Chapter 1

Lucas Aerospace Type TBS-720 Mk. 2 turbo-starter

DESCRIPTION AND OPERATION

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Issued Nov. 73

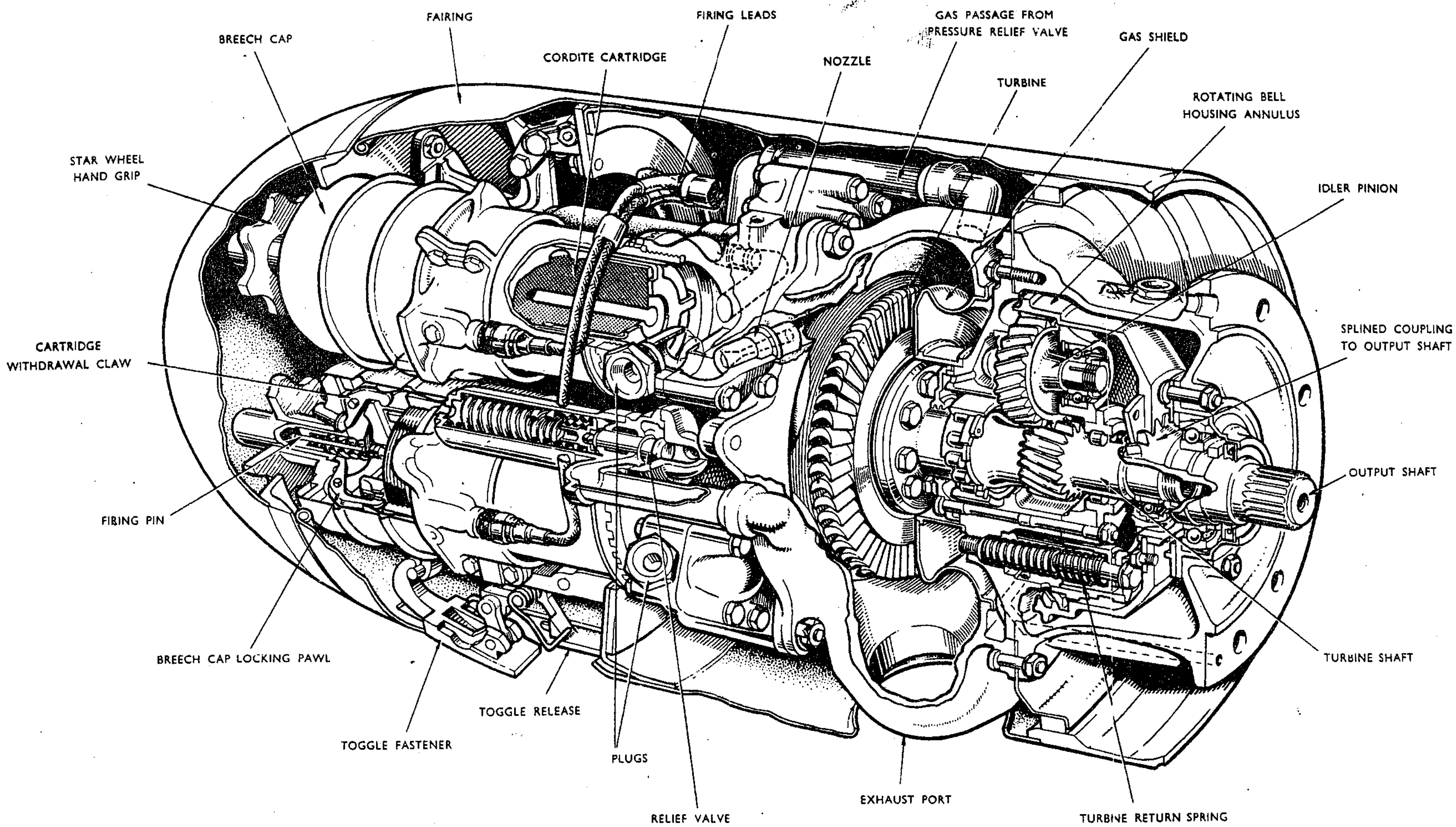


Fig. 1 Sectional perspective view of TBS-720 Mk. 2 turbo-starter

ILLUSTRATIONS (contd.)

