

Chapter 3

TYPE LTSA 70, LTSA 140 and LTSA 150

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LEADING PARTICULARS

Starter...	Liquid fuel—turbine
Direction of rotation	Anti-clockwise viewed on output drive shaft
Turbine	Single stage—impulse
Reduction gear	Epicyclic, ratio 3.75 to 1
Rotor speed (speed control in operation)	
Group 5 and 23	38 000 rev/min
Groups 5/1, 5/2, 5/3 and 8	44 000 rev/min
Nozzle plate	
Group 5 and 23	6 hole
Group 5/1, 5/2 and 5/3	8 hole
Group 8	9 hole
Atomizer swirl chamber orifice	
Group 5 and 23	0.225 in.
Groups 5/1, 5/2, 5/3 and 8	0.238 in.
Combustion chamber length	
LTSA 70 and 140	8.84 in.
LTSA 150	11.15 in.
Safety disc, (all group)	Ref. No. 37F/20804
Fuel	Iso-p ropyl-nitrate
Fuel, aviation, turbine engine starter, Ref. No. 34A/9423147 AVPIN	
Lubricants	
Starter gear	Oil OX-38
Quantity (initial filling)	100 cm ³
Air blower bearings	Grease XG-275
Air blower drive gears	Grease XG-285
Screw threads subject to torque loading	Grease ZX-13
Starter systems	
Installed weight (including airframe mounted components but excluding pipes, fuel tank and electrical wiring)	
LTSA 70	92 lb
LTSA 140	92 lb
LTSA 150	97 lb
High pressure switch operating pressure	
Groups 5 and 23	300 ± 10 lb/in ²
Groups 5/1, 5/2, 5/3 and 8	340 ± 10 lb/in ²
Fuel pump delivery (at 7500 rev/min and 600 lb/in²)	
Groups 5 and 23	230 cm ³ /sec
Groups 5/1, 5/2, 5/3 and 8	360 cm ³ /sec

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INTRODUCTION

1. Although Plessey LTSA I.P.N. starters are basically of the same design, they differ in the starting power developed, which is governed by the starter speed, and in installation requirements for specified types of aircraft.

2. Each starter system consists of a basic single stage turbine motor and its installation fittings plus the following airframe mounted components:—

- (1) Fuel supply tank.
- (2) Motor contactor.
- (3) Electrical circuit control box.
- (4) Ignition switch, actuated by the fuel supply at a predetermined pressure.
- (5) High pressure switch and anti-dribble valve incorporated in a single unit, with a solenoid operated valve located in the fuel pipe line.
- (6) Motor unit consisting of a combined fuel pump and air blower unit operated from a common motor driven drive shaft.
- (7) High frequency ignition unit supplying an almost continuous discharge to the starter igniters when energized.

3. The starter is operated by a push button in the aircraft cockpit, which, when pressed, starts a timed sequence of operations.

4. The starter motor develops its power from gases generated by the decomposition of a mono-fuel injected into the combustion chamber of the motor and ignited. The gases thus generated quickly build up a pressure within the chamber, and as they are exhausted therefrom pass through convergent-divergent nozzles in a nozzle plate. These nozzles direct the gases on to the blades of a single-stage axial flow impulse turbine causing it to rotate at a rapidly increasing speed up to the maxima quoted in the Leading Particulars. The rotor drives an output shaft through an epicyclic reduction gear.

5. The drive shaft is serrated to take a spur gear supplied with the aero-engine and which mates with the gears in the engine starter gearbox. The gear is secured to the drive shaft by a bolt and tabwasher. Further step down gearing of 6 : 1 is provided in the aero-engine. A speed control switch, operated centrifugally within the starter motor, comes into operation when the rotor has reached its predetermined speed and automatically shuts off the starter system.

FUEL

6. The fuel used in the starter system is iso-propyl nitrate (abbreviated as I.P.N.) (Inter Service designation AVPIN) a mono-fuel having the chemical formula $C_3H_7NO_3$. A mono-fuel is a fuel which, under certain conditions of temperature and pressure, will decompose in the absence of air or other oxidants. Under atmospheric conditions, however, it has a high degree of inflammability, and

when mixed with air it forms a fuel/air mixture which burns readily, and which rapidly develops a large volume of gas. This fuel/air mixture is easily ignited by means of sparking plugs or igniters. When ignited in a confined space, such as a combustion chamber, it causes the temperature and pressure to rise above the critical value needed to decompose the fuel as a mono-fuel.

7. Once conditions necessary to decompose the fuel have been created, the continued flow of iso-propyl nitrate into a combustion chamber enables it to continue decomposing without the need for air. Control of the fuel flow will therefore govern the combustion. Such a functional property is advantageous as, for instance, in the case of an aero-engine which is slow in lighting up. The starter will then continue to assist the aero-engine up to normal starting speed, within the time limits imposed by its control unit.

8. Iso-propyl nitrate fuel has been classified under British Home Office Regulations as a non-explosive highly inflammable solvent.

WARNING . . .

(1) Excessive inhalation of the vapour gives rise to headaches due to lowering of the blood pressure, and the same effect is produced by absorption through the skin.

(2) On LTSA 150 starter systems fitted to Hunter Mk. 6 aircraft, under certain conditions a poisonous deposit may be produced on the end fitting (the fairing around the atomizer head) and on the speed control cable conduit due to the action of exhaust gases on the protective treatment. Pending a change in protective treatment it is essential that hands are washed immediately after handling the starter motor assembly, and if removal of the deposit is carried out by wire brush or emery cloth, both should be thoroughly wetted to prevent dust.

9. The system obtains its electric current from the aircraft electrical supply of 24 volts, and will operate between 16 and 26 volts under load.

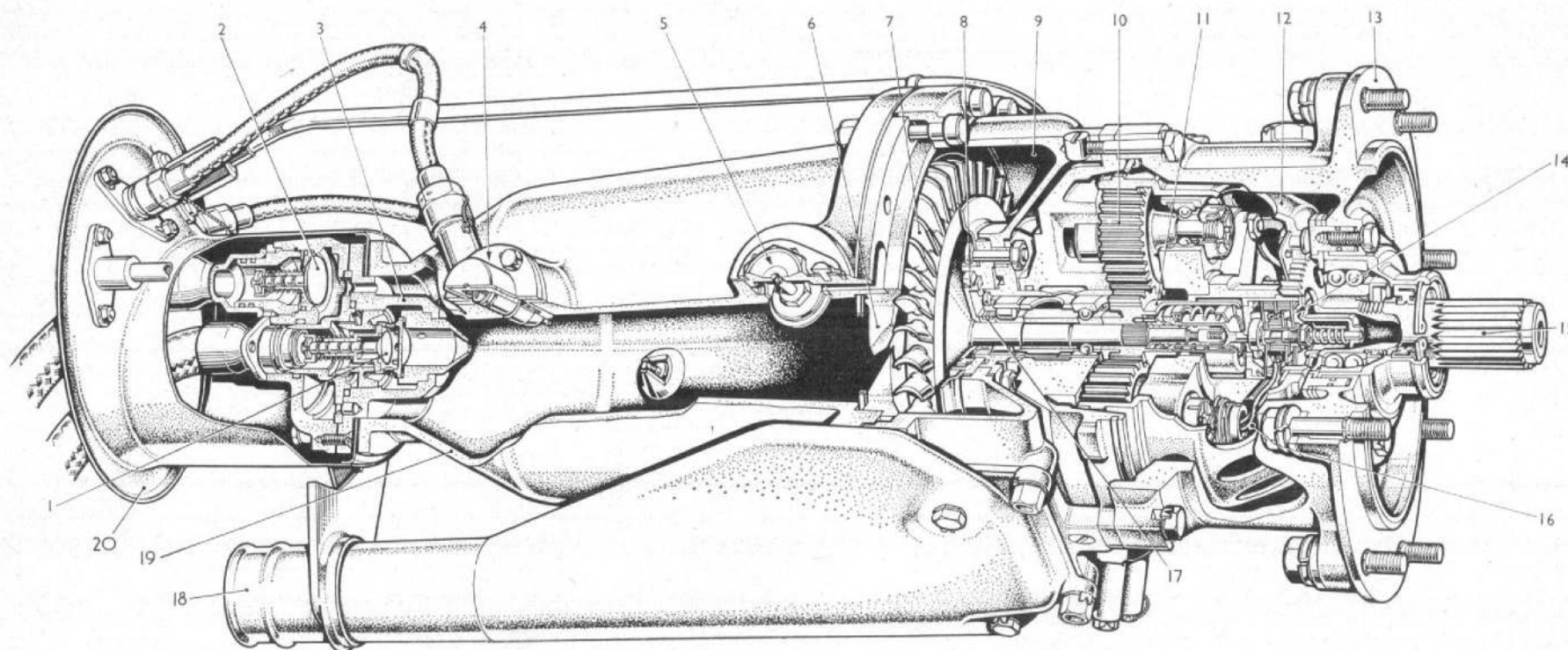
STARTER SYSTEM

General

10. The I.P.N. starter system (fig. 1) consists of a number of independent mechanical and electrical units which are inter-connected electrically so as to make a complete operable system. A sequence of timed operations, controlled by cam-actuated switches housed in an electrical control box, enables the system to function correctly from the time the electric circuit is initiated by the push button in the aircraft cockpit to the final stage when the energy created in the starter motor is transmitted through a drive shaft to the aero-engine. The units which go to make up the system are described briefly in the following

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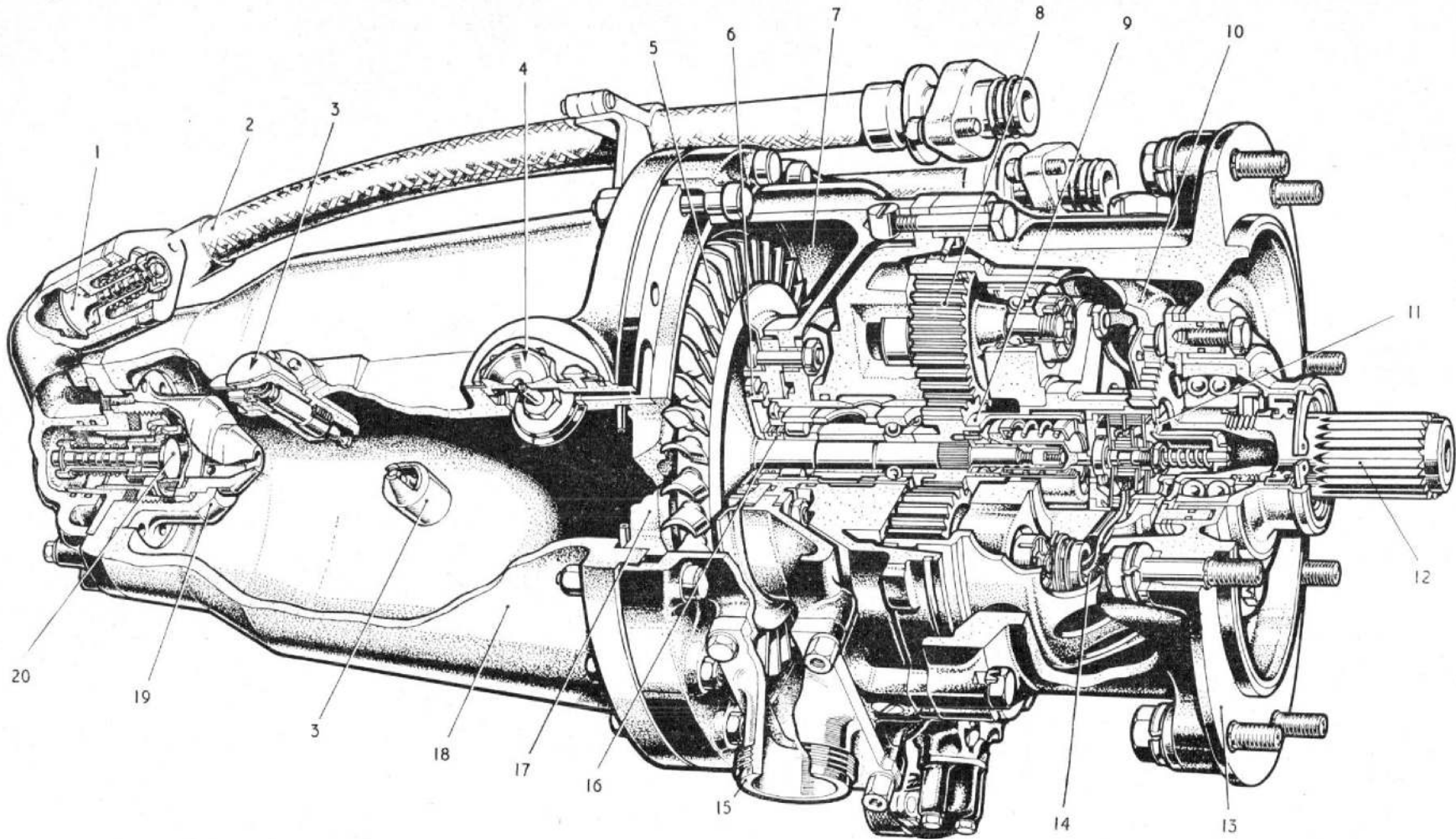
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- | | |
|-------------------------------------|----------------------------------|
| 1 FUEL INLET VALVE TO ATOMIZER HEAD | 11 ROTOR GEAR |
| 2 AIR INLET VALVE TO ATOMIZER HEAD | 12 ANNULUS GEAR |
| 3 ATOMIZER HEAD ASSEMBLY | 13 MOUNTING FLANGE |
| 4 IGNITER PLUG ASSEMBLY | 14 SPEED CONTROL SWITCH ASSEMBLY |
| 5 SAFETY DISC ASSEMBLY | 15 OUTPUT SHAFT |
| 6 NOZZLE PLATE | 16 SPEED CONTROL SWITCH LEADS |
| 7 ROTOR | 17 PISTON RING SEAL |
| 8 GAS LABYRINTH | 18 EXHAUST MANIFOLD |
| 9 EXHAUST VOLUTE | 19 COMBUSTION CHAMBER |
| 10 PLANET GEAR | 20 END PLATE |

