

Chapter 2

TYPE TSC.50, Mk. 3 and Mk. 4

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LEADING PARTICULARS

<i>Starter</i>	
<i>Type</i>	<i>Cartridge operated</i>
<i>Direction of rotation (looking at starter jaw)</i>	<i>Clockwise</i>
<i>Duration of start to engine idling speed</i>	<i>10 sec.</i>
<i>Installed weight</i>	<i>54.7 lb.</i>
<i>Lubrication (integral pump unit)</i>	<i>Two-stage spur gear type</i>
<i>Lubricant</i>	<i>Oil OM-13</i>
	◀ <i>Grease XG-275</i>
	<i>Grease XG-278</i>
	<i>Grease XG-285</i>
	<i>Grease ZX-13</i> ▶
<i>Safety disc Ref. No.</i>	<i>(Ref. No. CK.3251)</i>
<i>Turbine</i>	
<i>Type</i>	<i>Two-stage impulse</i>
<i>Speed</i>	
<i>Normal maximum</i>	<i>40,000 rev/min.</i>
<i>Overspeed operates at</i>	<i>52,000 to 60,000 rev/min.</i>
<i>Reduction gear</i>	
<i>Type</i>	<i>multi-stage</i>
<i>Ratio</i>	<i>4.34 : 1</i>
<i>Performance</i>	
<i>Output</i>	<i>60 h.p. at 9,200 rev/min.</i>
<i>Duration of working period</i>	<i>2 sec.</i>
<i>Breech</i>	
<i>Type</i>	<i>6-cartridge magazine</i>
<i>Indexing</i>	<i>Electrical</i>
<i>Firing mechanism</i>	<i>Simultaneous percussion of two-cartridge charge</i>
<i>Cartridge</i>	
<i>Type</i>	<i>170 g., No. 2, Mk. N.3</i>

RESTRICTED

INTRODUCTION

1. The Plessey turbo-starter, type TSC.50, Mk. 3 and 4, are identical except for the oil drain pipe, details of which are given in Sect. 2, Chap. 1, of this Air Publication. These starters, of which the Mk. 3 is illustrated in fig. 1, generate their power from a two-stage impulse turbine, rotated by high pressure gases liberated from the simultaneous combustion of two cordite cartridges. The gases are fed direct through two inlet nozzles to the blades of two contra-rotating rotors, after which the gases are collected in a volute of the rotor housing and exhausted to atmosphere.