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 40,000 rev/min and develops about 250 b.hp.

2. The drive from the turbine is transmitted through an epicyclic 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 lbf/in^2 by pressure relief valves and this in conjunction with the sliding shaft arrangement of the rotor, provides an overspeed prevention device.

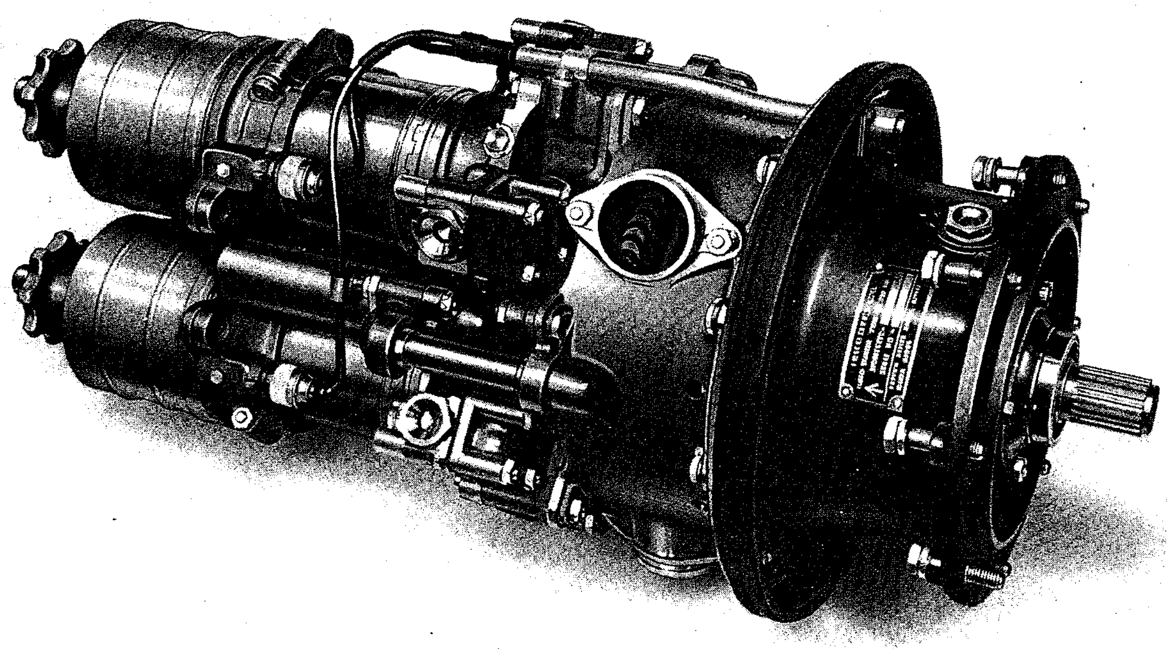


Fig. 2 Type TBS-720 Mk. 2 turbo-starter

DESCRIPTION

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 40,000 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 the aircraft supply by a bonded lead which plugs into 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.

6. The whole starter unit is enclosed in a fairing, the design and arrangement of which will vary according to the design of the aircraft and engine to 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.

Breech arrangement

8. 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.

9. 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.

10. 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

11. 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. 4). 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.

