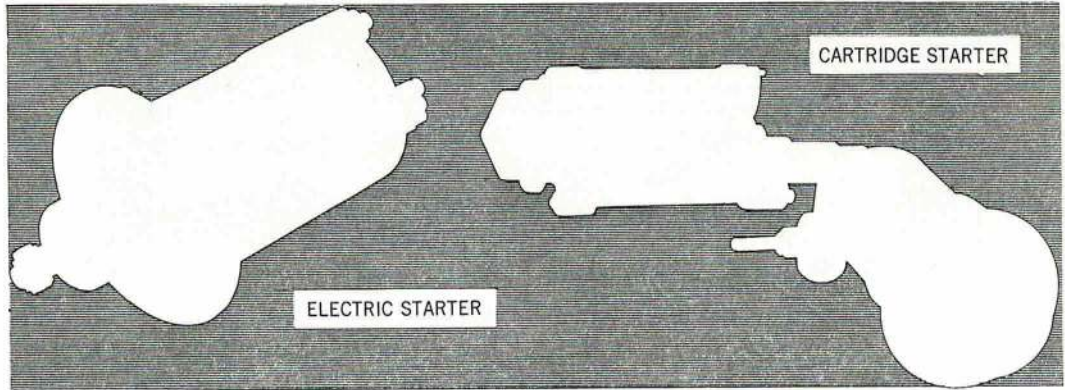


CHAPTER 9

PISTON ENGINE STARTERS



Objectives

1. This Chapter has been written with the aim of helping you to satisfy objectives in the relevant Skills and Knowledge Specifications (SAKS) for the trade in this subject area. When you have studied this Chapter, you will be able to:
 - a. Explain the purpose of electric and cartridge starters and the principles of operation of each.
 - b. State the safety precautions when loading and unloading cartridge starters, and how to handle cartridges.
 - c. State how the starters are serviced and the limitations regarding servicing.

Introduction

2. To start an engine, it is necessary to get the piston moving up and down to induce the fuel/air mixture to enter the cylinders. This can be done only by external means and is achieved by using either an electric starter or a cartridge starter to turn the engine over until such time as the engine fires and reaches a self-sustaining speed through the normal engine ignition system described in Chapters 7 and 8 of this Section.

Electric Starter

3. **Hand-cranking mechanism.** An electric starter fitted to a piston engine may or may not be fitted with a hand turning facility. This facility has additional gearing in the form of a hand cranking mechanism to allow hand turning of the engine, either free from, or coupled with, the electric motor. Fitted into the gear train between the handcrank and the final drive is a safety device, usually a ratchet mechanism to prevent damage to the operator should the engine backfire. Hand cranking may be required occasionally to 'unstick' very cold engines before attempting electric or cartridge starting.

4. The minimum requirement that must be met in design is that the gear ratio between the handle and the engine crankshaft must be low enough—about 18 to 1—to allow one or two men to turn the engine over and, at the same time, impart the minimum speed to the engine crankshaft at which the carburettor and magneto become effective for a start to take place. An example of hand turning through the starter mechanism is illustrated at Fig 1.9.1.

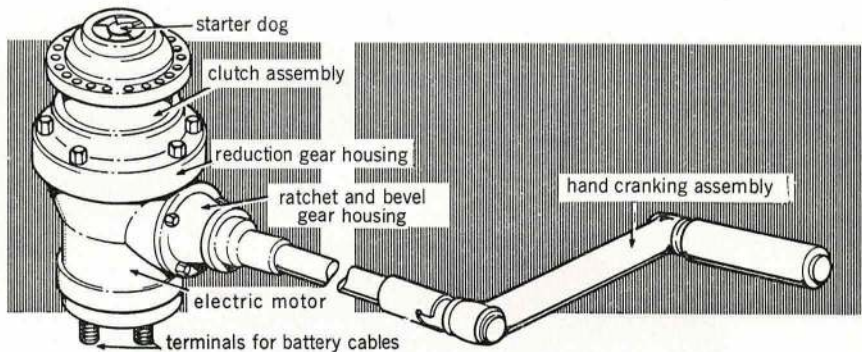


Fig 1.9.1 Hand turning through starter mechanism

5. **Electric starter components.** The main components of the electric starter are a dc motor fitted with a starting gear, a reduction gear of the epicyclic type (90 to 1), and an overload clutch. The purpose of the clutch is to prevent damage to the engine should it back fire or seize. A ratchet device provides automatic engagement with, and disengagement from, the engine.