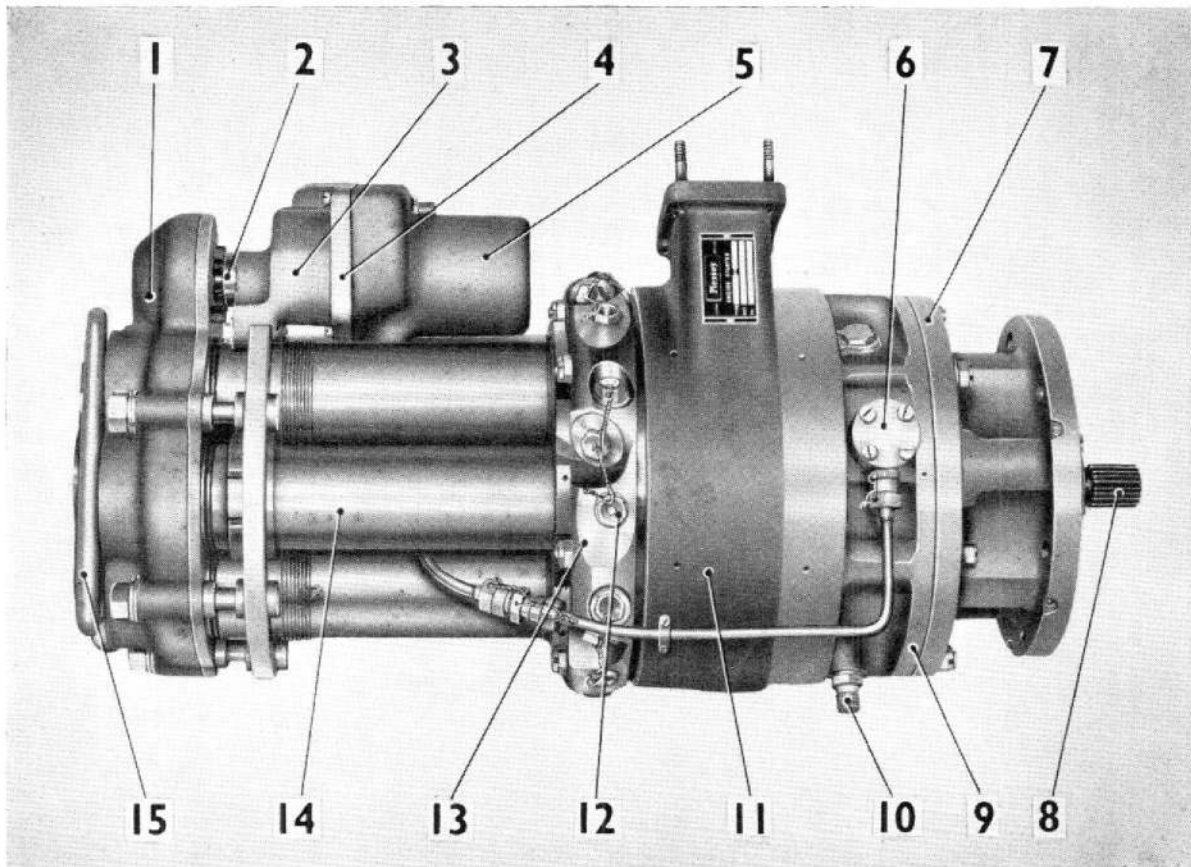
2. The burning time of the two-cartridge charge is approximately two seconds, producing an energy output of 64 000 ft lb. An output of approximately 60 h.p. is developed by the starter at a rotor speed of approximately 40 000 rev/min., giving an output shaft speed of 9200 rev/min.

With this energy output the starter provides a rapid and smooth acceleration which enables a start-to-engine-idling speed to be made in less than ten seconds.

3. The torque output of the high speed turbine rotors is transmitted to the starter drive shaft through a double reducing and combining gear train, and a torque limiting clutch.

4. A multi-shot breech is employed using six cartridges, fired in pairs, which provide three consecutive starts between loading. The breech is electrically indexed and the cartridges are percussion fired.

5. The pressure generated by the burning cartridges is of the order of 1100 lb/in². Bursting discs are fitted to protect the starter against excessive gas pressures.



- | | | |
|----------------------|--------------------------------------|-------------------------|
| 1 FIRING HEAD | 7 MOUNTING FLANGE AND CLUTCH HOUSING | 11 ROTOR HOUSING |
| 2 INDEX PIN WHEEL | 8 FINAL DRIVE SHAFT | 12 SAFETY DISC ASSEMBLY |
| 3 REDUCTION GEAR BOX | 9 INTERMEDIATE BEARING HOUSING | 13 NOZZLE BODY |
| 4 MOTOR PLATE | 10 OIL DRAIN | 14 BARREL ASSEMBLY |
| 5 MOTOR COVER | | 15 HANDLE ASSEMBLY |

Fig. 1. Plessey turbo-starter, type TSC.50, Mk. 3

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6. To prevent the turbine rotors over-speeding, an over-speed safety device applies a braking action to the rotors, and also prevents a further start being attempted should the rotor speed exceed a predetermined figure in excess of the normal maximum.

7. Two spur-gear type oil pumps in a common housing are driven from the starter reducing gear for circulating the lubrication oil to the rotor bearings and gear trains.

STARTER SYSTEM

8. The type TSC.50, turbo-starters are self-contained starting units mounted on the elbow of a Bendix engagement mechanism located on the engine wheelcase. The starter is set in action by a press button control located in the aircraft cockpit. When the button is pressed the indexing motor operates the firing mechanism which simultaneously fires a pair of cartridges. The products of combustion, in the form of high pressure gases (fig. 2), are directed at high velocity through nozzles on to the blades of the first-stage rotor, causing the rotor to turn anti-clockwise (when viewed from firing head end).

9. The gases acting on the first-stage rotor, are directed by the blade angle on to the blades of the second-stage rotor, causing this rotor to turn clockwise. The gases leaving this rotor are then exhausted to atmosphere through the exhaust port in the starter housing.