Fig. 2. Type LTSA 150 turbo-starter

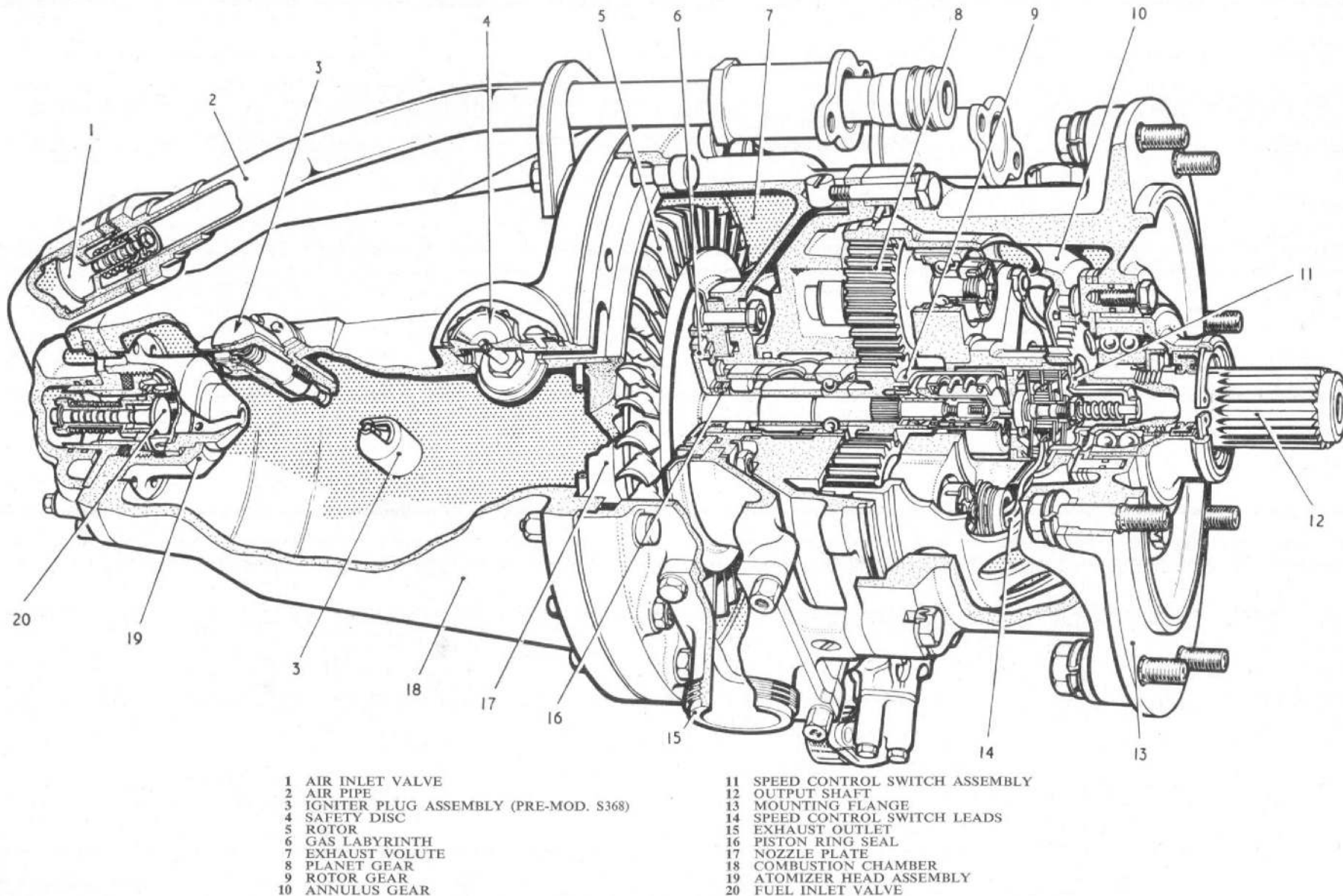
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- | | |
|---|----------------------------------|
| 1 AIR INLET VALVE | 11 SPEED CONTROL SWITCH ASSEMBLY |
| 2 AIR HOSE | 12 OUTPUT SHAFT |
| 3 IGNITER PLUG ASSEMBLY (PRE-MOD. S368) | 13 MOUNTING FLANGE |
| 4 SAFETY DISC | 14 SPEED CONTROL SWITCH LEADS |
| 5 ROTOR | 15 EXHAUST OUTLET |
| 6 GAS LABYRINTH | 16 PISTON RING SEAL |
| 7 EXHAUST VOLUTE | 17 NOZZLE PLATE |
| 8 PLANET GEAR | 18 COMBUSTION CHAMBER |
| 9 ROTOR GEAR | 19 ATOMIZER HEAD ASSEMBLY |
| 10 ANNULUS GEAR | 20 FUEL INLET VALVE |

Fig. 3. Type LTSA 140 turbo-starter ◀ (pre-Mod. S368 and S405) ▶

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- 1 AIR INLET VALVE
- 2 AIR PIPE
- 3 IGNITER PLUG ASSEMBLY (PRE-MOD. S368)
- 4 SAFETY DISC
- 5 ROTOR
- 6 GAS LABYRINTH
- 7 EXHAUST VOLUTE
- 8 PLANET GEAR
- 9 ROTOR GEAR
- 10 ANNULUS GEAR

- 11 SPEED CONTROL SWITCH ASSEMBLY
- 12 OUTPUT SHAFT
- 13 MOUNTING FLANGE
- 14 SPEED CONTROL SWITCH LEADS
- 15 EXHAUST OUTLET
- 16 PISTON RING SEAL
- 17 NOZZLE PLATE
- 18 COMBUSTION CHAMBER
- 19 ATOMIZER HEAD ASSEMBLY
- 20 FUEL INLET VALVE

Fig. 3A. Type LTSA 140 turbo-starter (Pre-Mod. S368 and Mod. S405)



16. Two igniter plugs are fitted into the casing of the combustion chamber and provide a continuous, but timed and controlled discharge of sparking from an H.F. ignition unit.

Safety discs

17. Fitted in the casing at the turbine end of the chamber are two safety disc assemblies, each containing a sheet metal diaphragm which ruptures when the gas pressure in the chamber rises excessively above the normal combustion pressures. On rupturing, the discs shear round their circumference and allow the gases to by-pass the nozzle plate and rotor and escape internally to atmosphere through the turbine exhaust volute.

Epicyclic reduction gear

18. Splined to the shaft of the rotor is a spur gear which meshes with and drives three planet gears, equally spaced and mounted in a fixed layshaft bearing housing located within the open end of an annulus gear assembly. The output shaft is connected to the closed, or dome end, of the annulus gear and is mounted in a self-aligning ball bearing in the rear bearing housing.

19. The three planet gears mesh with internal gear teeth inside the rim at the open end of the annulus gear, causing it to rotate. The rotary movement thus given to the annulus gear is transferred to the output drive shaft of the motor, which is located at its inner end by serrations in the dome end of the annulus gear. The output drive shaft is also serrated at its free end to accommodate a pinion which meshes with the gears in the aero-engine gearbox.

Speed control switch

20. Mounted on the end of the turbine rotor shaft is a centrifugally operated speed control switch. This switch is located inside the annulus gear and bolted to the face of the planet gear layshaft bearing housing at the dome end of the annulus. The inner portion of the switch is connected to and rotates with the turbine rotor shaft. The switch is set to come into operation at a pre-determined speed of the rotor shaft, and is connected electrically to the starter system control box. When the peak, or pre-determined speed of the rotor shaft has been reached, the centrifugal effect on the three balls in the cage moves the operating plunger and causes the switch to break electrical contact with the control box, and the starter system is automatically shut down.

Lubrication

21. Lubrication of the rotor bearings and the starter reduction gears is by splash, caused by the rotation of the gears in a bath of oil carried in the bottom of the gearbox housing. The oil is automatically replenished on each start from the aero-engine oil system by means of an oil feed piston incorporated in the aero-engine.

A gasket is provided to ensure an oil-tight seal between the engine and the starter flanges. For details of the oil system in the engine, see relevant

engine Air Publication. A labyrinth-type gas seal prevents leakage of gases from the rotor housing to the gear housing and special oil sealing is incorporated in the speed control switch to prevent oil from the gearbox fouling the contacts.

FUEL PUMP AND AIR BLOWER

22. The fuel pump and air blower are combined in a single unit and are driven by a 25V d.c. motor through a common drive shaft. The electric supply is obtained from the aircraft electrical supply system, and is automatically switched on by the control box at a pre-set point in the timed sequence of operations.

Fuel pump

23. The fuel pump is of the standard gear type, and is fitted with a pressure relief valve to safeguard the fuel system in the event of blockage of the fuel lines or other parts of the system. Also situated in the fuel pump casing is the air dump valve for the air blower. This valve is operated at a certain pressure above the by-pass pressure. The fuel supply is carried in an independent fuel tank conveniently located within the aircraft. From the pump the fuel is piped to the high pressure switch and anti-dribble valve, and from there it is either pumped to the atomizer head in the starter combustion chamber, or is by-passed back to the storage tank via the solenoid valve.

Air blower

24. The air blower is of the double rotor type and has a suitable filter incorporated. Air is passed through a passage in the pump casing to a pipe bolted to it, then through the pipe direct to the atomizer head. The blower is unloaded during the combustion period by means of the air dump valve located in the pump casing.

SOLENOID VALVE AND HIGH PRESSURE SWITCH

25. These two units are built-up as an integral component since their function is inter-dependent. The component is fitted into the fuel supply line, operation being controlled both electrically from the control box, and by variation in the fuel pressure.

26. When the two units are working in timed sequence, the fuel flow from the pump is so controlled that it may either be by-passed back to the fuel supply tank through one of the outlets, or it may be allowed to flow through a second outlet to the atomizer head in the starter motor combustion chamber, as the sequence of operations may warrant.

Solenoid valve

27. The solenoid valve, and its associated non-return valve, controls the flow of fuel from the fuel pump through the by-pass pipe back to the storage tank.

28. The valve assembly consists of a main spring-loaded valve and a port which can be opened or closed by the action of the solenoid. The valve is lifted off its seat by the pressure of the fuel acting on a shoulder on the valve skirt, thus allowing the fuel to flow into the by-pass pipe through the non-return valve back to the fuel storage tank. Energizing of the solenoid coil causes the valve to close under servo action.

29. Fuel also enters the bore of the valve by a small bleed hole and passes through an open port at the top, from where it is returned to the by-pass fuel line through interconnecting passages. Closing of this port by the action of the solenoid causes the valve to close hydraulically.

High pressure switch

30. The high pressure switch and its electric contact arrangement, provides for the starting cycle to be continued when combustion of the fuel has commenced. It further serves to switch off the ignition circuit which, once combustion has been initiated, is no longer required.

31. The unit incorporates an anti-dribble valve to prevent leakage of fuel into the system, and a micro-switch for breaking the electric circuit to the ignition unit.

Anti-dribble valve

32. The anti-dribble valve is a spring-loaded pressure-operated valve, seated in the fuel outlet passage to the starter motor atomizer head. The valve is located in one half of the high pressure switch assembly.

33. The valve has two functions, one to prevent the leakage of fuel into the starter motor during the air scavenging cycle, or while the starter system is standing idle under static conditions, and the other to admit the passage of fuel through an outlet to the combustion chamber of the starter motor during injection.

34. When the solenoid valve is closed, the flow of fuel from the pump through the by-pass pipe to the fuel tank is stopped. Fuel pressure builds up against a shoulder on the anti-dribble valve and lifts it off its seat, to allow fuel to flow to the starter motor combustion chamber.

35. When combustion takes place, the rapid rise in pressure in the combustion chamber is reflected back along the fuel line against the anti-dribble valve, lifting it further off its seating against a set of springs. The effect of this further movement is to operate the micro switch, thus breaking the electric circuit to the h.f. ignition unit but maintaining a supply to the motor contactor. Sparking at the igniters in the combustion chamber then ceases.

IGNITION SWITCH

36. The purpose of this switch is to make electrical contact between the main control box and the h.f. ignition unit, and thus to initiate the sparking of the starter motor igniters. This switch is fitted in

the fuel delivery line to the atomizer head of the combustion chamber and is actuated by the fuel pressure before combustion takes place.

37. As the pressure builds up in the fuel line, it acts on a diaphragm which moves a spring-loaded plunger upwards to operate a micro switch. This switching de-energizes the slugged relay in the control box and switches on the ignition.

H.F. IGNITION UNIT

38. The h.f. ignition unit is a special high energy, high frequency type having a high sparking range over a wide temperature variation and provides energy to the igniters which initiate combustion of the fuel/air mixture following the injection of fuel into the starter combustion chamber.

39. The two igniters are energized through a vibrator transformer and high frequency transformer incorporated in the h.f. unit giving an almost continuous rate of sparking. Sparking is virtually instantaneous once the electric circuit has been initiated by the ignition switch.

CONTROL BOX

40. This unit controls the timed sequence of operations for the whole starting system. It incorporates a motor-driven cam-operated time switch, and a relay unit comprising a slugged relay and a speed control relay. The box also serves as a junction box for the electrical services of the starter system.

Sequence of operation

41. The system is designed to operate between 16 and 26 volts; this supply is available at the starter push button through the 10 amp. fuse and switch A in the control box. On pressing the starter push button, current is fed to the speed control switch and relay R2, then to the negative supply point. The energizing of relay R2 makes the contacts R2 which then allow the positive supply to be fed through the normally closed contacts of the H.P. switch and ignition switch to the slugged relay, R1/2; at the same time current is fed to the motor contactor which is pulled in and allows current to pass to the pump unit through heavy duty leads. The energizing of the slugged relay R1/2 makes contact R1(A) which provides an alternative circuit from the positive supply through switch F to the speed control switch and relay when the circuit through the starter button is opened on releasing the starter button. Contacts R1(B) make immediately after R1(A) thus supplying current through switch B to the time switch motor.

42. Immediately the time switch motor is energized, the clutch is engaged between the motor and the camshaft operating switches B, D, E and F, and switch A is operated.

After $\frac{3}{4}$ sec of the time switch motor operation, switch D is operated. After $2\frac{3}{4}$ seconds switch E is operated by the camshaft thus energizing the solenoid valve.