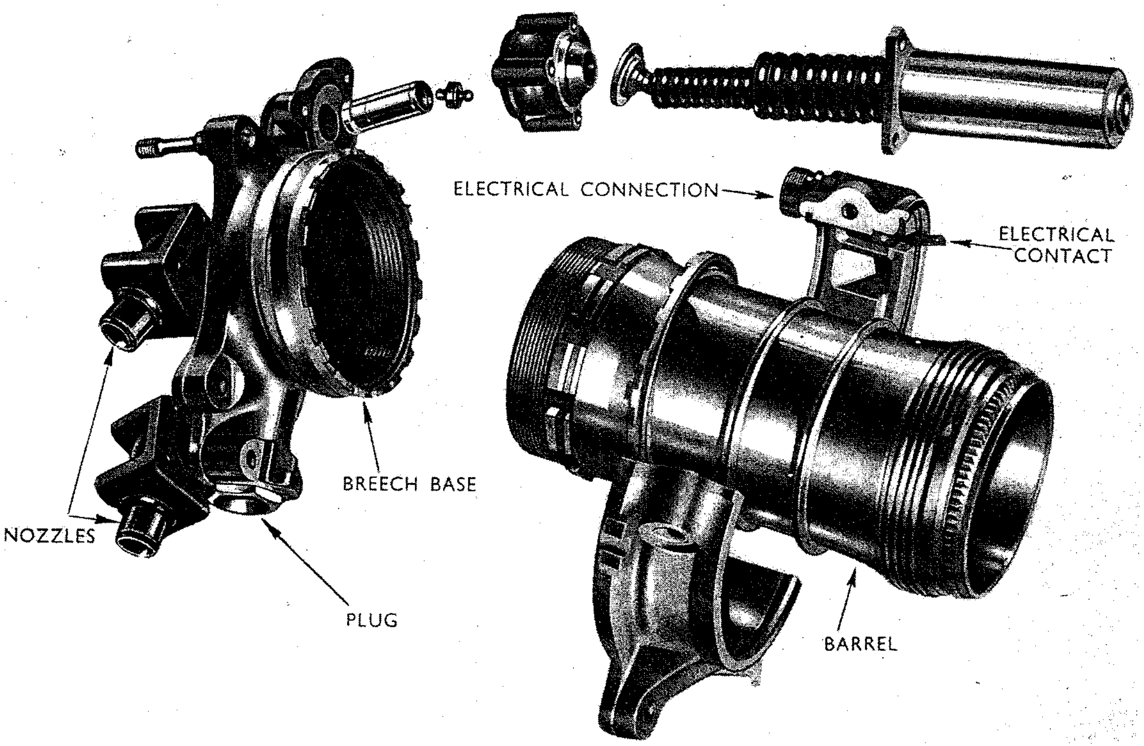


Fig. 3 Main components of breech assembly

12. 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

13. 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

14. 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.

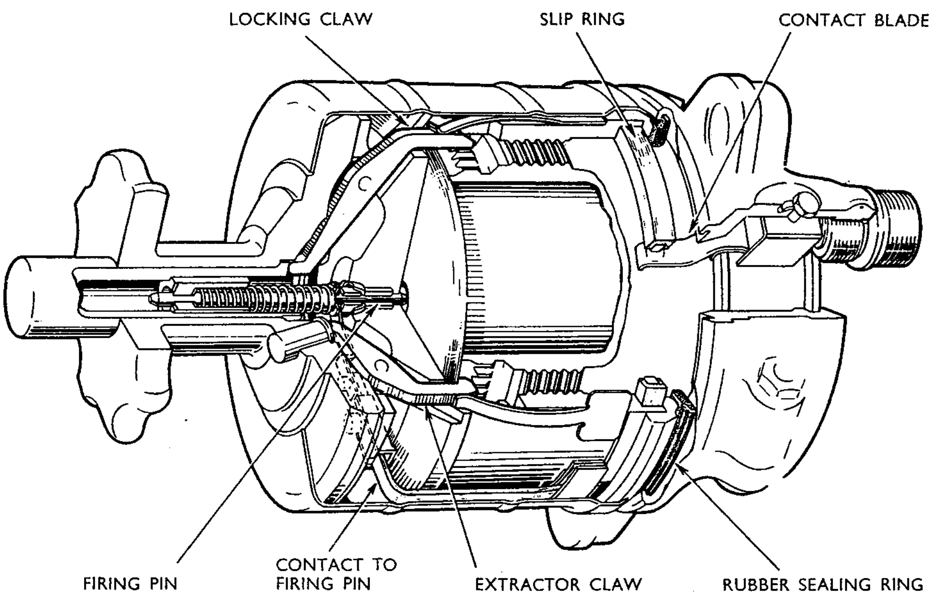


Fig. 4 Sectional perspective view of breech cap

15. 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

16. The breech mechanism is separated from the turbine and reduction gearing by the exhaust casing, illustrated in fig. 5. This is a heat-resistant