10. The effect of the high velocity gases impinging on the blades of the two contra-rotating turbine

rotors, gives then a speed of approximately 40,000 r.p.m. These two rotors are harnessed together, through a suitable two-stage reduction gear train, to a common drive shaft which is driven by them at a speed of approximately 9,200 r.p.m.

11. This turning force is transmitted to the final drive shaft through a multi-plate clutch, which absorbs peak loads during the initial engagement with the engine drive.

12. The clutch unit consists of a set of alternating steel and friction plates enclosed in an outer housing. The friction torque between the two sets of plates transmits the drive to the final drive shaft and thence to the engaging mechanism on the engine, a description of the engaging mechanism is contained in the relevant aero-engine Air Publication, Volume 1, Part 2.

13. Upon engagement of the starter to the engine, the inertia resistance of the engine results in the starter clutch slipping about one third of a turn, after which slipping ceases and the engine is accelerated to approximately 1,700 r.p.m.

14. The electrical circuit used in the starter for the indexing operation and the overspeed safety device is fed from the normal aircraft supply.

15. The two spur-gear type oil pumps in a common housing are driven from the starter reducing gear and effect lubrication of the rotor bearings and gear trains. Oil is drawn from the sump of the engine lubrication system.

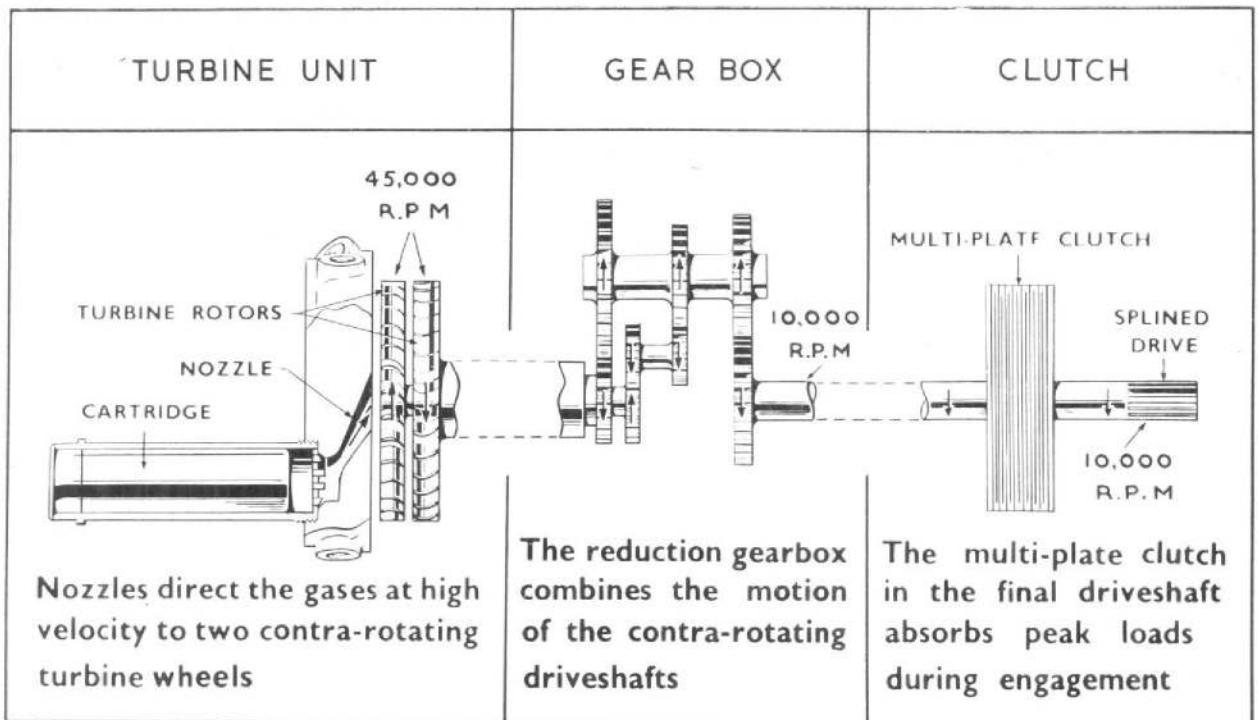


Fig. 2. Principle of the turbo-starter

16. To convey the exhaust gases to atmosphere, a pipe is secured to the exhaust port of the starter, terminating flush with the outer face of the engine cowling, or at some other point conforming to the design of the aircraft.