6. These components may be included in the starter itself or, except for the motor, form part of the engine gearbox.

7. **Engagement.** When the electric motor is energized from the ground batteries, the armature shaft drives the clutch at a much reduced speed by reason of the epicyclic gearing. The helical splines of the clutch tend to rotate the driving dog but, as the dog is held either by the oil seal or a friction ring, the dog moves forward to engage with the engine shaft. Only when the dog coupling has moved to the limit of its travel will the clutch impart a rotary movement to the dog to drive the engine.

8. The basic circuit of an electric starting system is illustrated at Fig 1.9.2. When the start switch is operated, the solenoid is energized and this connects the supply to the electric starter. All other necessary supplies (eg to magneto) are also completed, so that as the engine is rotated by the electric starter, the engine will 'fire' and start up.

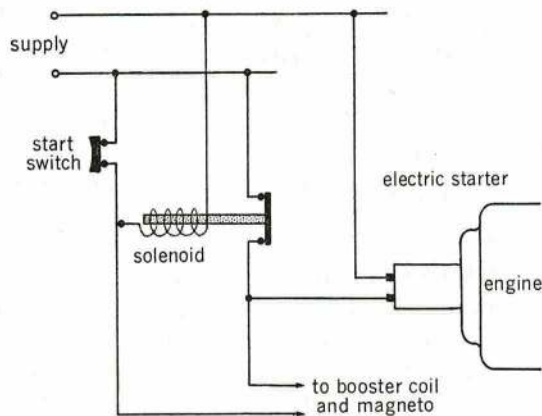


Fig 1.9.2 Electric starting system

9. **Installation.** Before installation of the unit, the depth of the engagement with the driving dog of the engine must be checked in the following manner:

- a. Measure the distance from the outer point of the engine gears to the starter mounting flange on the engine.

- b. Measure the projection of the driving dog of the starter from the mounting flange with the driving dog tapped back to the innermost position.
- c. The difference between these two measurements will give the free clearance when the engine is running. *This should not be less than $\frac{3}{8}$ in.*
- d. Check that the forward movement of the dog is satisfactory, by turning the hand turning crank. The dog should move forward approximately $\frac{1}{2}$ in. On some types of starters, the use of shims around the mounting flange is allowed, to obtain the required clearance.
- e. Offer up the starter to the engine mounting flange, ensuring that the hand cranking shaft is at the correct angle, and secure the starter. Numerous mounting holes on the flange will facilitate the correct angle of the cranking shaft.
10. **Servicing.** Apart from removing and refitting the starter motor, the servicing of the starter is the responsibility of the electrical tradesmen. However, the following routine inspection is necessary:
- The starter should be examined for insecurity of attachment, external damage and oil leaks.
 - Leads should be secure, and rubber grommets or sleeves should not be cracked, perished or oil soaked.
 - The gearbox oil level should be checked and topped up as necessary.
11. When a starter motor becomes faulty it is replaced. *Never use the aircraft internal batteries for starting.* If the engine fails to start within 20 seconds, pause for 30 seconds to allow the starter motor to cool off and the external battery to recover.

Cartridge Starting

12. **Introduction.** Although cartridge fired starters are rarely used to start piston engines in the Royal Air Force today, and the cartridge starting system will be more fully explained in the Gas Turbine Section of this Air Publication (Section 2), it will not be amiss to remind you briefly of its operation and the precautions you must take regarding its use.