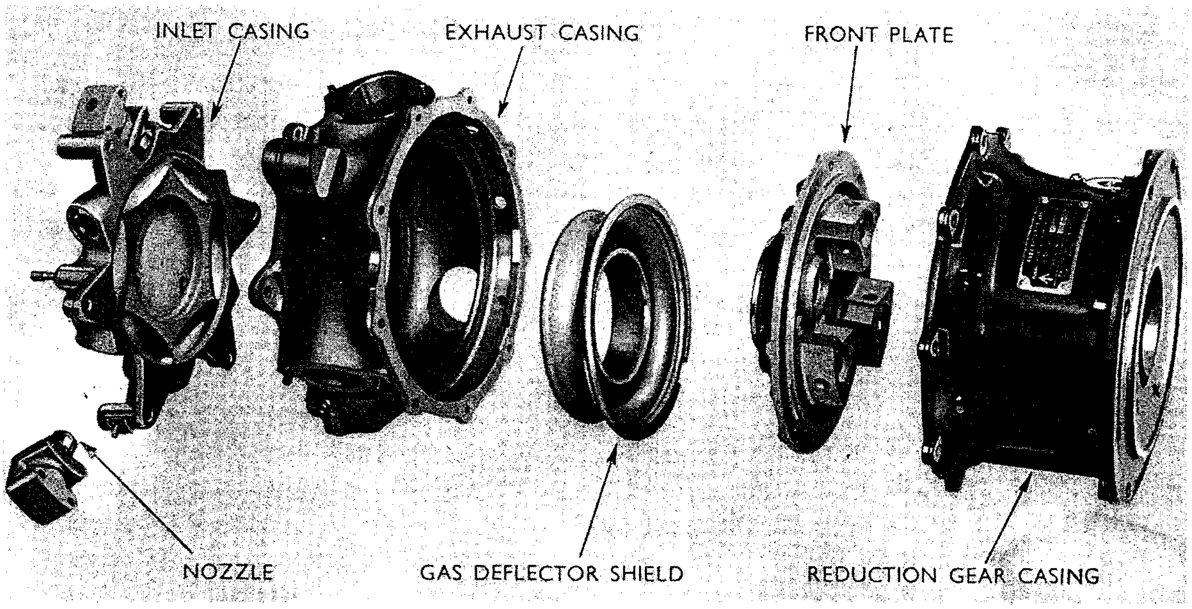


Fig. 5 Turbine and reduction gear casings

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.

<u>Pressure relief valves</u>

17. An important feature of the starter is the spring-loaded pressure relief valves which are shown in fig. 1 and 3. 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 lbf/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^o 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.

18. 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.

<u>Turbine wheel and shaft assembly</u> (fig. 6 and 7)

19. 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.

20. 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.

21. 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

22. 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.

