spherical ball race	CX.122279
Inlet casing	CX.122313
Rotor shaft	CX.122290

42. Upon satisfactory completion of the test, remove the starter from the test rig, and lock all parts by bending up the locking tabs or by the use of 20 S.W.G. stainless steel locking wire D.T.D.189. Touch up the starter where necessary with an approved black air drying paint. The nameplate, modification plate and the heads of screws which secure these should be given two coats of approved transparent lacquer. Check that the breech base pressure tapping holes have been sealed with a screw and tab washer and have been correctly locked.

DESPATCH

43. To protect the starter spline drive, fit the protection sleeve CX.126754. To prevent moisture and foreign matter entering the starter, fit an outlet cover CX.132429 over each of the three stub pipes. Fit a protecting ring CX.132430 to the spigot and secure in position with two $\frac{3}{8}$ in. B.S.F. black finish hexagon nuts.

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Ref. No. on Diagram (1)	Part and Description (2)		Dimension New (3)	Permissible Worn Dimension (4)	Clearance New (5)	Permissible Worn Clearance (6)	Remarks (7)
1	ROTOR SHAFT IN FRONT SLIDING BEARING—ROLLERS ON SHAFT	Roller track—width	0·251 / 0·252	0·252	0·0008 / 0·0022	0·0022*	
		Roller—width	0·2498 / 0·2502	0·2498			
	ROLLERS IN OUTER RACE	End float	—	—	0·001 / 0·002	0·002	End float is adjustable
2	ROTOR SHAFT AND OUTER RACE	Total axial clearance	—	—	0·0018 / 0·0042	0·0042*	
3	FRONT SLIDING BEARING—DIAMETRAL CLEARANCE	Bearing sleeve—internal dia.	2·17500 / 2·17525	2·17525	0·001 / 0·002	0·002*	
		Outer race—external dia.	2·17325 / 2·17400	2·17325			
4	ROLLER BEARING—TOTAL DIAMETRAL CLEARANCE	Outer race—roller track internal dia.	1·8850 / 1·8855	1·8855*	—	—	*No wear permitted outside drawing tolerances
		Rotor shaft—roller track dia.	1·3840 / 1·3845	1·3840*	—	—	
		Roller—dia.	0·2499 / 0·2501	0·2499*	—	—	
		Total diametral clearance	—	—	0·0003 / 0·0017	0·0017*	

SCHEDULE 1—*Continued* TURBO-STARTER TYPE TBS.720

Ref. No. on Diagram (1)	Part and Description (2)		Dimension New (3)	Permissible Worn Dimension (4)	Clearance New (5)	Permissible Worn Clearance (6)	Remarks (7)
5	IDLER GEAR—ROLLER BEARING	Diametral clearance	—	—	0·0003 / 0·0013	0·0013*	
6	OUTER RACE IN BEARING PANEL	Bearing panel—bore	1·18080 / 1·18105	1·18105	Tight / 0·00030 / 0·00045 Clear	0·00045*	
		Outer race—outside dia.	1·1806 / 1·1811	1·1806			
7	IDLER GEAR—BALL BEARING	Diametral clearance between inner and outer races	—	—	0·0004 / 0·0006	0·0006*	*No wear permitted outside drawing tolerances
8	OUTER RACE IN ENDPLATE	Endplate—bore	1·31190 / 1·31215	1·31215	Tight / 0·00030 / 0·00045 Clear	0·00045* Clear	
		Outer race—outside dia.	1·3117 / 1·3122	1·3117			
9	REAR SLIDING BEARING—DIAMETRAL CLEARANCE	Assembled bearing—dia. under rollers	0·9810 / 0·9815	0·9815	0·00030 / 0·00105	0·00105*	Bearing cannot be dismantled
		Rotor shaft—roller track dia.	0·98045 / 0·98070	0·98045			
10	THRUST PLATE AND ROTOR SHAFT—TOTAL DIAMETRAL CLEARANCE	Thrust plate—spherical dia.	1·7500 / 1·7505	1·7505	0·0005 / 0·0015	0·0015*	
		Seating ring—spherical dia.	1·7490 / 1·7495	1·7490			

Ref. No. on Diagram (1)	Part and Description (2)		Dimension New (3)	Permissible Worn Dimension (4)	Clearance New (5)	Permissible Worn Clearance (6)	Remarks (7)
10	THRUST PLATE etc. —*cont.*	Seating ring—bearing locating bore	1·5745 / 1·5770	1·5770	0·0003 / 0·0027	0·0027*	
		Bearing—outside dia.	1·5743 / 1·5748	1·5743			
		Ball bearing—diametral clearance between inner and outer races	—	—	0·0009 / 0·0011	0·0011*	
		Total diametral clearance when assembled	—	—	0·0017 / 0·0053	0·0053*	
11	DRIVING SHAFT SPHERICAL BEARING	Ball bearing—diametral clearance between inner and outer races	—	—	0·0007 / 0·0009	0·0009*	*No wear permitted outside drawing tolerances
12	DRIVING SHAFT	End float	—	—	0·002 / 0·004	0·004	End float adjustable by washer
13	ROTOR SHAFT	Travel	0·520 / 0·570	—	—	—	Actual dimension determined during Acceptance Test
14	SPRINGS—ROTOR RETURN	Loading	—	—	—	—	See B.T.H. Drawing CX.137360

Ref. No. on Diagram (1)	Part and Description (2)		Dimension New (3)	Permissible Worn Dimension (4)	Clearance New (5)	Permissible Worn Clearance (6)	Remarks (7)
15	ROTOR	Dia.	5·705 / 5·709	5·709	—	—	Not to be reground
16	ROTOR TO NOZZLE	Clearance at full load position	—	—	0·010 / 0·020	0·010	Actual dimension determined during Acceptance Test
17	NOZZLE	Bore	0·265 / 0·267	—	—	—	Parallel portion of bore will collapse
18	NOZZLE INSERT	Bore	0·256 / 0·258	—	—	—	Ream out nozzle bore to insert size if necessary
19	ROTOR SHAFT—GEAR	Dia.	1·519 / 1·524	1·519	—	—	Check diameter over 0·125—0·0002 steel balls or rollers located in opposite or nearest opposite gaps
20	IDLER GEAR	Dia.	2·4228 / 2·4278	2·4228	—	—	Check diameter over 0·125—0·0002 steel balls or rollers located in opposite or nearest opposite gaps
21	ANNULUS GEAR	Internal dia.	5·663 / 5·670	5·670	—	—	

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