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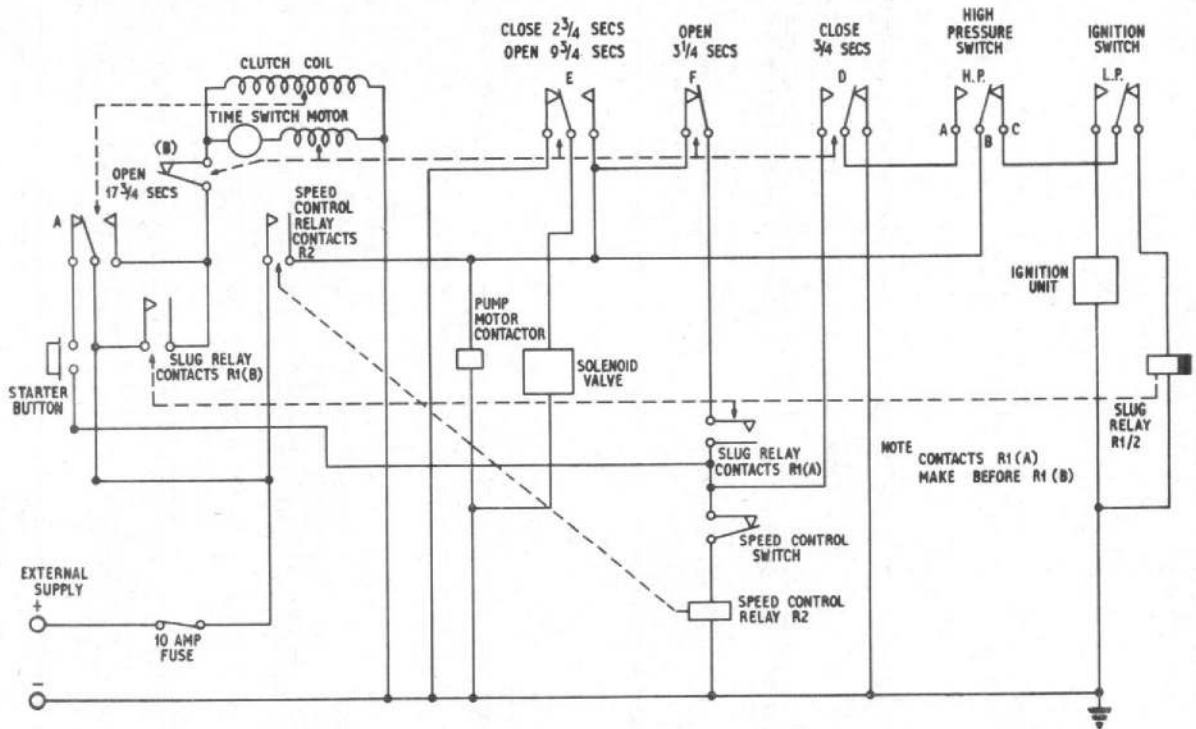


Fig. 4. Circuit of diagram of control box

Note . . .

During this $2\frac{3}{4}$ seconds the fuel pump has been by-passing the fuel back to the tank and the air blower delivering air to the combustion chamber. Operation of the solenoid valve closes the by-pass port and diverts the fuel through the supply line to the combustion chamber. The H.P. and ignition switches are in communication with the fuel in that supply line.

43. Fuel pressure builds up in the supply line to the combustion chamber, opens an air dump valve close to the air blower and spills the air to atmosphere. The rise in fuel pressure also operates the ignition switch thus cutting the circuit to the slugged relay R1/2 and bringing the ignition unit into circuit. The energizing of the ignition unit causes sparking to occur at the igniters in the combustion chamber thus igniting the fuel/air mixture. The rise in pressure due to combustion is reflected along the fuel supply pipes and operates the H.P. switch, thus making an alternative circuit to the speed control switch and relay via switch D, by-passing the slugged relay contacts R1 (A).

44. The de-energizing of the slugged relay R1/2 causes contacts R1 (A) and R1 (B) to open after 0.18 seconds. If combustion does not take place the H.P. switch will not be operated and the circuit to the speed control switch and relay is broken, which allows contacts R.2 to open, breaking the circuits to the motor contactor and solenoid valve; the starter, therefore, shuts down.

45. A slugged relay is used to provide a shut down of the starter before an excessive quantity of fuel is pumped into the combustion chamber if ignition of

the fuel does not occur within 0.18 seconds. An additional safeguard is the opening of switch F between 0.3 and 0.5 seconds after switch E is closed, which will automatically break the circuit if the slugged relay contacts remain closed for any reason.

46. Assuming combustion takes place satisfactorily, the starter turbine rotor accelerates to 44 000 rev/min (38 000 rev/min on some L.T.S.A. 70 starters) and turns the engine rotating assembly through reduction gearing. At this speed the speed control switch is operated, breaking the circuit to the relay R2 and the starter is shut down by the opening of contacts R2.

47. The normal combustion time is about 6 seconds when the starter reaches its maximum speed and is shut down by the operation of the speed control switch. The control box time switch motor will continue to operate until switch B is opened by the camshaft after about $17\frac{3}{4}$ seconds. During this time, switch E is opened by its cam, 7 seconds after it was closed. This action is designed to cover the circumstances when, for some reason such as a stiff engine, the starter does not reach its maximum speed and the speed control switch contacts are not opened. The opening of switch E breaks the circuit to the solenoid valve causing the fuel to be by-passed to the fuel tank and the starter therefore shuts down.

48. When the time cycle of the control box ends with the opening of switch B, the control box is automatically reset to the starting condition in readiness for another start.

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MOTOR CONTACTOR

49. The motor contactor in normal use is solenoid-operated and is used to control the supply to the electric motor driving the fuel pump and air blower. The solenoid is energized from the aircraft supply via the control box circuits.

On certain types of aircraft installations, a different type of motor contactor is used. Reference should, therefore, be made to the relevant airframe Air Publication for details of the type of contactor fitted.

ELECTRICAL SYSTEM

50. For detailed information on the electrical system, and the units concerned, reference should be made to the following Air Publications:—

(1) Control box, motor contactor, high pressure switch and solenoid valve, ignition switch, ancillary switches and cockpit push button are described in Air Publication 4343C, Vol. 1.

(2) The high frequency ignition unit is covered in Air Publication 1374G, Vol. 1.

(3) The motor driving the combined fuel pump and air blower is described in Air Publication 4343D, Vol. 1.

SEQUENCE OF OPERATION

General

51. As previously mentioned, the IPN starter system consists of a number of mechanical units in an electrical circuit which are so inter-related as to produce a definite timed sequence of operation. From the time the push button in the cockpit is pressed to the moment when the aircraft engine is idling under its own power, each unit comes into play in a controlled time cycle. This sequence of operation is described in the following paragraphs.

52. For the purpose of this description, the operations have been divided into the following main stages. Each stage has been diagrammatically shown in a corresponding illustration. These stages, in the correct sequence of operation, are:—

1. SCAVENGING See fig. 5
2. INJECTION See fig. 6
3. IGNITION See fig. 7
4. COMBUSTION See fig. 8

SCAVENGING

Initiating the time cycle

53. A positive voltage from the aircraft electrical system is passed through an internal 10 amp fuse and closed switch A in the control box to the starter push button in the aircraft cockpit. On pressing the starter button current is fed through the speed control switch (*normally closed on starting*) to the coil of the speed control relay, which is energized.

54. Current then passes from the main supply and 10 amp fuse, through the contacts of the speed control relay, high pressure switch and ignition switch, to the coil of the slugged relay which is energized; its contacts perform two functions.

(1) Group R1 (A) provides an alternative supply, when the starter button is released, from the fuse through the closed contacts of the speed control relay, switch F, contacts R1 (A) and the speed control switch to the coil of the speed control relay.

(2) Group R1 (B) contacts complete a circuit from the supply fuse through switch B to the time cycle motor to start the timing sequence.

55. When the time cycle motor is energized, a magnetic clutch is engaged and connects the motor to a cam shaft which opens and closes switches D, E and F in a pre-determined time cycle. The motion of the magnetic clutch is linked to switch A and closes this switch when the clutch is energized to ensure a continuous supply to the motor until the time sequence is complete. At the same time, switch A interrupts the supply from the fuse to the starter push button.

Note . . .

The push button may be depressed further for a maximum period of 16 seconds without initiating a fresh cycle.

Combined fuel pump and air blower motor

56. The contacts of the speed control relay (*para. 54*) also complete a circuit to the coil of the motor contactor, the contacts of which connect a direct supply to the motor driving the fuel pump and air blower.

57. Fuel is pumped from the supply tank past the anti-dribble valve in the high pressure switch to the solenoid valve. The pressure of the fuel opens the solenoid valve which allows the fuel to return to the supply tank through the non-return valve located in the outlet connection from the solenoid valve. At the same time air from the blower is discharged into the starter combustion chamber and scavenges the chamber of any gases which may remain from a previous start. These gases are exhausted to atmosphere through the exhaust volute of the starter.

58. Switch D is incorporated as a safety device. Should there be a short between A and C contacts, or associated wiring, in the high pressure switch, the current passing through normally closed switch D to earth, would blow the fuse. The contacts of switch D open 0.75 seconds after pressing the starter button.

59. A further safety device, switch E is incorporated to prevent possible operation of the starter should there be any contact between the motor contactor wiring (*fig. 4*) and the solenoid wiring; the current would pass through the closed switch E to earth and blow the fuse.

60. Also, at this period in the time cycle, the circuit of the fuel and air pump motor contactor is maintained in the energized condition via the contacts of the speed control relay (*see para. 56*).

INJECTION

61. The scavenging operation described in the previous paragraphs continues for approximately 2.75 seconds. At this period in the time cycle, switch E is closed by the action of the time motor cam and current is fed to the solenoid valve. Energizing the solenoid closes the valve leading to the fuel by-pass pipe, and the flow of fuel back to the supply tank is stopped. Any surge that may occur in the by-pass fuel line due to the closing of the solenoid valve is prevented from affecting the system by the non-return valve.

62. The action of closing the solenoid valve raises the fuel pressure on the anti-dribble valve in the high pressure switch, lifting the valve off its seat and allowing fuel to flow along the pipe leading to the atomizer head in the combustion chamber. The fuel then passes through a fuel valve and swirl chamber into the combustion space. The electrical circuit and position of the valves during this stage are illustrated in fig. 6.

IGNITION

63. This stage in the timed sequence of operations is illustrated in fig. 7.

64. As the fuel pressure builds up due to the restriction of the atomizer, the air dump valve in the pump casing is opened and air is spilled into the atmosphere, thus relieving the load on the blower.

65. The continued increase in the build-up of fuel pressure in the pipe line to the combustion chamber acts on a diaphragm in the ignition switch located in this fuel line. The movement of the diaphragm against its spring-loaded push rod operates the micro switch, breaks the circuit to the slugged relay, and brings into circuit the high frequency ignition unit. This occurs after approximately 3 seconds in the timed sequence of operation.

66. The energizing of the high frequency ignition unit causes high frequency sparking across the gaps of the two igniter plugs fitted into the casing of the starter combustion chamber. This sparking initiates the combustion of the fuel/air mixture now present in the combustion chamber.

COMBUSTION

67. The initial combustion of the fuel/air mixture rapidly increases the pressure and temperature in the combustion chamber, and allows the incoming fuel to decompose as a mono-fuel without the addition of more air. The gases resulting from this combustion are forced through a series of convergent-divergent nozzles on to the blades of the turbine rotor, causing it to rotate and accelerate rapidly to its operating speed.

68. The increase of pressure in the combustion chamber is reflected back down the fuel supply pipe line on to the anti-dribble valve in the high pressure switch. This causes the valve to lift further off its seating (see para. 35), and to act on a spring-loaded push rod. Movement of this push rod operates the

micro switch at a fixed fuel pressure and interrupts the circuit through the ignition switch to the h.f. ignition unit. Sparking at the starter igniters then ceases. The combustion, once initiated continues for 5.5 to 7 seconds, depending on engine starting conditions.

69. At the same time that the circuit to the ignition switch is interrupted by the action of the high pressure switch, an alternative circuit is completed to the speed control switch and the coil of the speed control relay.

70. The high pressure gases resulting from combustion cause the turbine rotor to accelerate to maximum rev/min. At this speed, the pre-set speed control switch on the rotor shaft comes into operation and automatically breaks the circuit to the speed control relay, thereby opening the relay contacts. This breaks the whole electrical circuit and the starter system ceases operation.

71. In the normal and successful start in the timed sequence of operation, this stage is reached in less than 10 seconds, and the aircraft engine accelerates to its idling speed under its own power. Fig. 8 shows diagrammatically the various phases in the combustion stage of operation.

72. The time cycle motor in the control box completes its time cycle with the opening of switch B after approximately 18 seconds. At this point the cam assembly automatically returns to the start position ready for another engine start.

73. In circumstances where the starter system fails to make a successful start, or due to extraneous causes, such as a stiff engine, the starter is slow in making a start, certain safety devices come into operation. These devices are designed to prevent damage to the starter system, and to avoid the likelihood of injury to personnel operating the starter system. The various safety devices are described in greater detail in the succeeding paragraphs 75 to 86.

74. The procedure to be taken to correct any defects in the system, or to remedy a failure in case of an unsuccessful start are described in Fault diagnosis.

SAFETY DEVICES

General

75. The numerous safety devices incorporated in the starter system may be classified in two main categories.

- (1) Those which are mainly mechanical in their operation, and are an integral part of the unit in which they are fitted, and
- (2) Those which are basically electrical in their function, and become operative in the normal sequence of operation of the system.

The safety devices could operate as the result of a defect in the aero-engine, or consequent upon an internal disruption of the starter system caused by any extraneous mechanical or electrical defect.

Safety discs

76. Two safety disc assemblies are fitted in housings in the casing of the combustion chamber. They are fitted diametrically opposite to each other at a point near to the combustion chamber nozzle plate (fig. 3, item 4). Each assembly contains a metal disc of nickel, which is in direct contact with the pressurized gases formed during combustion in the chamber. The discs are designed to shear at a pre-determined pressure within the limit of safety of the structure of the starter motor.

77. If, for any reason the pressure builds up excessively in the combustion chamber, the metal discs shear round their circumferential edge and allow the gases to escape through ports into the exhaust volute and so to atmosphere, thus by-passing the turbine rotor.