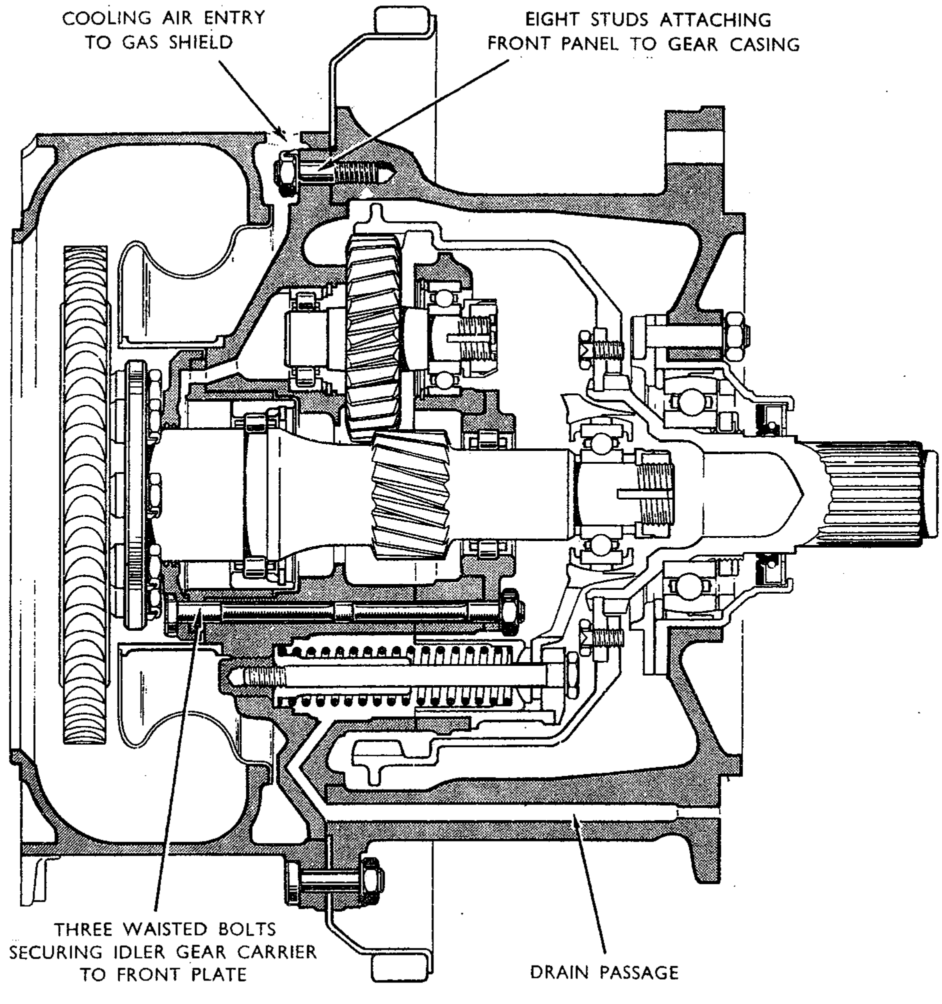


Fig. 6 Gear train assembly

Reduction gear (fig. 6 and 7)

23. 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.

24. 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 (fig. 7 and 8)