13. **Principle of operation.** A cartridge starter derives its power from the gases produced by the combustion of a cordite propellant-charged cartridge. The complete assembly consists of two main units—a starter section and a breech. The arrangement of these units varies with the installation; in early types, the two units are connected by a stainless steel pipe but, in later types, they can be integral units bolted together, and with this method the combustion takes place entirely in the breech. When combustion takes place in the breech, stick-filled cartridges

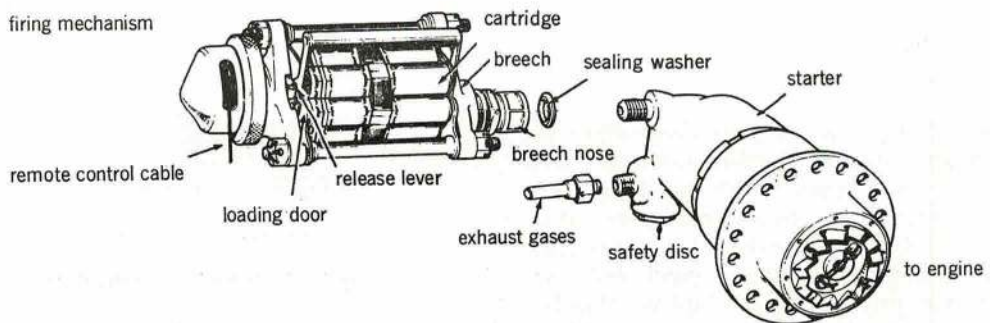


Fig 1.9.3 Cartridge starter

are used because they make starting easier at low temperatures, and a slow burning torque is applied over a longer period. Pellet filled cartridges were used on the earlier type of starter, *ie* where the starter and the breech were interconnected by the steel pipe. This cartridge consists of a waxed cardboard cylinder, seated in a rimmed brass cup, with a fuze head at the bottom. Mechanite (a form of cordite) is used for the charge and consists of pellets of two sizes, the smaller of which are quick burning and are packed around the fuze head.

14. **Breech.** The cartridges are held in a revolving magazine which consists of cartridge barrels held between two end plates (Fig 1.9.3). This barrel assembly is carried in the two end frames of the breech assembly. One end frame contains the firing mechanism and the other forms the port transferring the combustion gases to the starter. The firing mechanism can be electrically or percussion operated. When electrical firing is used, a safety device is incorporated to ensure the cartridge cannot be fired either when selecting a fresh cartridge or when the barrel is not correctly positioned.

15. The revolving magazine may be fixed or removable, and each cartridge may be brought into position by a remote control cable from the cockpit. On the removable type breech, when the indexing mechanism is operated, initial movement of the pulley cable rotates a pulley in a clockwise direction to engage a pawl in the ratchet wheel and rotate the barrel assembly (*see* Fig 1.9.5). At the same time, the firing unit is rotated until the lug on the sealing pad abuts the end of the stop plate on the release lever, as illustrated at Fig 1.9.4. Rotation of the pulley also loads the main spring. Movement of the pulley then indexes the barrel assembly one-sixth of a turn to bring the next barrel in line with the firing unit and simultaneously rotates the firing cam, relative to the sealing pad and the firing hammer. When the indexing movement is complete, the half-moon boss on the drive shaft locates in the crescent in the index wheel to lock the barrel, and the firing cam then pushes the sealing pad into the barrel (Fig 1.9.4).

16. Further movement of the pulley, and hence the firing cam, lifts the hammer, compressing the firing unit spring until the lugs on the hammer disengage, and the hammer returns under spring pressure to fire the cartridge. At this stage, the pulley stop abuts its stop plate to prevent further movement and the catch pawl engages with the drive shaft flange to prevent it moving when the cable is released. On releasing the cable, the ratchet wheel disengages from its pawl and the pulley is returned to its original position by the main spring, leaving the sealing pad in the barrel, and the index wheel locked at the lug on the sealing pad abutting the end of the release lever stop pad.