17. A full description, and the servicing and minor repair of the starter is contained in Section 2, of this Air Publication, and information on the application of the starter to aircraft and engine combinations is given in Chapter 1 of this section.

BREECH

18. The breech comprises three assemblies, the firing head assembly, the indexing gearbox assembly, and the nozzle body assembly (including barrels). The breech is attached to the starter body by studs located on the rotor housing, and is secured by castellated nuts and split pins.

19. Six barrels are screwed into the nozzle body (fig. 3). A grid is located between each barrel and the nozzle body, and serves to prevent the cartridge charge moving forward into the nozzle body during

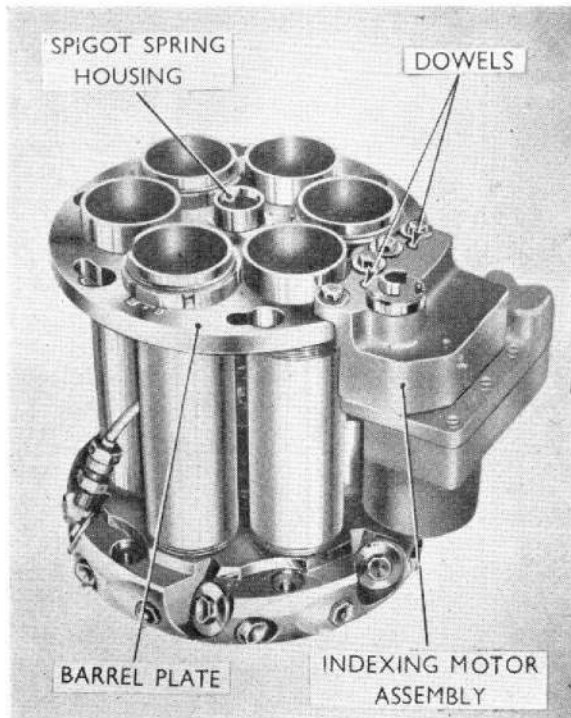


Fig. 3. Breech and nozzle body

combustion, thereby reducing the possibility of damage to the rotor blades which may result from the incursion of extraneous solid matter in the high velocity gases.

20. A barrel plate fits over the barrels at their top end, and is retained by three ring nuts and tab washers which lock No. 2, 4 and 6 barrels. The indexing motor and its associated gearbox housing is located by dowels and attached with bolts to this barrel plate.

Note re-interchangeability of firing heads

The firing head may be used on another starter only after carefully checking that the geneva wheel engages correctly and that the head can be removed and

replaced satisfactorily. If necessary the indexing gearbox should be re-dowelled in a new position to suit the new condition.

For full details of positioning and dowelling see Sect. 2, Chap. 2, Para. 95.

21. The firing head is positioned on the barrel plate by five studs, which have their shanks located through the slots in the barrel plate. The heads of the studs fit into recesses on the underside of the barrel plate and lock the firing head in the firing position. A spigot spring, housed in the barrel plate and in compression against a spigot on the firing head front plate, causes the stud heads to bear firmly in the recesses, thus preventing any tendency for engine vibration to rotate and unlock the head.

22. Contained in the firing head is the firing mechanism which is actuated by a geneva wheel driven by the indexing motor. The sealing pad retracting mechanism is manually operated by using the handle fitted on the firing head. This mechanism enables the sealing pads and firing pins to be lifted clear of the cartridge caps and thus permit rotation of the firing head when removing.

23. The selecting of the firing pins and the firing of the cartridge percussion caps form part of one complete indexing cycle. The firing gears operate the firing hammer assemblies to "cock" and release two of the six firing pins simultaneously in the following order, No. 1 and 4; 2 and 5; 3 and 6.

CARTRIDGE

24. The cartridge specified for use in this starter is the No. 2, Mk. N3, 170 grm. percussion-fired type. Under no circumstances may any other type of cartridge be used, unless it has been officially approved. If the wrong type of cartridge is used, damage to the starter and engine may result.