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

26. 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

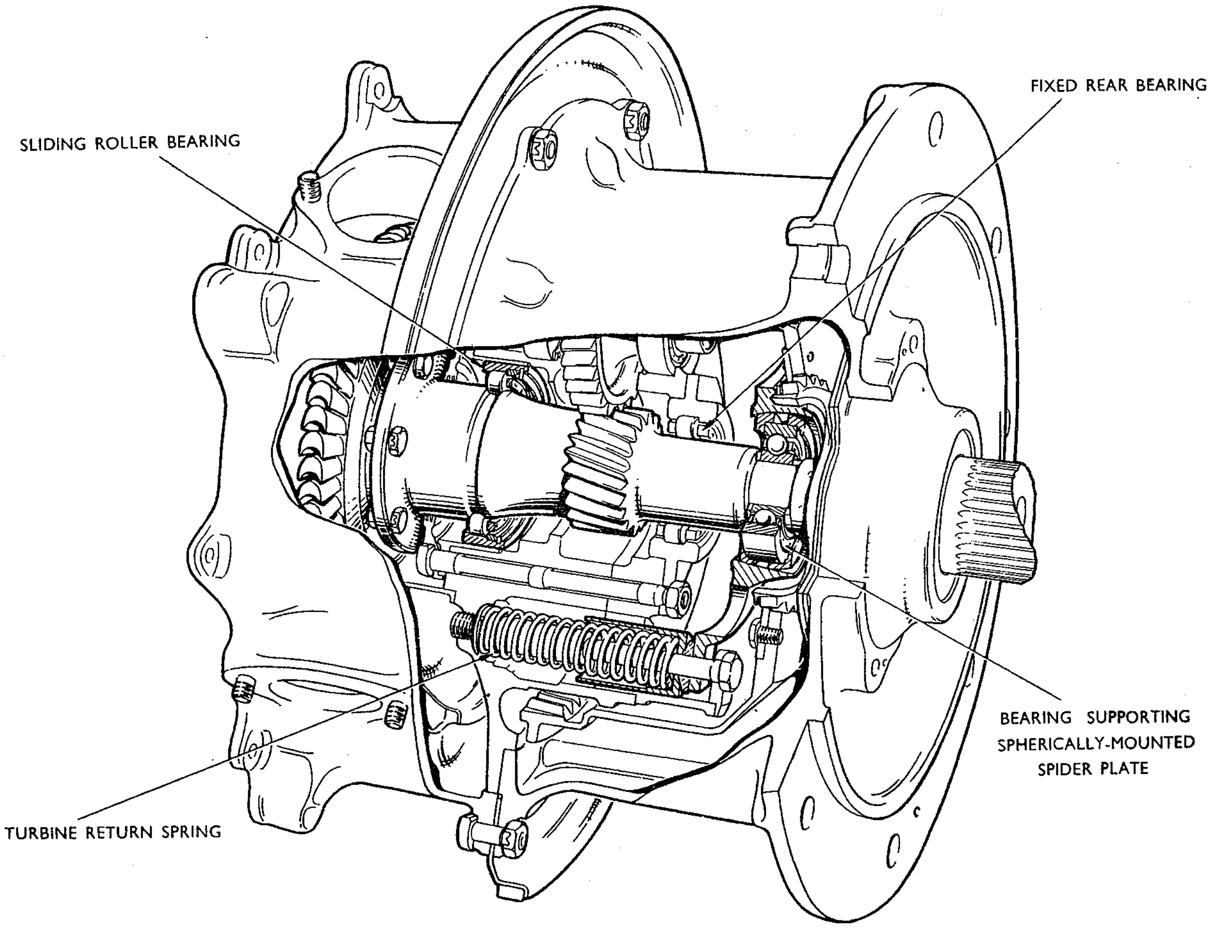


Fig. 7 Sliding turbine shaft and return spring

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).

27. 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

28. 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.

29. 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.

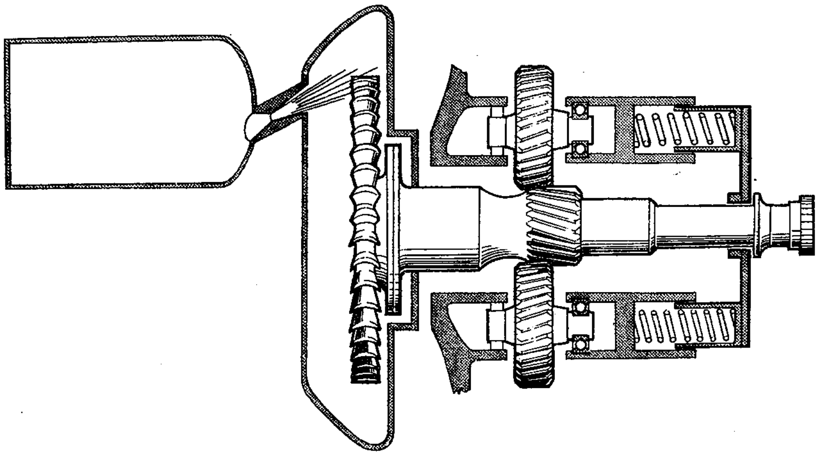
Gas pressure control

30. 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 lbf/in^2 the maximum speed of the starter is governed even under tropical conditions of operation where the burning time of the cartridges may be accelerated.