78. The shearing of a safety disc is indicated visually on the outside of the safety disc housing by the projection of the disc stem, which is displaced from its normal position.

79. When a disc shears, it must be replaced by a new disc before another start is attempted.

Speed control switch

80. This is operated by a centrifugal-type governor mounted on the turbine rotor shaft and is connected in series with the coil of the speed control relay. The switch is pre-set to operate when a pre-determined speed is reached by the rotor shaft.

81. In a normally successful start the speed control switch comes into operation when the rotor has reached maximum rev/min. This breaks the circuit to the speed control, de-energizing the relay and opening its contacts, thus breaking the circuit to the motor contactor, when the system will cease to operate and the starter motor will run-down.

82. As the rotor shaft slows down, the speed control governor will automatically re-set itself, and a connection is made through the speed control switch to the relay. No action is necessary to prepare the starter for a new start.

Slugged relay

83. The slugged relay is a component part of the control box. It is used to switch in the time cycle motor on initial starting and to provide a shut down of the starter when combustion does not occur and so prevent the continued flow of fuel to the combustion chamber.

84. If combustion does not take place, the slugged relay which has already been de-energized by the operation of the ignition switch through the build-up of fuel pressure in the combustion chamber pipe line, will open its contacts after 0.18 seconds. This causes the circuit to speed control switch and relay from switch F to be broken and this in turn breaks the circuit to the motor contactor and solenoid valve through the speed control relay contacts and the starter system ceases to operate. This automatic shut-down of the system will occur when the fuel fails to ignite or combustion is not sustained.

85. An additional safeguard to the starter system is also provided should the contacts of the slugged relay remain in the closed position. In the event of such a failure, the opening of switch F later in the time cycle, automatically shuts down the starter system. Switch F operates 3.2 seconds after commencement of the time cycle.

86. Another safety device which comes into operation should the start be protracted or the speed control switch not operate, is the re-opening of switch E. This de-energizes the solenoid valve, and by-passes the fuel back to the supply tank. The operating time for switch E (*in seconds after the commencement of the time cycle*) is 9.75 seconds.

PREPARING FOR SERVICE

87. Before installing the starter on the engine inspect all external parts for damage and ensure that all locking is correct and secure. It is particularly important to examine the ignition and speed control switch leads for damage, and to make a continuity check between the two pins of the speed control switch plug. A check must also be made between both pins and earth to ensure that earthing is not occurring.

88. After removing the various protective coverings and blanking caps, drain any inhibiting oil from the starter gearbox by removing the oil filler plug. After draining, inject 100 cm³ of oil (OX-38) into the gearbox, replace and lock the plug.

89. As the oil in the starter gearbox is supplied and replenished from the main engine oil system, it is important to ensure that the oil feed hole in the starter mounting flange is clean and unobstructed and that the starter is installed so that the feed hole in the starter flange is aligned with the hole in the aero-engine starter mounting flange.

90. Check that the starter output shaft is free to rotate in either direction.

91. Detailed instructions for installing the starter on the aero-engine are given in the relevant engine Air Publication.

FUEL PRIMING AND FAIL-SAFE CHECK

General

92. It is essential that, after the initial installation of a starting system, or when either the starter electrical or fuel system has been disturbed, the priming procedure, as follows, is carried out. These priming checks ensure that there are no obvious fuel leaks in the system, and that the starter is failing-safe. The essential checks which must be made are:—

(1) A combined fail-safe and fuel priming check, which must be carried out after the initial installation of a starting system or whenever the fuel system has been disturbed.

(2) A fail-safe check which must be carried out whenever the starter electrical system has been disturbed. The check must also be carried out after each minor servicing of the aircraft

as a check against any deterioration occurring in the electrical circuits, or mechanical parts, of the starting system. ◀ The amount of fuel emitted from the exhaust, after each of these checks, must be recorded. ▶

(3) In order to minimize the risk of fire due to fuel leaks on Canberra and Lightning aircraft an inspection of the atomizer to fuel pipe joint must be made during, or immediately after, a fail-safe check. In Lightning aircraft a small piece of rag is to be wrapped around the joint to absorb and indicate any leakage.

Note . . .

It is important that no attempt be made to perform a fail-safe check when the starter is hot, as the draining fuel will vaporize and may become ignited by the hot exhaust pipe. At least one hour should elapse after a start before a check is attempted. If fuel vapour is then still present, a further wait of half-an-hour is necessary.

Combined fuel priming and fail-safe check

93. In this check the following sequence of operations must be followed.

(1) Fill the tank with Iso-propyl nitrate fuel (AVPIN).

Note . . .

Ensure that the fuel is clean and that it is poured through the filter in the tank filler neck.

(2) Disconnect the 2-pin socket from the ignition unit: this renders the ignition system inoperative and prevents any combustion from taking place.

(3) Using either the aircraft batteries, or those of a ground starter trolley giving not more than 26 volts on load, carry out a simulated start by pressing the starter button in the cockpit. The air cycle should function for about three seconds and then the starting system will shut down. After shut-down, some fuel may drain from the starter exhaust pipe. This fuel should be collected in a suitable tray or container which can be moved when actual starting is to be carried out.

(4) After allowing the control box to run out (after about 18 seconds), and allowing any fuel to finish draining from the exhaust, press the cockpit starter button again. Check the fuel system for leaks.

(5) ◀ Repeat the operation detailed in sub-para. (4) seven times more and measure the quantity of fuel draining from the exhaust after each of the last three runs. ▶

(6) If the starter system is failing-safe, both mechanically and electrically, the quantity of fuel which drains from the exhaust should be within the limits specified for the particular aircraft installation (sub-para. 9). Approximately three-quarters of the normal fuel drainage occurs during the first minute, and the remainder, other than odd drops, during the next minute. Although normal quantities of fuel cannot be expected to drain during initial priming runs, the rate of drainage should follow the same pattern.

◀ (7) During this check, laboured operation of the pumping unit, which can be heard, and a lack of pressure which should be felt against a hand held over the exhaust, will indicate a sticking air valve in the atomizer. Refer to para. 116 and 120 to check and rectify and, on completion, continue with priming and fail/safe checks until fuel emerges from the exhaust pipe. As, at this stage, fuel may be running through one of the lower apertures in the nozzle plate and not the drain hole, it is necessary to check the nozzle drain as detailed in para. 122, on the successful completion of which, continue with the fail/safe check. ▶

(8) Where the fuel drainage does not follow the correct pattern, in that either the fuel stops draining early or continues to drip steadily, the nozzle plate drain hole may be blocked, in which case check for a blocked drain hole as described in para. 122.

(9) With a supply of 23 to 26 volts on load, measured at a convenient point as near as possible to the pumping unit, the quantities of fuel which drain from the exhaust should fall within the following limits:—

Groups 5 and 23	...	80 to 100 cm ³
Group 8	...	80 to 110 cm ³
Groups 5/1, 5/2 and 5/3		80 to 125 cm ³

If the quantities are not within these limits refer to fault diagnosis, ◀ para. 117, 122 and 123, and rectify.

Note . . .

Partial blockage of the nozzle plate drain hole would cause repeated low fuel drainage, the remaining fuel emitted being retained in the combustion chamber; at the first actual start this fuel would ignite and cause serious damage to the starter. ▶

WARNING . . .

Under no circumstances should a start be attempted if the fuel drainage exceeds these stipulated quantities.

(10) Remove any traces of fuel round the exhaust pipe, and remove the tray or container.
(11) Re-connect the 2-pin socket to the ignition unit. The starting system can now be used for normal starting operations.

Fail-safe check

94. This check must be carried out in exactly the same manner as the combined fail-safe and fuel priming check, except that only three air cycle runs need be made. The fuel drainage should be measured on each run. If the fuel drainage is less than the maximum permitted on each run, a normal start can be made.

OPERATION

95. The starter is operated by momentarily depressing the starter button in the aircraft cockpit. This action pulls in the speed control relay which then energizes the slug relay thus passing a current to the time switch, and the timed sequence of operation commences.

96. The aero-engine ignition system is wired into the starting system and is brought into operation automatically.

97. The starting system control box runs for approximately 18 seconds before re-setting itself for another start, irrespective of whether the starter operates correctly or not, or whether the cockpit starter button is depressed within that time.

98. The sequence of operation of the starting system can be stopped at any time by switching off the electrical supply to the control box. The actual method of switching off this supply depends on the design of the aircraft electrical system, and reference should be made to the relevant aircraft Air Publication for details.

99. If the starter system fails to operate correctly reference should be made to the fault diagnosis chart given at the end of this chapter.

PRECAUTIONS

WARNING . . .

All personnel must keep clear of the aero-engine air intake and the starter exhaust pipes when a start is about to be made.

Intervals between attempts to start

100. There must be an interval of not less than one minute between each attempt to operate the starter. The time interval between normal starter operation should be kept as close as possible to the minimum of one minute to prevent heat soakage affecting the operation of the starter, except when cooling is provided by engine running.

Operation resulting in normal engine start

101. Three normal engine starts may be made from cold at short intervals, minimum one minute between each start, but a cooling period of 45 minutes, or an engine run of at least 15 minutes, must precede a fourth or further single start.

Starter operates normally but engine fails to light up (dead crank)

102. (1) *Hunter 6 variants.* Three successive attempts to start the engine from cold may be made with intervals as close as possible to one minute between each dead-crank. A fourth and any subsequent attempt to start should only be made with an interval for cooling, of 45 minutes between each attempt.

(2) *Lightning Mk. F1, F1A, F2, T4 aircraft without Mod. S 393 embodied, and Canberra P.R.9 aircraft.* Only two successive attempts may be made to start the engine from cold, the third attempt must not be made until a cooling period of 45 minutes has elapsed. If this results in another dead-crank a further cooling period of 45 minutes must elapse before the fourth attempt. Should this also result in a dead-crank the cooling period between subsequent attempts is to be increased to 90 minutes.

(3) *Lightning Mk. F1, F1A, F2, T4 aircraft with Mod. S 393 embodied, and Canberra P.R.9 aircraft.* The intervals between starts will be as for Hunter 6 variants, sub-para. (1).

(4) *Lightning Mk. F3.* The intervals between starts will be as for Hunter 6 variants, sub-para. (1).

Engine fails to start

103. In the event of the engine failing to start the cause must be investigated. Reference should be made to the relevant aero-engine Air Publication.

FAULT DIAGNOSIS

General

WARNING . . .

The aircraft batteries must be disconnected during continuity tests.

104. The following sequence of fault diagnosis is applicable to all installations of the IPN starter system in which the Mk. 8 and Mk. 9 control boxes are used. In some installations the inaccessibility of the components may be such that the electrical tests detailed in the following paragraphs cannot be carried out exactly as stated. When this condition arises, the check should be carried out as near as possible to the component, using the aircraft wiring diagram for reference.

105. Four types of failure to start may be experienced; these are as follows:—

(1) Starter fuse blows when an attempt to start is made.

(2) System fails to start when the cockpit push-button is pressed.

(3) A-failure, i.e. when combustion of the fuel in the combustion chamber does not take place and the starter system ceases to operate after 0.5 to 3.2 seconds.

(4) B-failure, i.e. when combustion is initiated in the combustion chamber but is not maintained for the normal 5 to 7 seconds. This failure can normally be recognized by a heavy discharge of gases from the exhaust pipe over a very short period, followed by the shutting down of the starter system. Six attempts should be made to start before making the necessary checks where A- or B-failures have occurred.

Failure of starter to operate correctly (A-or B-failures)

106. If starter combustion does not occur, A-failure, or occurs for less than one second, B-failure, wait one minute before the next attempt to start. Up to six attempts to start may be made where A- or B-failures occur each time, as no heat factor is involved. Following these attempts the cause of the failure must be investigated. Further attempts to start may be made immediately after rectification.

WARNING . . .

If for any reason the iso-propyl-nitrate fuel catches fire, carbon tetrachloride type fire extinguishers MUST NOT be used as they tend to spread the fire. Foam or CO₂ type fire extinguishers ONLY should be used. In an emergency a continuous spray of water is quite effective.

Starter system 10 amp fuse blows on pressing the starter button

107. (1) Check the following for shorting to earth:—

(a) Starter button circuit.

(b) Speed control switch.

(c) Positive side of the motor contactor.

RESTRICTED

- (d) Pin A lead of the high pressure switch.
- (e) Pins A and B of the ignition switch.
- (2) Check the following for shorting between leads:—
 - (a) Positive lead of the motor contactor and supply pin of the solenoid valve.
 - (b) Pins A and C of the high pressure switch.
- (3) If combustion takes place immediately after pressing the starter button and the 10 amp fuse blows, check whether:—
 - (a) The solenoid valve has stuck closed.
 - (b) There is any continuity between pin C in the red socket and pin B in the blue socket of the control box. If there is continuity then the E contact has stuck in the closed position.

System fails to start

108. Should the system fail to start after pressing the starter button in the cockpit check the 10 amp fuse and associated wiring in the supply circuit to ensure the current is reaching pin A of the 2-pin socket in the control box.

Note . . .

The supply into the control box on Lightning Mk. 1, 1A, 2 and 4 aircraft is fed through an auxiliary relay from the positive busbar positioned in the spine of the aircraft fuselage. If the fuse is intact, refer to the aircraft wiring diagram and check this relay and its associated wiring.

109. If the fuse is intact check the circuit of the speed control relay as follows:—

- (1) Disconnect the blue-painted socket from the control box and check the continuity between pins A and D. If there is no continuity, disconnect the speed control lead socket from the starter and test the individual leads for continuity. If these are correct, the speed control switch is at fault and the starter should be changed.
- (2) Test the speed control switch leads for insulation to earth through the airframe.

WARNING . . .

ON NO ACCOUNT may an attempt be made to short-circuit a defective speed control switch as extensive damage may be caused to the starter.

110. If the starter pumping unit starts up, but closes down when the cockpit push button is released, the high pressure switch and ignition switch circuits should be tested as follows:—

- (1) Ensure that there is continuity between pins A and B in the plug on the ignition switch.
- (2) Ensure that there is continuity between pins A and B on the high pressure switch.
- (3) Ensure that there is continuity in the lead which connects pin B on the high pressure switch with pin A on the ignition switch.
- (4) Ensure also that there is continuity between the lead from pin B on the ignition switch to pin D in the red painted socket on the control box.