25. Details of the construction of the cartridge and the components used in the charge are given in A.P.1661F, Volume 1.

GAS SEAL

26. The cartridges, which are normally an easy fit in the barrels, effect an automatic gas seal when they are fired. The back pressure of the gas forces the cartridge head hard against the sealing pad and expands the shell of the cartridge so that it fits tightly in the barrel.

GAS FLOW

27. The high pressure gases, generated by the products of combustion, are ducted through passages in the nozzle body and nozzle plate. The convergent-divergent shape of each gas passage results in the gases acquiring a high velocity in which state they are directed, at a suitable angle, on to the blades of the first stage rotor, causing it to rotate anti-clockwise when viewed from the breech end. The angle at which the gases leave the first stage rotor blading is such that they proceed directly on to the blading of the second stage rotor, causing it to rotate clockwise. When the gases leave this rotor they enter the volute in the rotor housing from whence they are exhausted through the exhaust port in the outer casing to atmosphere.

SAFETY DEVICES

28. The starter unit is fitted with two independent safety devices, the safety disc assemblies and the overspeed device, each being functionally different in their operation. The first consists of six safety disc assemblies which limit the build-up of excessive gas pressure following the ignition of the cartridge. The second limits the degree of overspeed which the starter would reach if operated against a light or zero load.

29. Should the overspeed device operate, the starter must be removed from the aero-engine for dismantling, partial replacement of the overspeed unit and checking of the clutch assembly.

PREPARING FOR SERVICE

30. Before the starter is mounted on the aero-engine all protective material and rubber blanking caps must be removed. Detailed instruction for installing the starter on the engine are given in the relevant aero-engine Air Publication, Vol. 1, Part 2.

OPERATION

31. Instructions for starting any specific engine will be found in the relevant aero-engine Air Publication. A start should normally be obtained, if the engine is in good running order, with the simultaneous combustion of a two-cartridge charge. When difficulty in starting is experienced, a check should be made for possible engine faults.

32. The starter is operated by depressing the firing button located in the cockpit of the aircraft. The engine controls should be set prior to starting as the subsequent cycle of operations is too rapid to allow further adjustment. Should starting trouble be experienced, reference should be made to the Fault Diagnosis Chart given at the end of this chapter.

33. The electrical circuit in the engine forms part of the starting control system, a description of which is given in the relevant aero-engine Air Publication, Vol. 1. The function of the system is to control the starting cycle of the engine and to protect the starter by means of the following protective devices:—

- (1) After one pair of cartridges has been fired, at least 15 seconds must elapse before a second pair can be fired. This allows for the possibility of a delayed cartridge ignition.
- (2) No starts can be made when the engine is rotating at a speed greater than 400 rev/min.
- (3) Only one start can be made for each depression of the starter button. Thus, if the starter button sticks in the ON position, only one start is made and the button must be released before further starts are possible.

Warning . . .

- (1) *All personnel must keep clear of the engine air intake when an engine is about to be started.*
- (2) *If the charge fails to ignite, or one of the cartridges fails to fire, wait one minute before unloading.*

(3) *If repeated starting attempts are necessary, the following firing rate should be observed:—*

With a cold starter, the first 3 pairs of cartridges may be fired within a period of 5 mins. Further cartridges should be fired at not more than 3 pairs in 30 minutes, incl. loading time, to provide adequate cooling time between breech load.

(4) *When it becomes necessary to work on, or to check the electrical circuits, ensure that the breech does not contain a live cartridge.*

(5) *If the safety disc ruptures, do not fire another cartridge until a new disc has been fitted. Should a cartridge be fired on an open system (disc burst) it will produce inefficient combustion of the charge resulting in low pressures and excessive carbon deposit.*

(6) *A sudden reduction of breech pressure caused by failure of the safety disc may result in extinction of the charge. If it is suspected that a cartridge charge has failed to burn completely, wait until it is certain that no further burning is taking place, then remove the cartridge and check whether any of the charge remains. If a residue exists, the cartridge must be disposed of in accordance with the safety precautions laid down for the handling of explosives.*

Loading the breech**Warning . . .**

The following instructions for loading the breech must always be carefully carried out, and on no account must the firing head be forced on the starter during these operations. If seizure or stiffness of the head on the barrel plate or of the handle assembly in the head occurs during the loading operations, the cause must be located and rectified before the loading operations are continued. Incorrect fitting of the firing head can result in damage to the starter.