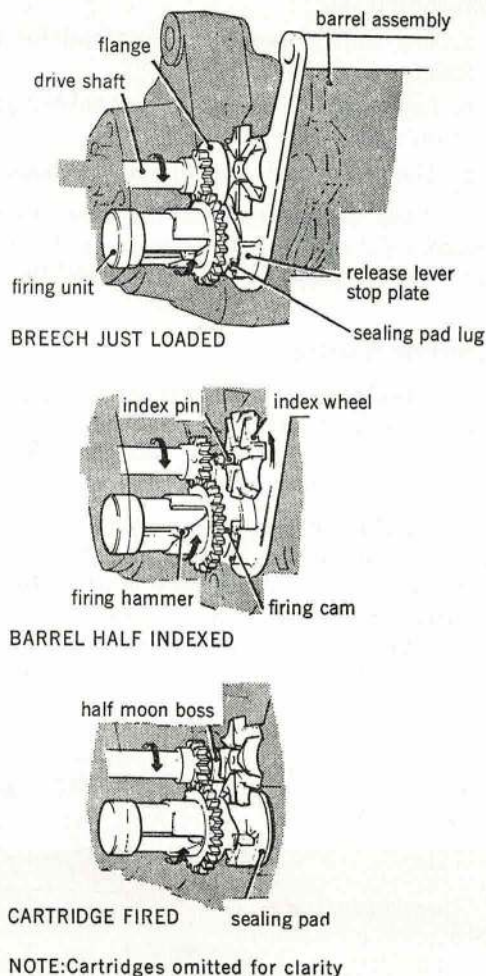


Fig 1.9.4 Indexing mechanism

17. On the type of breech operation described, the indexing control fires the cartridge *mechanically*. There are other starters though in which, after indexing, the cartridge is fired *electrically* by pressing the starter button in the cockpit.

18. **Loading.** On a non-removable barrel:

- Raise the loading door slightly and, looking at the loading end, turn it anti-clockwise.
- Insert a cartridge into the barrel.
- Operate the lever by hand to bring the next barrel in line with the loading doorway.
- Close the loading doorway carefully.

19. On a removable barrel:

- Swing the release lever to the OPEN position and withdraw the barrel assembly from the breech frame, using an extractor tool to remove the spent cartridge cases.
- Check that the barrel assembly is clean and undamaged and ensure that the end cap of the cartridge enters the recess provided in the rear end of each barrel.
- Locate the barrel assembly between the end plates of the breech with the cartridge caps towards the breech pulley and the bearings entered in the slots.
- Turn the barrel until a groove in the face of the index wheel lines up with the slot in the rear cover plate. Ease it in, and lock by swinging the release lever to 'SHUT'.

WARNING. MAKE SURE THAT YOU OBTAIN THE CORRECT TYPE OF CARTRIDGE AS SPECIFIED IN THE MOD FORM 700; MAKE SURE ALSO THAT THEY ARE UNDAMAGED AND FREE FROM OIL AND GREASE.

20. **Unloading.** Make sure that spent cartridges are removed as soon as possible from the breech barrel because of the corrosive effect of the burnt gases. When the aircraft is out of use, the barrel assembly should be unloaded; similarly, when work is to be carried out on the engine. If the cartridges are removed from a fixed barrel assembly, the cartridges should be returned to stores; if the barrel assembly is removable, it should be removed and stowed in the aircraft.

21. A breech assembly is illustrated at Fig 1.9.5.

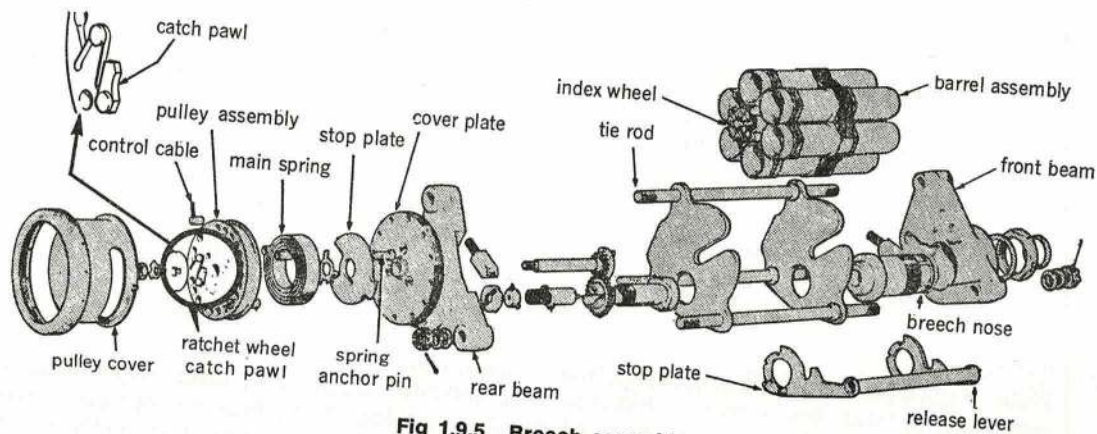


Fig 1.9.5 Breech assembly

Starter

22. The gas pressure from the breech is led to a cylinder above a piston. The piston is secured to an internally and externally helically splined shaft, which is itself splined to the starter dog