- (5) Ensure that there is continuity in the lead from pin A on the high pressure switch to the positive connection on the pump contactor.

A-FAILURES

WARNING . . .

The aircraft batteries must be disconnected during continuity tests.

Fuel drains from exhaust but combustion does not occur

111. Whenever combustion does not occur, proceed as follows:—

- (1) Check that the battery is fully charged; if not, change the battery and recheck.
- (2) Connect a 24-volt lamp across pins A and B of the 2-pin socket which has been removed from the ignition unit (*para.* 93 (2)) then carry out a fail-safe check.
- (3) When the fuel drains the lamp should light for 0.18 seconds before the system shuts down, thus proving the l.t. supply to the ignition unit.

112. If the lamp does not light before the system shuts down, proceed as follows:—

- (1) The solenoid valve may be sluggish in operation or may not be closing completely, in which case disconnect the 2-pin socket from the solenoid valve and connect an external 24 volt supply with a switch in circuit. Exercise the valve six times and, finally, with the external supply still connected, carry out another fail-safe check. Operate the solenoid valve after one or two seconds of the air cycle have elapsed and observe the test lamp in the ignition socket. If the lamp lights disconnect the external supply of the solenoid valve and reconnect the aircraft socket, then carry out a routine sequence of three fail-safe checks. Should the valve still be sluggish it must be changed.

- (2) Check the continuity between pin C in the socket of the ignition switch and pin A in the 2-pin socket of the h.f. ignition unit. Rectify if necessary and recheck the operation of the ignition system. If there is no supply from the ignition switch, this will be faulty and must be changed.

113. If the lamp lights the l.t. supply is not at fault. Check that the h.f. ignition unit is operating, as follows:—

- (1) Disconnect the igniter leads and fit slave leads and igniter plugs.
- (2) Carry out a fail-safe check with the 2-pin socket connected to the ignition unit and check for strong sparking which should be maintained for 0.18 seconds.
- (3) If only weak sparking is apparent change the h.f. ignition unit and recheck for strong sparking.

114. If all the foregoing checks are satisfactory the fault will be in the leads to the igniters or in the igniter plugs. To check, proceed as follows:—

(1) Disconnect the h.t. leads from the ignition unit and check the insulation of the igniter leads and plugs combined. Using a 500-volt megger the reading obtained must be not less than 0.5 meg/ohm. Should it be below this figure, disconnect the igniters from the leads and check each individually, the resistances indicated must not be less than:—

- (a) Igniter leads, 5 meg/ohm
- (b) Igniter plugs, 0.5 meg/ohm

Change lead or plug as necessary.

(2) If the fault cannot be traced using a 500-volt megger, carry out a fail-safe check with the l.t. supply connected to a known serviceable ignition unit with the slave igniters installed in a sealed box with a transparent lid, connected to the aircraft h.t. leads. If sparking is satisfactory the igniters will be at fault and should be changed, if the sparking is weak change the leads.

Note . . .

The use of a standard h.t. tester is not recommended as the insulation of the h.t. leads is easily damaged when subjected to h.t. current for periods of more than one second.

115. Recheck the operation of the starter and, if this is still faulty it should be changed.

Air valve stuck in the closed position

116. An air valve which is stuck in the closed position will prevent air scavenging and cause an A-failure. If the valve is stuck closed the pumping unit will be very laboured in its operation and this can definitely be heard. During a fail-safe check scavenging air pressure should be felt against a hand held over the exhaust. If pressure is not felt, the air valve should be flushed as detailed in para. 121.

Fuel does not drain from exhaust pipe

117. Blockage of the nozzle plate drain hole may be caused by particles of carbon washed from the walls of the combustion chamber, particularly after engine or starter change. Should two consecutive A-failures occur without normal fuel drainage, a third attempt to start must not be made until a fail-safe check has been performed to confirm that the hole is clear. When fuel does not drain from the exhaust pipe after two attempted starts proceed as follows:—

- (1) Ensure that there is fuel in the supply tank.
- (2) Check that the fuel pump and air blower motor starts at the beginning of the starter time cycle. If the pump motor fails to start, apply the tests detailed in para. 131.
- ◀(3) If the correct quantity of fuel does not drain after the motor check, apply the checks detailed in para. 122. ▶
- (4) If the starter stops after approximately 3.2 seconds and fuel does not drain from the exhaust pipe, test the supply to the solenoid

valve by removing the 2-pin socket and checking that a test lamp placed across pins A and B lights momentarily after about 2.75 seconds during a fail-safe check. If the lamp lights the solenoid valve is faulty and must be changed. If the supply to the lamp is not satisfactory, test for continuity between the supply pin in the 2-pin socket of the solenoid valve and pin C in the 4-way, red painted, socket on the control box; rectify if necessary. Ensure there is continuity between the negative pin in the valve socket and the negative terminal. If these leads are correct the fault must be in the control box which must be changed.

B-FAILURES

WARNING . . .

The aircraft batteries must be disconnected during continuity tests.

Fuel supply

118. Ensure that the batteries are fully charged. Low battery voltage will cause low fuel output from the pump resulting in insufficient fuel being available to sustain combustion. If necessary change the batteries.

119. Check the contents of the fuel supply tank; replenish if necessary.

Sticking air valves

120. An air valve which sticks closed, or nearly closed, causes poor air scavenging and very late initial combustion, particularly after a previous start. Check for a sticking air valve as detailed in para. 116, or by pressurizing the air pipe from an external source. The air valve in the atomizer head should open at 2 to 3 lb/in² and close again on reduction of the pressure. Where possible the air valve assembly should be removed and thoroughly washed in hot water, or it may be flushed in situ with hot water as detailed in para. 121.

Cleaning air valve and guide in situ

121. The air valve seating and guide may be cleaned in situ without removal of the engine from the airframe as follows:—

Hunter aircraft installation

- (1) Disconnect the flexible air hose at the junction with the aircraft rigid pipe and connect it to a convenient extension hose so that the hose assembly can be drawn up through the panel above the starter bay, thus leaving the air valve at the lowest point.
- (2) Connect a low pressure air supply to this extension hose and, commencing at 10 lb/in² increase the pressure until the air valve opens. This will be indicated by the passage of air through the starter exhaust pipe.
- (3) Disconnect the air supply and pour into the extension hose 50 cm³ of boiling water. Allow to stand for 15 minutes.
- (4) Reconnect the air supply, adjust the pressure to 30 lb/in² and blow through the air valve for one minute.
- (5) Disconnect the air supply and the extension hose and reconnect the flexible air hose to the aircraft rigid pipe.

Lightning aircraft installation

(6) On the lower engine (No. 1) disconnect the flexible air hose on the port side of the engine at a junction adjacent to the low pressure switch behind the D panel, 20 P (refer to Air Publication 4700 A and F, Vol. 1, Book 1) and on the upper engine (No. 2) the rigid air pipe at the rear of the spine where it enters the aircraft skin.

(7) Carry out the operations detailed in sub-para. (2), (3), (4) and (5) but, after inserting the boiling water apply a momentary burst of air pressure to ensure that the water reaches the valve.

Canberra aircraft installation

(8) Remove the leading edge panel on the main plane between the engine nacelle and fuselage as detailed in Air Publication 4326J, Vol. 1, Book 1, then disconnect the air hose at a convenient position in the engine nacelle. Carry out the flushing operations detailed in sub-para. (2), (3), (4), and (5), but, after inserting the boiling water, apply a momentary burst of air pressure, to ensure that the water reaches the valve.

(9) During these cleaning operations some carbon may be dislodged from around the atomizer air holes or from the walls of the combustion chamber and obstruct the drain hole at the bottom of the nozzle plate. Carry out a fail-safe check, and, if the quantity of fuel which drains is more than 40 cm³ carry on normal starting. If it is less than 40 cm³ repeat the fail-safe check once only, if it is again less than 40 cm³ the drain hole will be blocked. Normal starting is permissible only if 40 cm³ of fuel is drained out at the second check. If the drain hole is blocked rectify as detailed in para. 122.

Blockage of nozzle plate drain hole

122. To clear a blocked drain hole, proceed as follows:—

(1) Remove one safety disc and inspect the inside of the chamber for a quantity of fuel lying in the bottom. Use a standard R.A.F. type probe torch.

(2) If complete blockage of the drain has occurred, attempt to clear it through the port safety disc hole using a piece of wire, hooked at the end. The drain hole is drilled through the plate at an angle running from starboard to port. If the fuel cannot be drained from the chamber by this method, the starter must be changed.

(3) Clearance of the drain hole must be followed by a fail-safe check before a start is made, following the instruction in sub-para. (4) if partial blockage occurs.

(4) If partial blockage only has occurred, check that the total fuel drainage from ONE fail-safe check complies with the normal fail-safe check requirement. If this is satisfactory,

confirm that the chamber is empty as in sub-para. (1) and then carry out a start which will completely clear the drain hole.

◀ Fuel consumption check ▶

123. Carry out a fail-safe check as detailed in para. 93, to discover the quantity of fuel ejected (sub-para. (9)). If much less than the specified amount drains from the exhaust pipe, make the following checks:—

(1) Check that the fuel consumption of each start, taken from periodic checks, has not shown a decline. If it has, the fuel pump is suspect, alternatively there is a partial blockage, or an air leak, in the fuel feed to the pump. Check the fuel lines and supply tank, including the vent. If these are satisfactory, change the fuel pump assembly.

(2) Disconnect the pipe leading from the solenoid valve to the tank at the solenoid valve and check that the valve is closed. Also check that it opens and closes freely against its spring pressure.

(3) Check the electrical operation of the solenoid valve by placing a 24-volt supply across the pins in the valve socket, and check that a light click is audible; if a click does not occur, change the complete solenoid valve. Where the operation appears to be satisfactory, check the leads to the solenoid for an intermittent fault. Refer to para. 111.

(4) If the solenoid is not operating fully, or is operating sluggishly, it should be exercised six times as detailed in para. 121 (1).

Note . . .

The solenoid must not be energized for more than 15 seconds at any one period. It must not be energized for more than a total of two minutes during any ten minute period or the solenoid windings will be damaged.

(5) In some installations, to prevent surge, a non-return valve is fitted in the outlet to the tank union of the solenoid valve. Surge would result in B-failures. Check that this valve is not stuck open.

High pressure switch

124. B-failures can be caused by the high pressure switch not operating or through no circuit between pin C in the switch plug and pin B in the red-painted plug on the control box. If this circuit is found satisfactory, change the high pressure switch.

Note . . .

A lamp must never be placed across the leads to pins A and C in the high pressure switch as damage may result on a check start.

Safety disc failure

125. The failure of a safety disc is indicated by the stem of the safety disc assembly protruding through the hole in the disc holder in the side casing of the combustion chamber. The duration of a B-failure due to a ruptured disc is much shorter than that of a B-failure from other causes.

126. A safety disc failure is rectified by replacing the ruptured disc assembly with a new unit. Before replacing the disc ensure that the outer edge of the ruptured disc is removed from its seating in the combustion chamber.

127. If safety disc failures persistently occur, fit a new safety disc holder; further failure of the safety disc will necessitate replacement of the starter motor.

Insufficient rise of fuel pressure

128. Insufficient rise of fuel pressure during the initial combustion stage with consequent failure to operate the high pressure switch can be caused by an external fuel leak in the supply pipes or from any of the components in the fuel line. Alternatively insufficient pressure can be caused by leaks from the two main fuel sealing O-rings inside the atomizer head. Inspect all fuel lines and components for leaks and rectify when necessary; change components if rectification is not possible.

Faulty speed control switch

129. If the starting system shuts down before reaching the normal cut out speed, check the speed control circuit. Test all leads from the switch for intermittent faults. If the leads are satisfactory the speed control switch or internal wiring is faulty and the starter must be changed.

Excessive fuel drainage during fail-safe checks

130. If the fuel drainage on a fail-safe check exceeds the amounts specified in para. 93, the following checks must be made:—

(1) *Electrical supply.* The voltage at the nearest convenient unit point to the pumping unit terminals must not exceed 26 volts on load; if it is above this figure reduce it to 23 to 26 volts and recheck.

(2) *Control box.* Using a slave control box, carry out a fail-safe check. If this is satisfactory, fit a serviceable control box and recheck the system.

(3) *Low pressure switch.* Remove the switch from the aircraft and check the pressure setting, which should be 40 to 45 lb/in². Reset if incorrect; or change the switch.

(4) *Wiring.* Remove the sockets from the h.p. and ignition switches and, using a 500-volt megger, measure the insulation resistance between B contact in the h.p. switch socket and B contact in the ignition switch socket. If the resistance is less than 2 meg/ohm, trace the cause and rectify. Using a 500-volt megger, measure the insulation resistance between pins A and C and earth in the plug on the ignition switch. If the resistance is less than 10 meg/ohm, dry out the plug or change the switch.

Note . . .

If the quantity of fuel draining cannot be reduced it may be necessary to embody modification S 310 on Lightning aircraft.

Low fuel drainage during fail-safe checks

131. Carry out the following checks:—

(1) *Electrical supply.* Check the voltage at the nearest convenient checking point to the

pump-unit terminals. This should be 23 to 26 volts on load; rectify if necessary and recheck.

(2) *Blockage of fuel drain hole.* Refer to para. 117 and 122.

(3) *Leaks in fuel system.* Refer to para. 128.

Drainage of oil from exhaust pipe

132. Small quantities of oil which may drain from the exhaust pipe are acceptable. If, however, this becomes excessive it will be indicated by its presence on the aircraft skin. The starter should then be removed and the oil contents in the gearbox checked. If found to be high, check the engine oil replenishment device after reference to the relevant aero-engine Air Publication.

MISCELLANEOUS FAILURES

“Popping” during the air cycle

133. During the first three seconds of operation, when the starter is hot following a series of starts, “popping” may occur in the combustion chamber and exhaust pipe during the air cycle. The following steps should be taken to remedy these faults:—

(1) Remove the air pipe from the blower in the fuel pump assembly, and check for fuel in the port. If a dribble of fuel appears, the O-ring on the air dump valve is defective and must be changed. If there is doubt regarding fuel leaking past the O-ring, a fail-safe check should be carried out with the air pipe disconnected, when a check can then be made for the presence of fuel in the air.