34. For the purpose of the subsequent loading drill, the starter is assumed to be empty of cartridges and to have the firing head correctly assembled and locked. To load the breech, proceed as follows:—

- (1) Lift the two handles on the firing head (14, fig. 1) into a vertical position.
- (2) Depress the handle assembly as far as possible and turn it in an anti-clockwise direction until it is felt to come against the pin stop. The firing head must not move during this operation. Now depress the head to disengage the head studs from the recesses on the underside of the keyhole slots in the barrel plate. Turn the firing head in an anti-clockwise direction until the heads of the studs line up with the holes in the barrel plate.
- (3) Remove the firing head by lifting it vertically off the starter.
- (4) Examine the barrel and remove any carbon or residue from the previous charge, using approved cleaning brushes. Insert into each barrel a new cartridge, pressing it hard down until the lip of the brass cap contacts the top of the barrel. If any cartridge is excessively

tight DO NOT use undue force to get it into the barrel. Suspected oversize cartridges (swollen by damp), or a cartridge that is tight in the barrel and will not go right home should be removed and another cartridge fitted.

Note . . .

The firing head must never be forced on the starter under the impression that the firing pads will push the cartridge right home; this action will only result in a damaged head.

- (5) Before attempting to place the head on the starter, ensure that the handle assembly has been turned fully anti-clockwise and that it has "clicked" upwards approximately $\frac{3}{32}$ in., and is therefore in the locked position with the sealing pads and firing pins in the retracted position.
- (6) Locate the firing head over the starter so that the index pin wheel, viewed from above, is just to the right of the geneva wheel, and position the stud heads over the holes in the barrel plate.
- (7) Grip the firing head as shown in fig. 4, enter the heads of the studs into the holes in the barrel plate, pushing well down against the spigot spring loading, and WITHOUT depressing the handle assembly, turn the firing head in a clockwise direction as far as possible. Ensure that the heads of the studs click up into position in the recesses machined on the underside of the barrel locking plate. Check this by attempting to turn the firing head, first in one direction and then the other. Do not use the handle assembly for this operation otherwise the sealing pads may be inadvertently brought forward before the head is properly located.

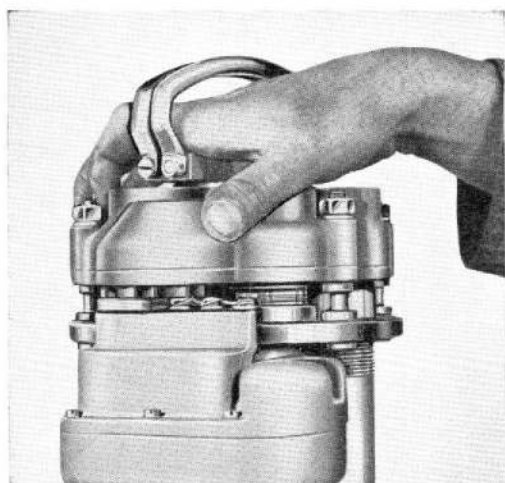


Fig. 4. Replacing firing head

- (8) Depress the handle assembly and rotate it in a clockwise direction to the limit of its travel.
- (9) Release the handle assembly and ensure that it moves up into the locked position.
- (10) Swing down the handles.

Unloading the breech

35. With the firing head removed, as described in Sect. 2, Chap. 2, the cartridges can be removed with the aid of a special tool (Mk. 10425) as follows. Locate the lifting arms of the extractor under the rim of the cartridge cap and push the tool forward over the cartridge. This action will raise the cartridge slightly, after which it can be lifted vertically from the barrel as shown in fig. 5.