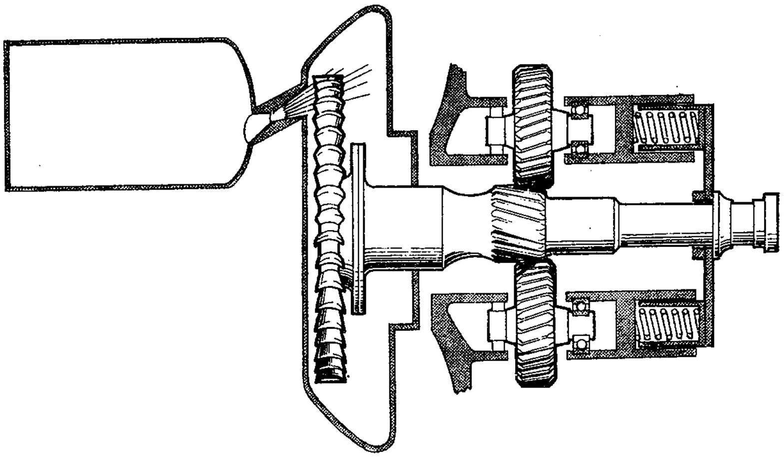
LUBRICATION

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

32. 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.



A. TURBINE UNDER NO-LOAD CONDITIONS



B. SPRINGS COMPRESSED AND TURBINE RECEIVING FULL TORQUE

Fig. 8 Diagrammatic illustration of torque control

33. This system ensures that on every start of the engine a shot of approximately 6 cm^3 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.

OPERATION

OPERATING CYCLE

Cartridges

34. The cartridge designed for use in the triple-breech starter consists of

approximately 720 g 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

35. 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.

36. 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

37. 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

38. 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 lbf/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.

39. 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 (fig. 9)

40. 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. 9 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.

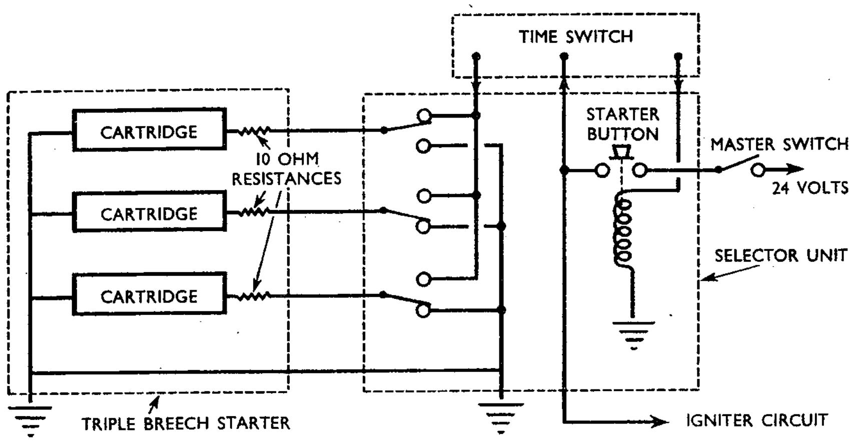


Fig. 9 Simplified electrical circuit

PREPARING FOR SERVICE

41. 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.

42. 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

43. 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 geat.

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

OPERATING INSTRUCTIONS

44. 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

45. 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 over-tightening may cause jamming and subsequent difficulty in removal after firing.

Unloading

46. Before attempting to reload the breeches refer to Warning, para. 47.

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

47. 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 OF 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 PRE-CAUTIONS LAID DOWN FOR THE HANDLING OF EXPLOSIVES.