(2) When no fuel leak into the air system at the pump end can be found, the O-rings on the fuel valve sleeve in the atomizer head are suspect. Failure of these rings permits fuel to enter the air system, in which case the atomizer must be changed.

Fuel pump and air blower motor fails to operate

134. If the fuel pump and air blower motor fails to operate, the following checks should be made:—

(1) Listen for the operation of the control box. If this is not running carry out checks detailed in para. 108 and 109.

(2) If the control box is operating normally refer to the relevant aircraft Air Publication for details of the electrical system and check the fuse or circuit breaker which serves the pumping unit; rectify if necessary.

(3) Check the electrical circuits to and from the motor contactor, and the operation of the contactor itself.

(4) If the above checks are satisfactory the pumping unit itself will be faulty and must be changed.

Note . . .

If the starter system 10 amp fuse persists in blowing, a thorough testing of the components in the system must be carried out. If a short circuit or low insulation resistance to earth is found in the motor circuit, the faulty component must be replaced.

135. If combustion occurs for the full 7 seconds, but the engine does not rotate, the starter is faulty and must be removed for examination. Check for a seized rotor or damaged rotor blade and gears. If either is damaged change the starter.

Fuel depriming in atomizer

136. Fuel depriming, causing intermittent A-failures, may occur if particles of foreign matter become trapped between the fuel valve and seating in the atomizer. The symptoms are recurring instances of one or two A-failures followed by successful starts. To check, immediately after a flight, or two hours after a successful start, carry out fail-safe checks and carefully examine all pipes and connections for external leaks whilst these are in progress. During the first operation there will probably be a discharge of less than 70 cm³ of I.P.N. initially, the remainder continuing to drip for a much longer period than the usual two minutes. The rate of discharge should become more normal during subsequent attempts as the system becomes primed, but the dripping will still continue longer than usual. If this occurs carry out the fuel valve checks detailed in Sect. 3, Chap. 2, para. 31.

"Bang-start" during initial light-up

137. A "bang" may occur at the initiation of combustion during a successful start immediately

following a previous start, i.e. when the starter is hot; A or B failures may also occur under these conditions. Failures of this type are due to a slight delay in ignition which may be caused by an increase in the pressure setting of the ignition switch. The procedure for correcting the pressure setting is contained in Sect. 3, Chap. 2, para. 20.

Faulty ignition unit

138. After high altitude flying pressure is slow to equalize at ground level and a negative pressure may exist inside the ignition unit. This could cause a breakdown of current at the ignition unit spark gap resulting in no sparking at the starter igniters with consequent failure to ignite the mixture in the combustion chamber, and no start. If no combustion occurs after three or four attempts to start, and the fault is traced to the ignition unit, unscrew the captive screw positioned in the top left hand corner of the cover, and the pressure within the unit will return to ambient; then tighten the screw. The correct screw is identified by a red flash painted across it and the corner of the cover.

139. If no red flash is painted on the cover, remove the ignition unit from the aircraft and carry out the operations detailed in Section 3, Chapter 2, para. 49.



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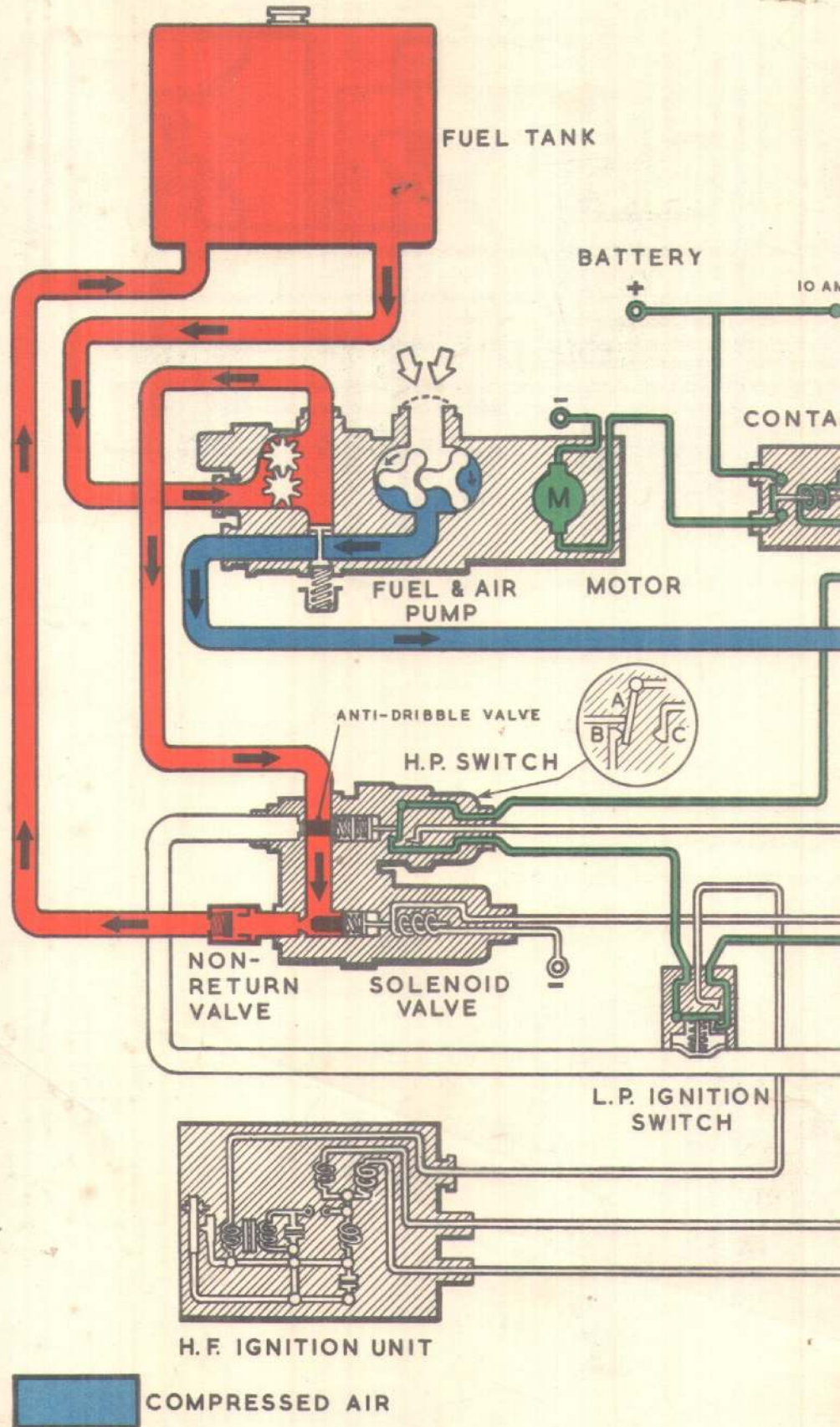
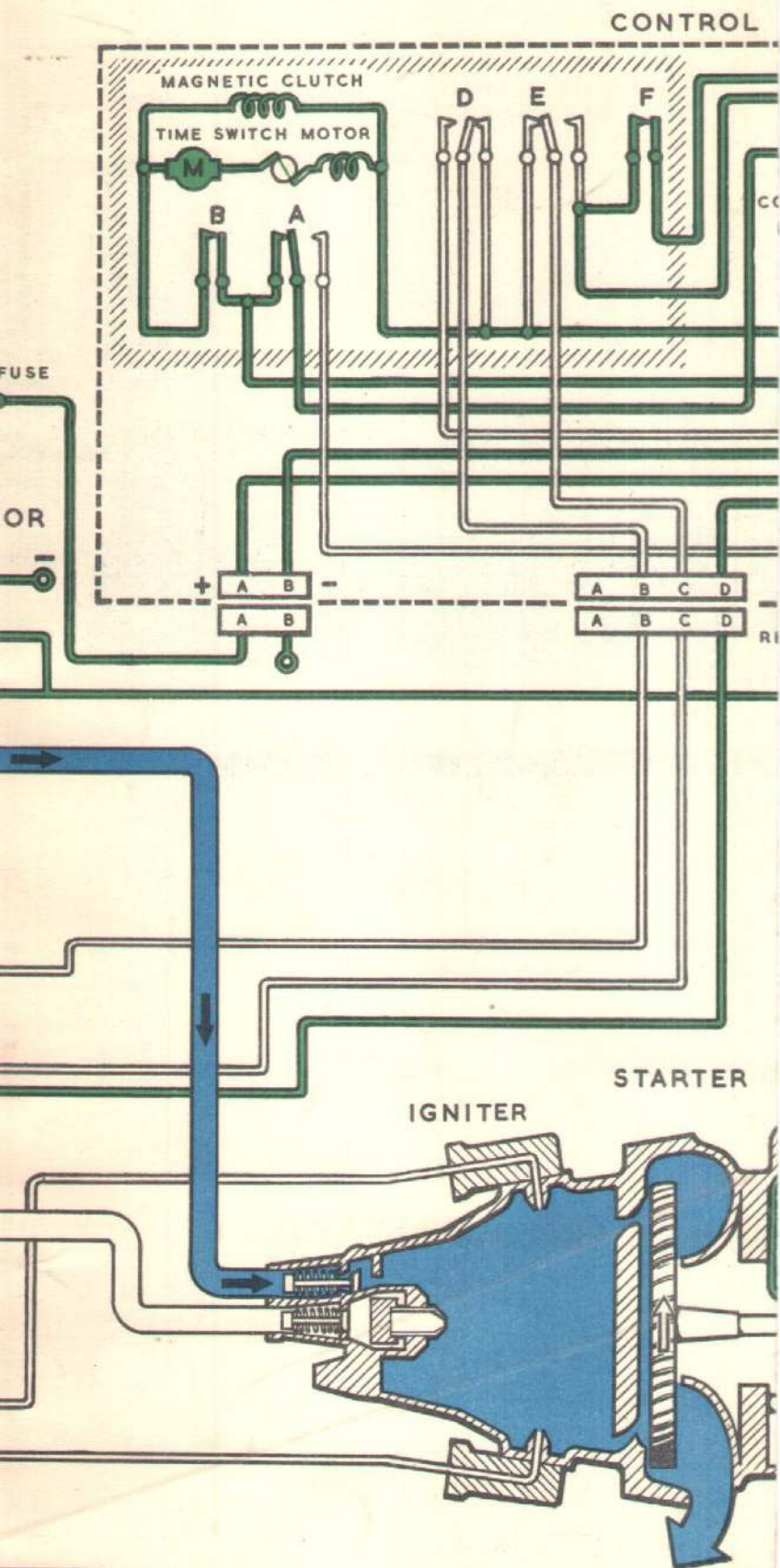
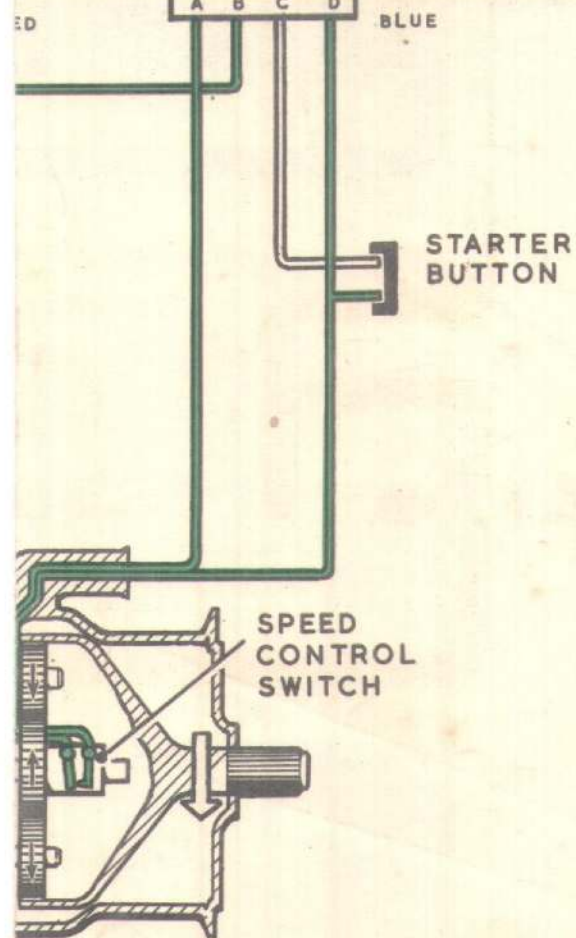
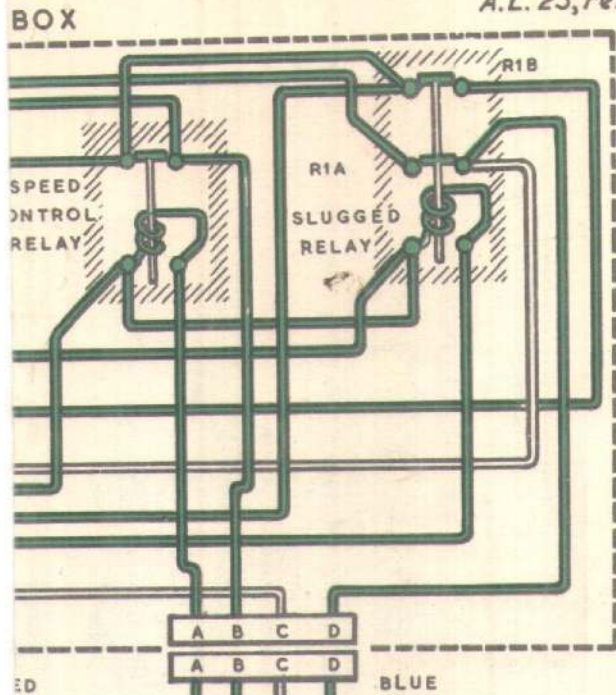