Fig. 5. Use of special tool for removing cartridges

Indexing and firing

36. The indexing and firing movements are completed in one operation, actuated by pressing a control button in the aircraft cockpit. The action of "cocking" the firing mechanism and firing the charges is so rapid as to be almost instantaneous. Only one start can be made for each depression of the starter button, as a relay in the electrical circuit of the motor prevents a repetition of the firing movement occurring with the continued depression of the button. The starter button must be released before further starts can be made.

Engine fails to start

37. If the engine fails to start after a number of attempts, the cause must be investigated as detailed in the relevant aero-engine Air Publication. All cartridges must be removed from the barrel assembly before work on the aero-engine is commenced (Refer to para. 33, *WARNING*, sub-para. (4)).

Cartridge fails to fire

38. If one pair of cartridges fail to fire, a period of 30 secs. must be allowed to elapse before a second pair is indexed and fired. Should two

consecutive charges fail to fire, wait at least one minute and then remove the ◀ firing head ▶ from the breech and examine the cartridge percussion caps. If firing-pin dents of normal depth appear on the caps it may be assumed that the cartridges are defective, and the breech should be reloaded with fresh cartridges. If the dents are very slight, or entirely absent, a defect in the breech firing mechanism is indicated.

39. Should a failure to fire occur due to the firing head being incorrectly fitted to the starter, remove the head in the normal manner and with the pads locked in the fully forward position manually index 3 or 4 times, using key (*Part No. Mk. 3851*) then electrically index the indexing motor to bring the pin wheel to its normal OFF position. When the firing head has been correctly positioned the starter is ready for service.

FAULT DIAGNOSIS CHART

Fault	Possible cause	Correction
1. Starter button is pressed but cartridge fails to fire.		
WARNING		
<p><i>After failure to fire—</i> <i>30 SECONDS must be allowed to elapse before attempting to fire again.</i> <i>ONE MINUTE must be allowed to elapse before approaching the starter.</i> <i>DO NOT TOUCH the firing head without first referring to Possible Cause (1) and its correction.</i></p>		
	(1) Indexing movement not completed due to:—	(1) Before touching the firing head, observe the position of the indexing pin relative to the geneva slot. If the pin is engaged in the slot, proceed as follows:—
	(a) Firing head studs not properly located on the underside of the barrel plate. (It is assumed that the handle assembly has been fully turned clockwise and has "clicked" upwards to lock).	(a) If less than approximately two thirds of a complete index has been made the head handle should be depressed and turned anti-clockwise to remove the head in the usual way.
	(b) Faulty electrical circuit causing the indexing motor to stall.	Note . . . <i>A complete index is 60 deg. rotation (one sixth revolution) of the geneva wheel.</i>
		(b) If more than approximately two thirds of a complete index has been made then, unless the indexing is very nearly complete, it will not be possible to fully depress the handle. This is because the dogs on the handle sleeve and those on the indexing gear will be opposite each other. In this case proceed as follows:—
		(i) Slacken the five $\frac{3}{8}$ in. nuts on the firing head studs (<i>fig. 1</i>) sufficiently to enable the head to be lifted vertically approximately $\frac{1}{8}$ in. This will lift the geneva wheel clear of the indexing pin, after which the head can be turned to remove it in the usual way. With the head removed, the stud nuts tightened and the sealing pads forward, artificially index the head a few times by rotating the geneva wheel (<i>fig. 7</i>) in a clockwise direction with the indexing key (Stores Ref. No. 37F/13276), thereby establishing correct operation.
		(c) If the indexing pin is just on the point of disengaging from the slot it is possible that the firing pins are just "teetering" on the edge of the cam and

Fault Diagnosis Chart—contd.