and the starter body respectively (Fig 1.9.6). The force of the gas moves the piston, and the downward movement is converted by the action of the helical splines to a rotary motion of the starter dog. At the end of the stroke, the piston moves an exhaust valve off its seating and a large compression spring, compressed by the downward movement of the piston, returns the piston to the start position. To prevent damage to the starter from unnecessarily high pressure, a thin copper or nickel safety disc is fitted to communicate with the cylinder head. Excessive pressure shears the disc, and the gases can vent to atmosphere. The operation of the splined shaft within the starter is illustrated at Fig 1.9.6.

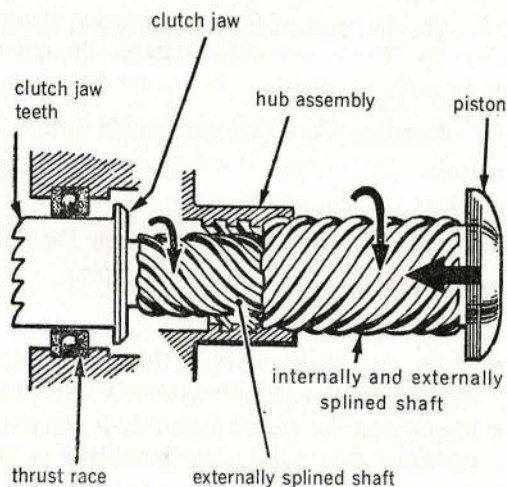


Fig 1.9.6 Operation of splined shaft within the starter

Safety Precautions

23. There is no need to remind you that a cartridge starter is as lethal as a loaded shotgun. Although you will have to read and sign the Engineering Order book from time to time regarding many safety precautions, it is worth repeating the safety precautions regarding cartridge starters.

24. The speed of operation of a cartridge starter is very high, the entire cycle being completed within a fraction of a second. To prevent damage to life or to the engine, the following points are to be strictly observed:

- a. Ensure that everyone stands clear of the propeller and starter exhaust whenever the starter is loaded.
- b. Engines should be hand turned for two complete revolutions to reduce the possibility of hydraulic lock damage.
- c. If the starter has been indexed by the cable and the cartridge has not fired, wait three (3) minutes before operating the starter mechanism a second time.
- d. If the starter has been indexed by the cable and the cartridge has fired, but the engine has failed to start, wait 30 seconds before operating the starter mechanism a second time.
- e. After two consecutive failures to start, the cause should be investigated.
- f. If a full set of cartridges has been fired without achieving a start, the starter is to be allowed to cool for 20 minutes.
- g. If you want to remove the starter barrel when a cartridge has been indexed and failed to fire (or, having been indexed, has fired and failed to start the engine), wait for three (3) minutes.

Note: Before removing a starter barrel when a cartridge has been indexed but not fired, you may tap the rear beam with a hide-faced hammer (or similar soft faced implement) to attempt to dislodge the firing hammer and fire the cartridge. If this fails, remove the starter pulley cover and check the position of the catch pawl. If the pawl is engaged in the notch on the ratchet wheel, the movement is complete and it is safe to remove the barrel assembly. If the pawl is not engaged, turn the drive shaft nut anti-clockwise until the firing mechanism is turned BACK to the safe position (*ie* the pawl is engaged in the notch on the ratchet wheel (Fig 1.9.5).

Electrical Operation of Cartridge Starter

25. The electrical circuit of the starting system is so arranged as to energize the booster coil and to fire the cartridge with a single operation of the engine starter switch. This means that, when starting, the following operations must be completed before the starter button is pressed:

- a. Fuel 'ON'.
- b. Engine fuel priming.
- c. Positioning of throttles, propeller governor, mixture control, *etc.*
- d. Magneto and booster coil switches 'ON'.