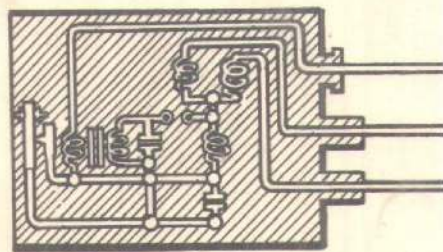
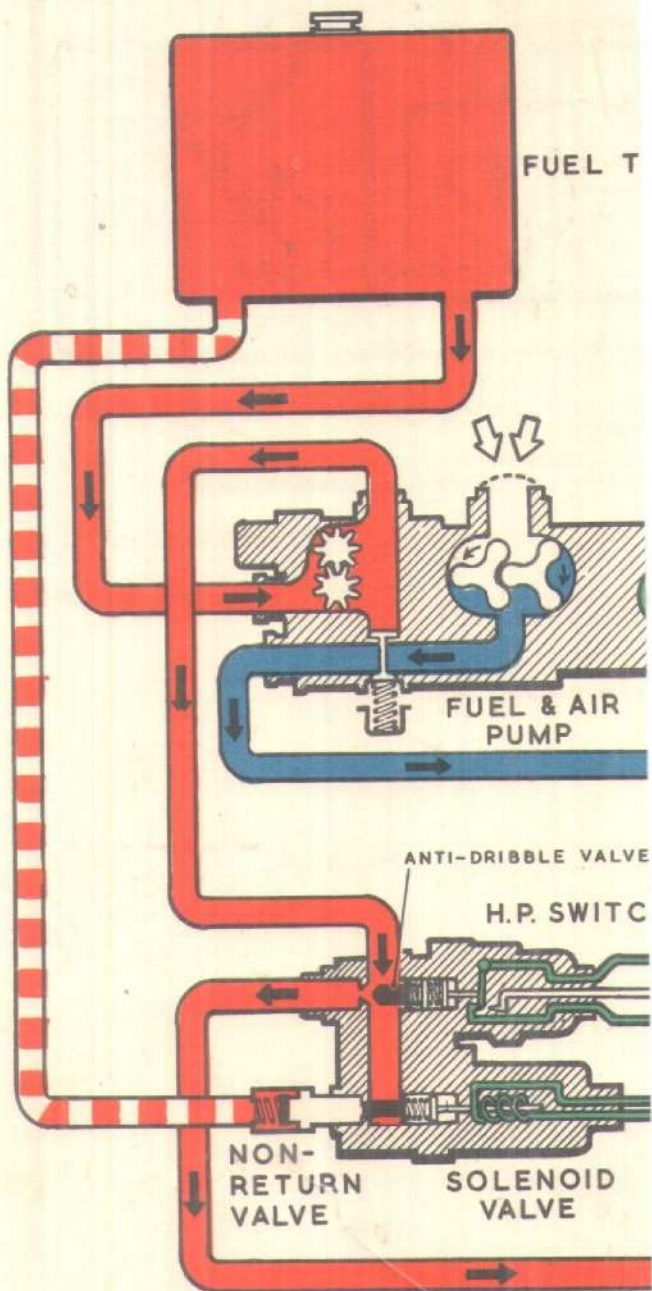
Fig.5 Principle



of operation: first stage (scavenging)
RESTRICTED



 LIVE ELECTRICAL CIRCUIT



 COMPRESSED AIR

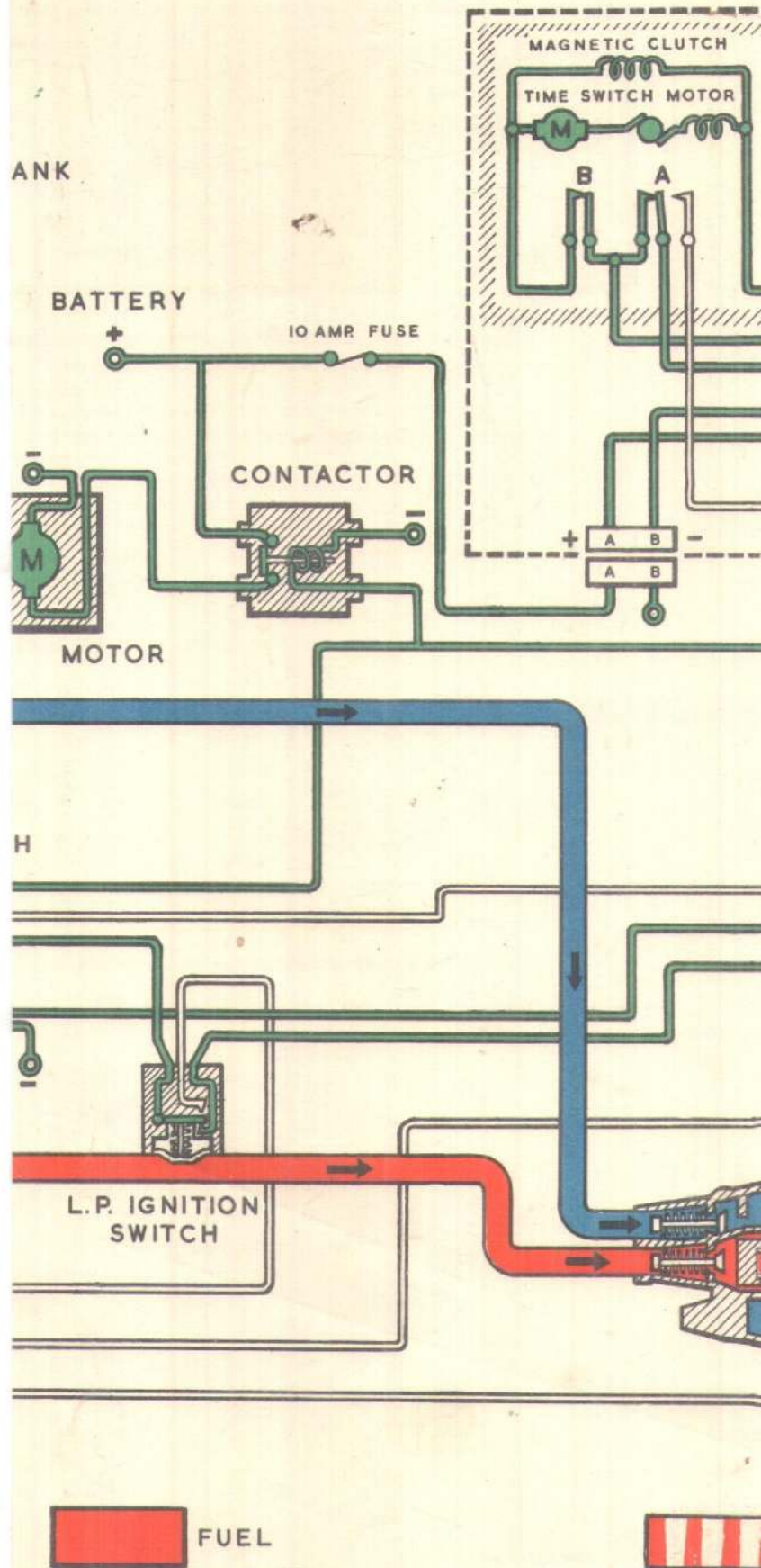
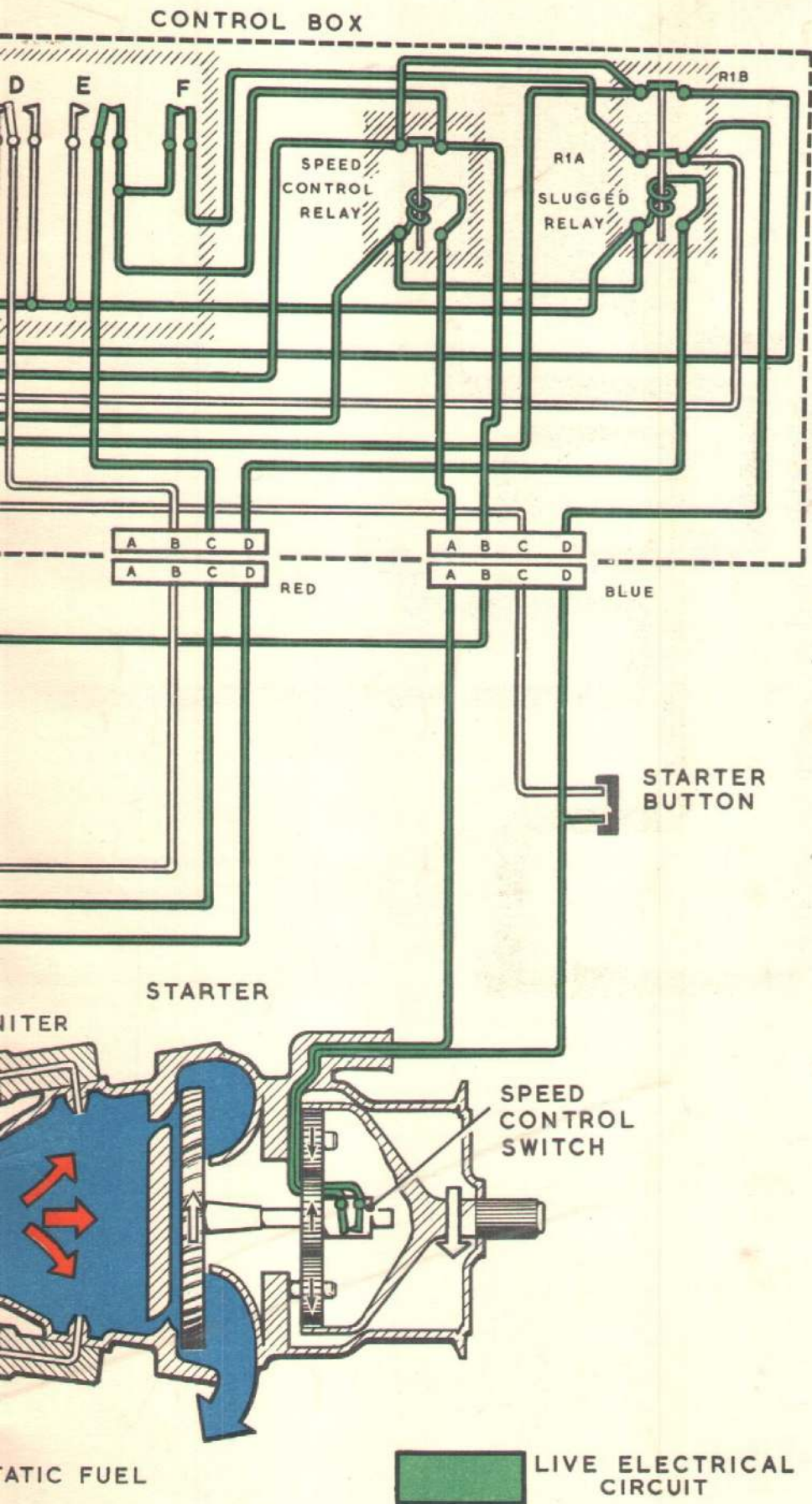
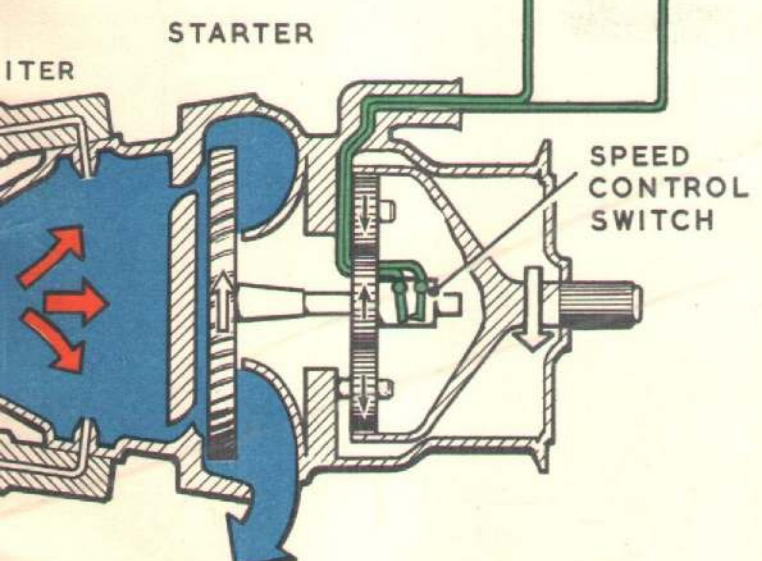
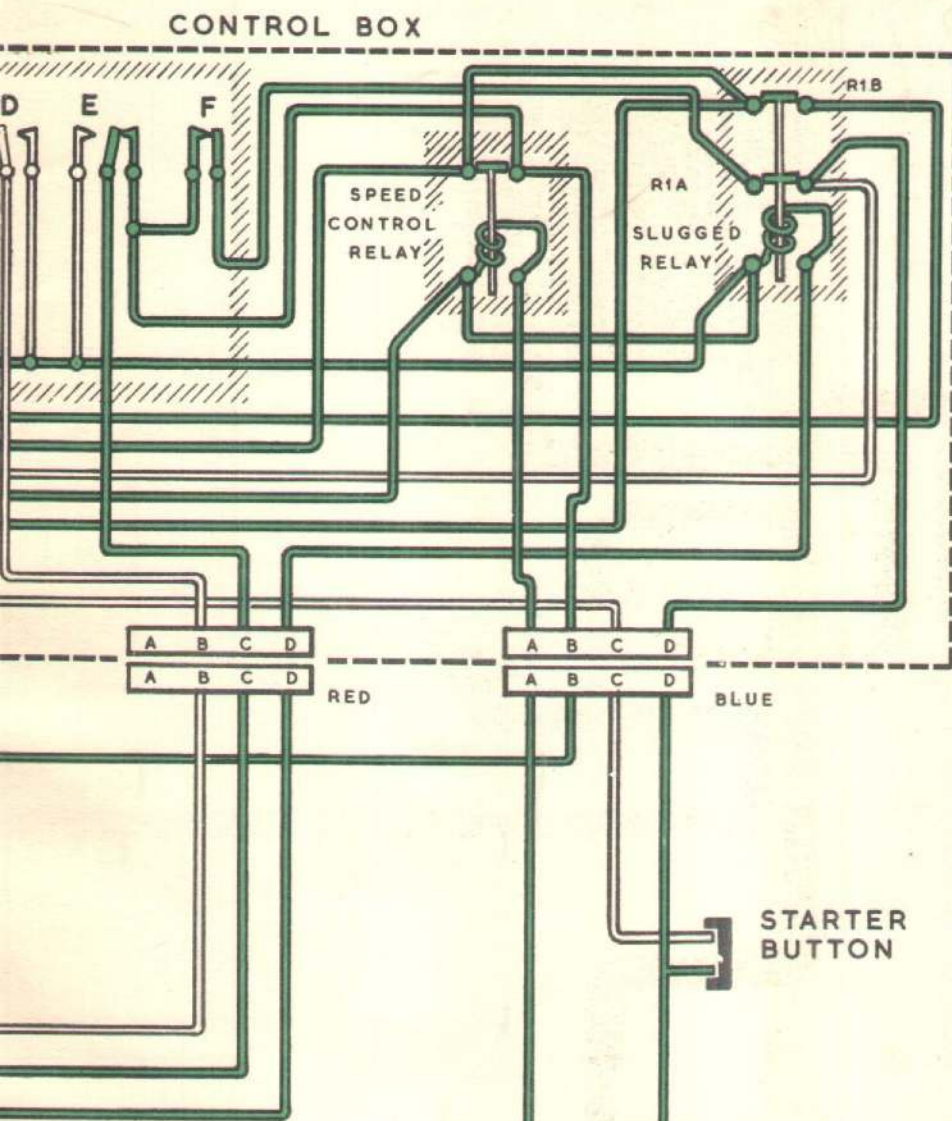