Fault	Possible cause	Correction
(2) Faulty indexing due to the handle either not being depressed and turned, or else being depressed but not turned sufficiently for it to "click" upwards and lock.	(3) Fuse ruptured in engine control panel due to overspeed device having operated.	<p>they may drop and fire the cartridges if the handle is depressed and/or turned. An attempt should be made to depress and turn the handle WITHOUT DISENGAGING THE HEAD STUDS FROM THE BARREL PLATE, so that, if possible, the pair of cartridges are fired before work is started on the head. If the cartridges do not fire, strike the firing head smartly with the palm of the hand in an endeavour to cause the firing pins to drop. The fact that the starter may fire under these circumstances is in no way dangerous in itself, but PERSONNEL MUST KEEP QUITE CLEAR OF THE STARTER EXHAUST. If the starter does not fire during the performance of the foregoing operations, the firing head should be removed as detailed in Correction (b) (i). When the head has been removed the pin indexing wheel should be operated several times, by pressing the starter button in the aircraft cockpit, firstly to complete the indexing movement of the pin indexing wheel, and secondly to prove satisfactory operation of the mechanism and the electrical system.</p>
		<p>(1) Should an attempted index take place under these circumstances, the starter might fire, after which it may prove necessary to remove the head as detailed under Cause (1), Correction (1) (b). The firing gear train will then have to be re-timed as described in Vol. 6, Part 4, Sect. 2, Chap. 4, para. 21, of this publication.</p>
		<p>(1) If the fuse is found ruptured, check the position of the pin indexing wheel relative to the geneva wheel. Where the pin is still engaged in the geneva slot, reference should be made to Cause 1, Correction (1) a, b or c, as appropriate, in order to remove the head. Where the foregoing conditions are found, it is probable that a fault has developed in the engine control panel which is permitting continuous indexing. Reference should therefore be made to Vol. 1 of the engine publication. In this, as in all</p>

Fault Diagnosis Chart—contd.

Fault	Possible cause	Correction
2. Cartridge fires, but engine fails to light up.	(1) Normal r.p.m. given to engine. (2) Low r.p.m. given to engine	other cases, it is essential that the cause of the overspeed be determined before fitting another starter. That an overspeed has actually occurred may be verified by checking for continuity between the two plug pins on the indexing motor cover. (2) An overspeed can also be caused by:— (a) Oil ingress into the clutch. (b) Sheared quill drive or starter component. In either case the starter must be removed and reconditioned as described in Vol. 6, Part 4, of this publication.
	(4) Faulty cartridges.	<p>IMPORTANT</p> <p><i>In all cases similar to these mentioned in the foregoing faults where incorrect indexing results, always complete the index of the pin wheel, and check the functioning of the firing head. Index the head a few times by means of the key (Stores Ref. No. 37F/13276) applied to the geneva wheel, with the sealing pads forward, before replacing the head. The indexing may then be checked as follows:—</i></p> <p><i>Load the breech with six spent cartridges and replace the firing head, interposing tissue paper between the sealing pads and the cartridge heads. Ensure that the sealing pads move forward and nip the paper, then index three times. Remove the head between each index and observe that two diametrically opposite pieces of paper are punctured for each index. Any fault in the head or the motor mechanism will be shown by this test.</i></p> <p>Note . . .</p> <p><i>Observe that full voltage is applied, otherwise the indexing motor will stall. This fact should be borne in mind when fault finding.</i></p> <p>(1) Remove the firing head and extract cartridges. If the caps are fully indented then faulty cartridges are being used and a fresh batch should be fitted.</p> <p>Make a second attempt and, if still unsuccessful, refer to relevant engine A.P., Vol. 1.</p> <p>Wait a minimum of 30 seconds then make a second attempt.</p>
	(1) Engine control setting wrong. Fault in engine or its associated equipment. (2) Delayed ignition on one or both cartridges.	

Fault Diagnosis Chart—contd.

Fault	Possible cause	Correction
	Ruptured safety disc.	Renew the safety disc assembly. Note . . . <i>With a full breech of live cartridges another two attempts to start can be made.</i>
	(3) Clutch slip caused by:—	
	(a) Engine fault causing resistance to turning.	Refer to relevant engine A.P. Vol. 1.
	(b) Oil on clutch.	Change starter.
	(c) Internal resistance in starter due to bearing failure, oil supply failure, etc.	Change starter.
3. Cartridges fire but starter fails to turn engine.	(1) Quill shaft failure.	Renew quill shaft, and starter. Check removed starter for high clutch setting and for overspeeding consequent upon quill shaft failure.
4. Repeated blowing of one safety disc.	(1) Gas passage blocked.	Change starter.
5. Repeated blowing of all safety discs.	(1) Batch of faulty cartridges.	Use a fresh batch of cartridges.
	(2) Cutting of safety discs due to excessive tightening.	New disc assemblies should be tightened lightly but firmly prior to wire-locking.

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