Chapter 2

Lucas Aerospace Type TBS-720 Mk. 2 turbo-starter

SERVICING

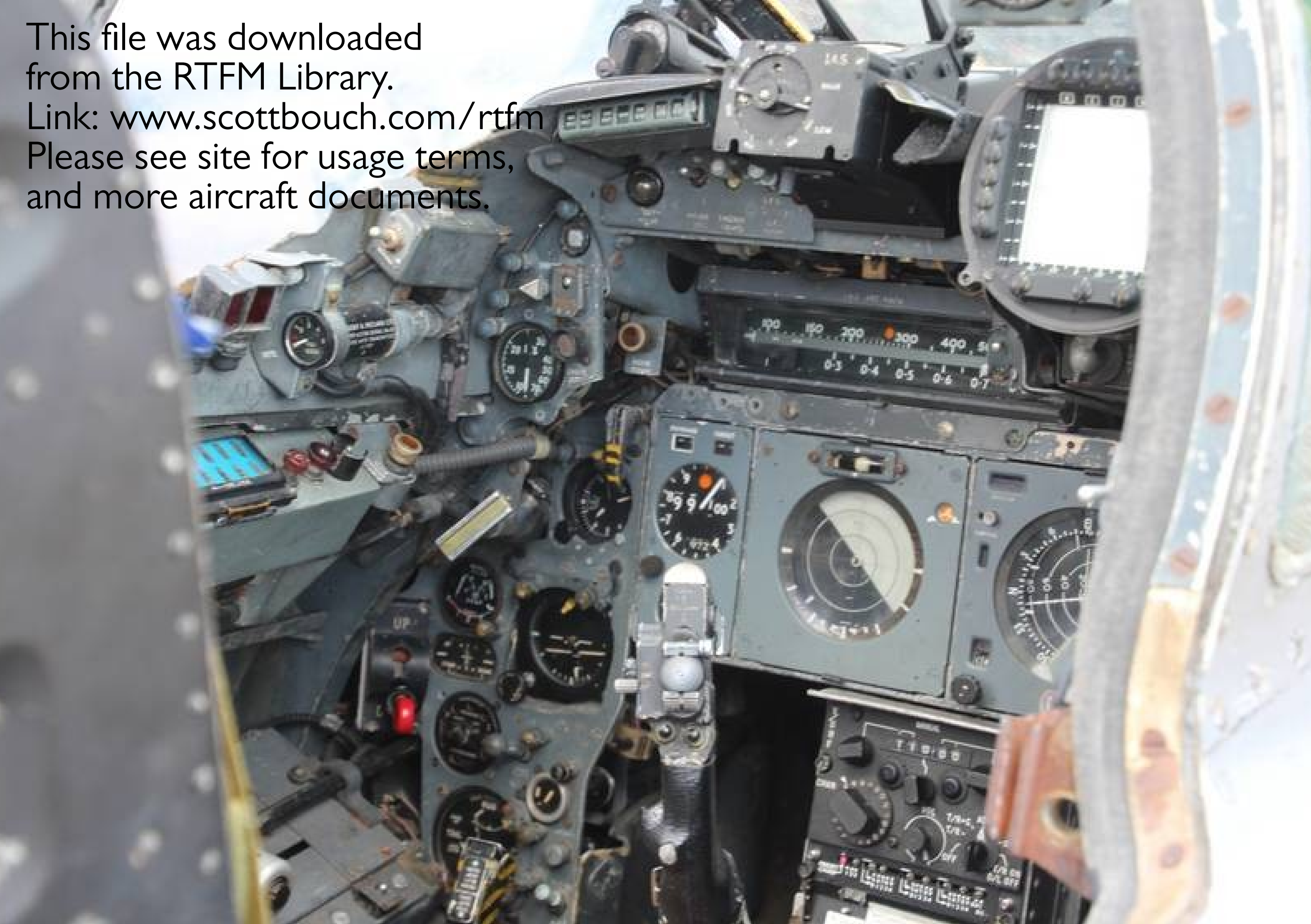
Very little servicing is required to keep the starter efficient; while the starter is attached to the engine, it is automatically supplied with oil from the engine oil pressure system. After approximately every 50 shots, the breech caps and contacts should be wiped clean and a light smear of graphite-grease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

Chapter 3

Lucas Aerospace Type TBS-720 Mk. 2 turbo-starter

FAULT DIAGNOSIS AND RECTIFICATION

	Fault	Possible cause	Action
(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 relevant engine change unit Air Publication, Topic (-1) and (-6).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