26. The starter button must be held in when starting until the engine picks up, or the booster coil will cease to function. A simple cartridge starter wiring system is illustrated at Fig 1.9.7.

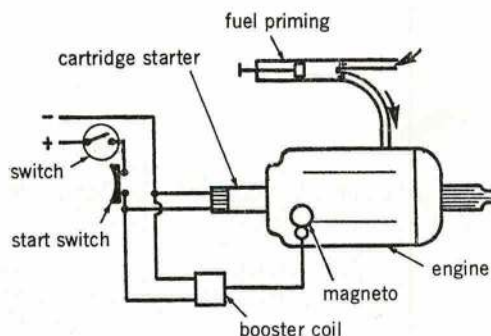


Fig 1.9.7 Cartridge starter wiring system

27. **Installation.** Prior to assembly of the starter section to the engine, the depth of driving dog engagement is ascertained in a similar manner to that of electric starters. The starter is then positioned with the vent holes at the top, and the starter is secured to the engine mounting. This will probably give misalignment of the breech and the combustion chamber ports. To align these parts, the clamping bolts are slackened and the cylinder, complete with combustion chamber, is turned to the correct position. The gaps at the horns of the clamping ring are then equally spaced and the clamping bolts tightened evenly. The breech may then be mounted and secured.

28. **Servicing.** Day-to-day servicing consists mainly of keeping both the breech and starter clean, together with the following:

- a. Lubricate the breech sealing piston at every reloading period of six cartridges.
- b. Keep the vent holes clear.
- c. Change the safety disc in accordance with the schedule, normally after so many shots are fired (not engine starts).

29. After a number of shots have been fired, the starter is removed for cleaning and decarbonizing of the combustion chamber, exhaust valve and cylinder. The combustion gases from the cartridge charge are highly corrosive. The combustion chamber and exhaust valve must be removed before attempting to dismantle the cylinder. This will permit a spring compression tool to be used on the heavy coil spring under the piston, when the cylinder clamping ring can be detached without the possibility of damage to personnel or the starter.

30. The combustion chamber and cylinder must be washed in hot soda water, dried, rinsed in kerosine and again dried. Any carbon is removed and a careful inspection made for excessive corrosion. The components are then cleaned, dried and lubricated before re-assembly. During re-assembly, further use is made of the spring compression tool when fitting the cylinder clamping ring.

Fault Diagnosis

31. Some of the faults which may be encountered when working with cartridge starters, the cause of the fault and the remedial action to be taken are listed below:

| Fault | Possible Cause | Correction |
|--|--|--|
| Cartridge will not fire. | a. Defective cartridge. b. Possible delayed action. c. Barrels not indexing. d. Broken firing hammer and broken spring. | Wait 30 seconds and then check cable, breech unit, and barrel assembly. Fit new units if necessary. |
| Cartridge fires but engine will not turn. | Safety disc blown. | Fit new disc. |
| Control cable remains extended (after operation). | a. Friction in index mechanism. b. Excess friction in control cable. c. Broken pulley return spring. | See Airframe or Engine Air Publication, Volume 1. If necessary fit new breech unit. |
| Safety disc ruptures continually. | a. Engine hard to turn. b. Piston assembly seized. | Check the engine. Decarbonize the starter. |
| Engine turns slowly (<i>ie</i> loss of power in the starter). | Symptom: smoke from exhaust tube immediately prior to normal exhaust noise. | Check cartridges, safety disc, seating and holder. |
| | Starter housing air vent obstructed. | Clean air vent. |
| Clutch jaw will not return to its initial position. | Broken valve return spring. | Fit new starter assembly. |
| | a. Piston seized. b. Clutch jaw worn or broken main spring. | Decarbonize starter. Fit new starter. |

Propeller Swinging

32. On relatively low power engines, where the compression ratios are low, the start may be attempted by propeller swinging. Practical instruction will be given on this method at squadron level, according to the type of engine to be started. It should always be remembered that, when starting the engine, the ignition switches are 'ON' and *extreme care is necessary in swinging the propeller*. As with all engine starting procedures, the aircraft wheels must be chocked, the nose of the aircraft must be facing into wind; fire extinguishers must be available and loose clothing must not be worn.

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