Fig.6 Principle of operation: second
RESTRICTED





 LIVE ELECTRICAL CIRCUIT

stage (injection)

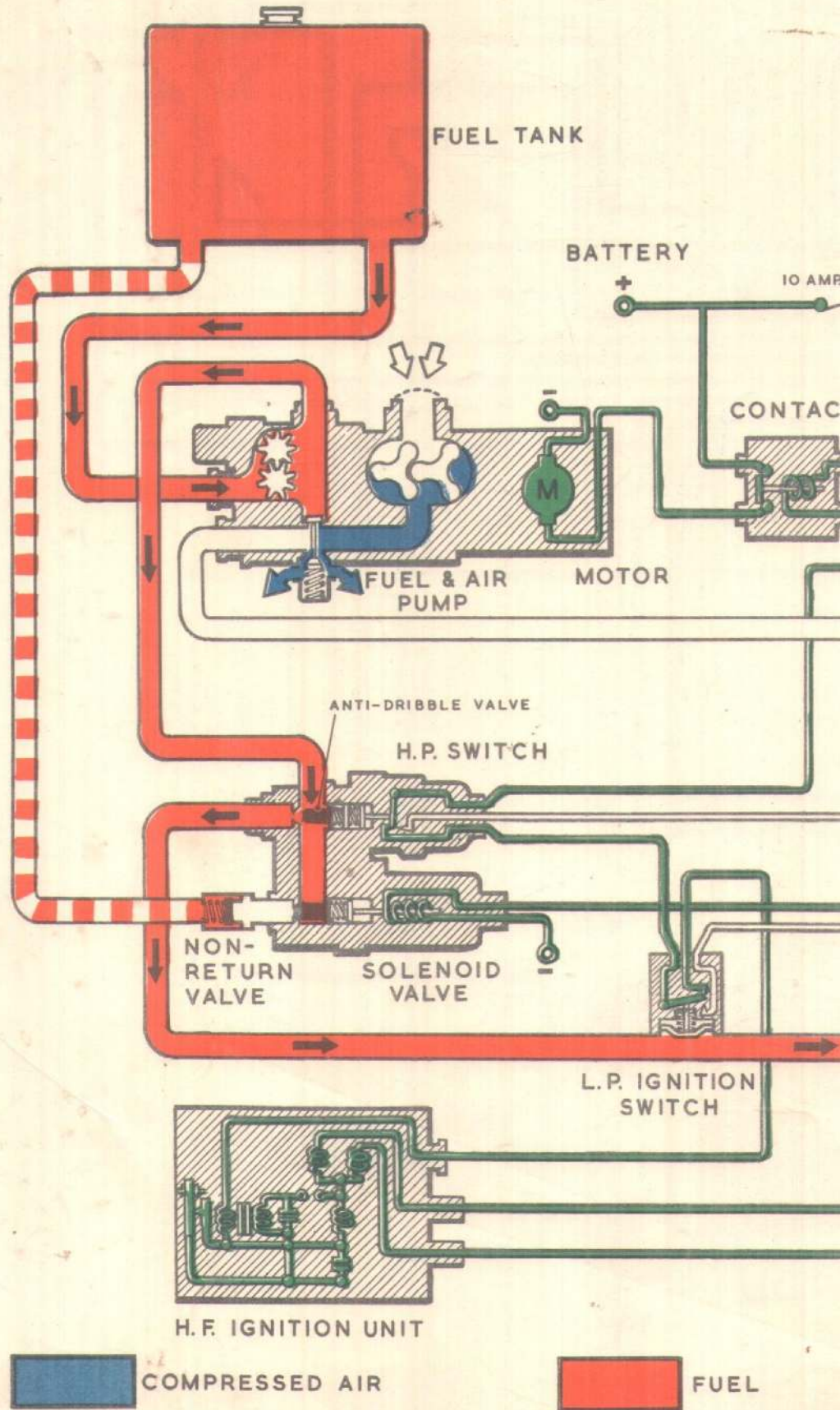
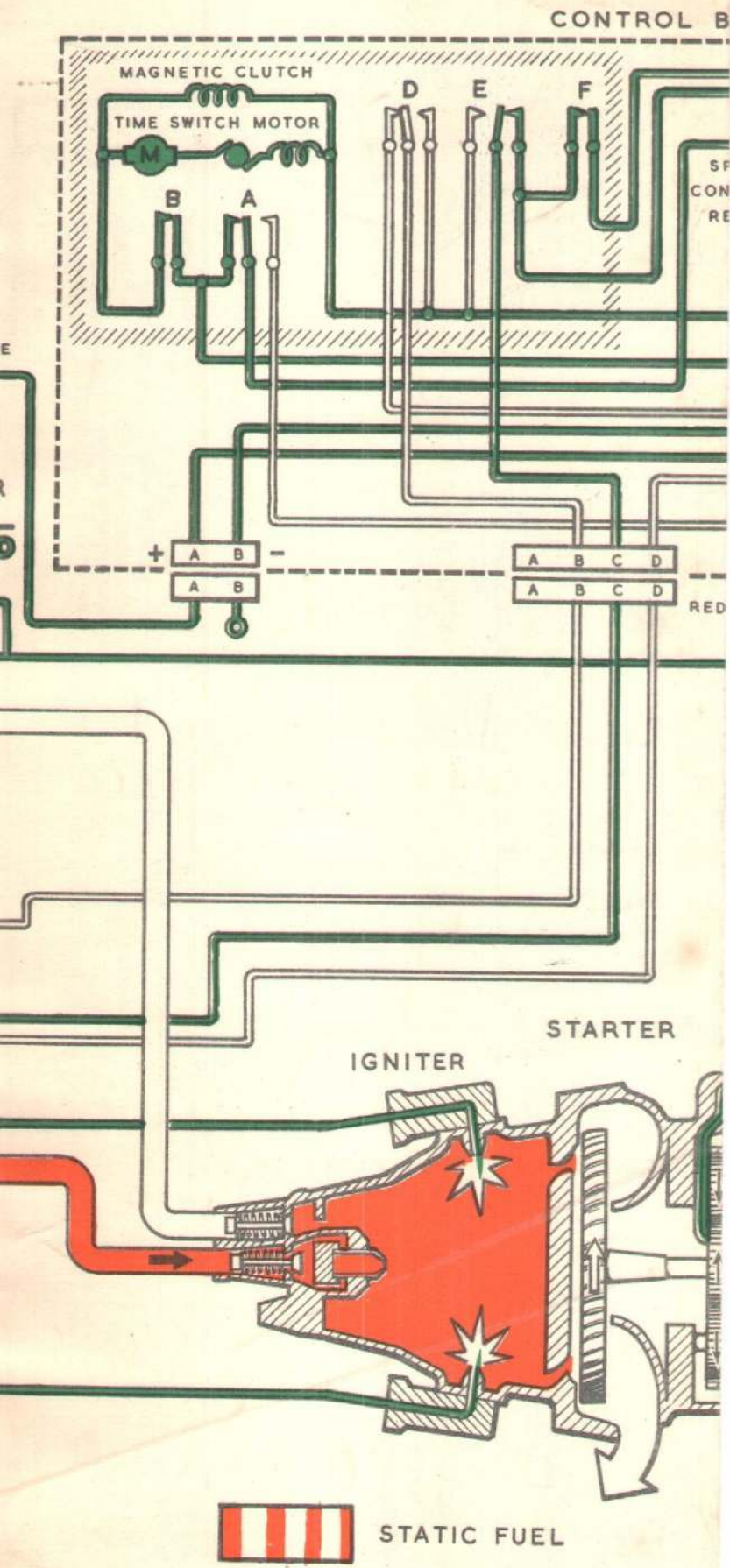
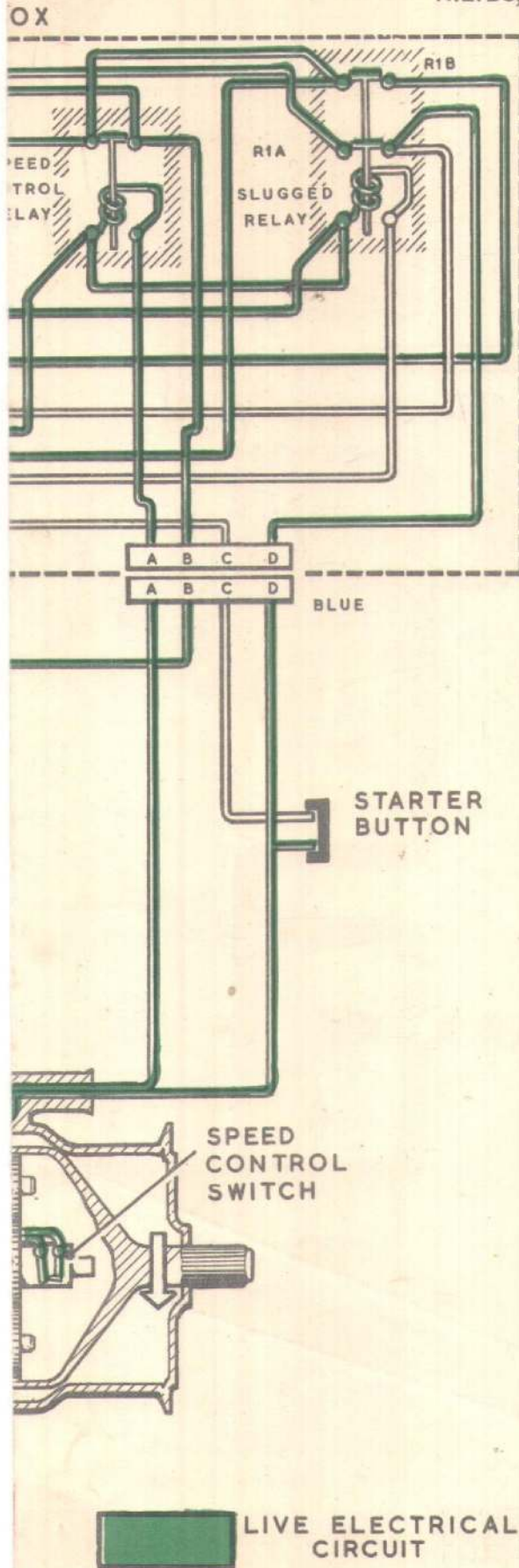


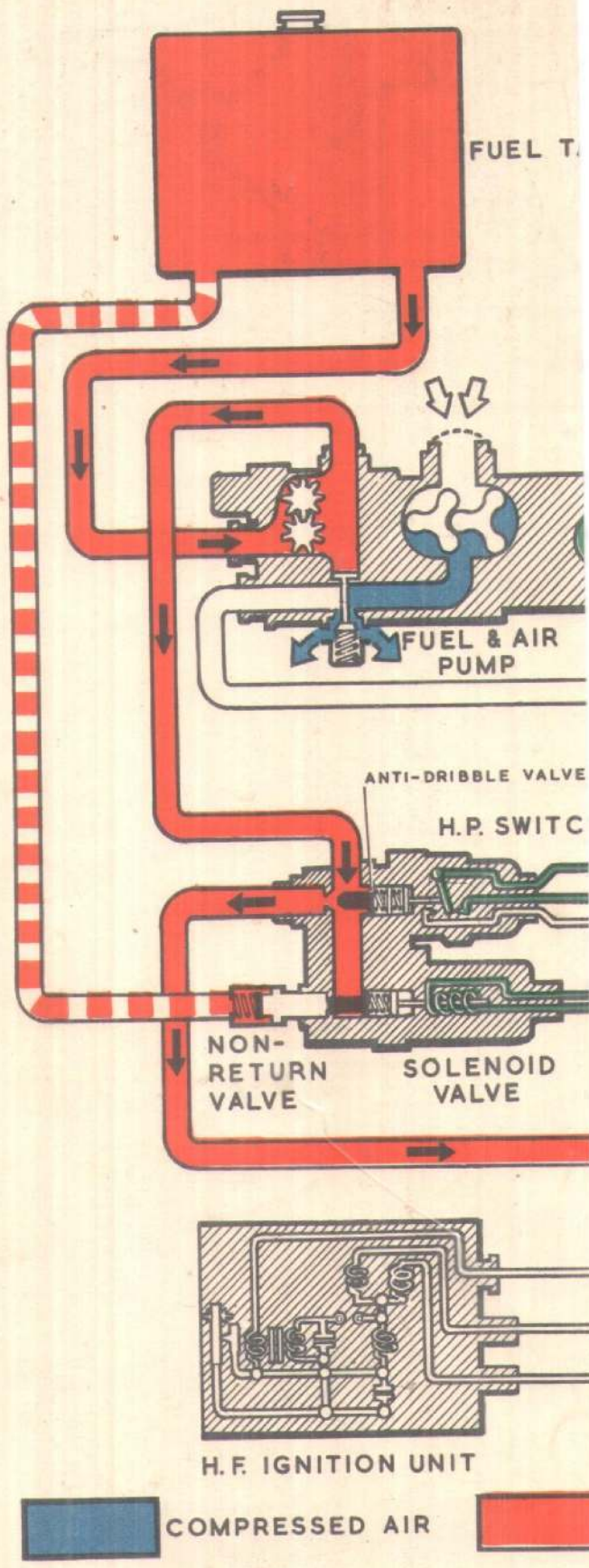
Fig.7 Principle of



 STATIC FUEL

operation: third stage (ignition)
RESTRICTED





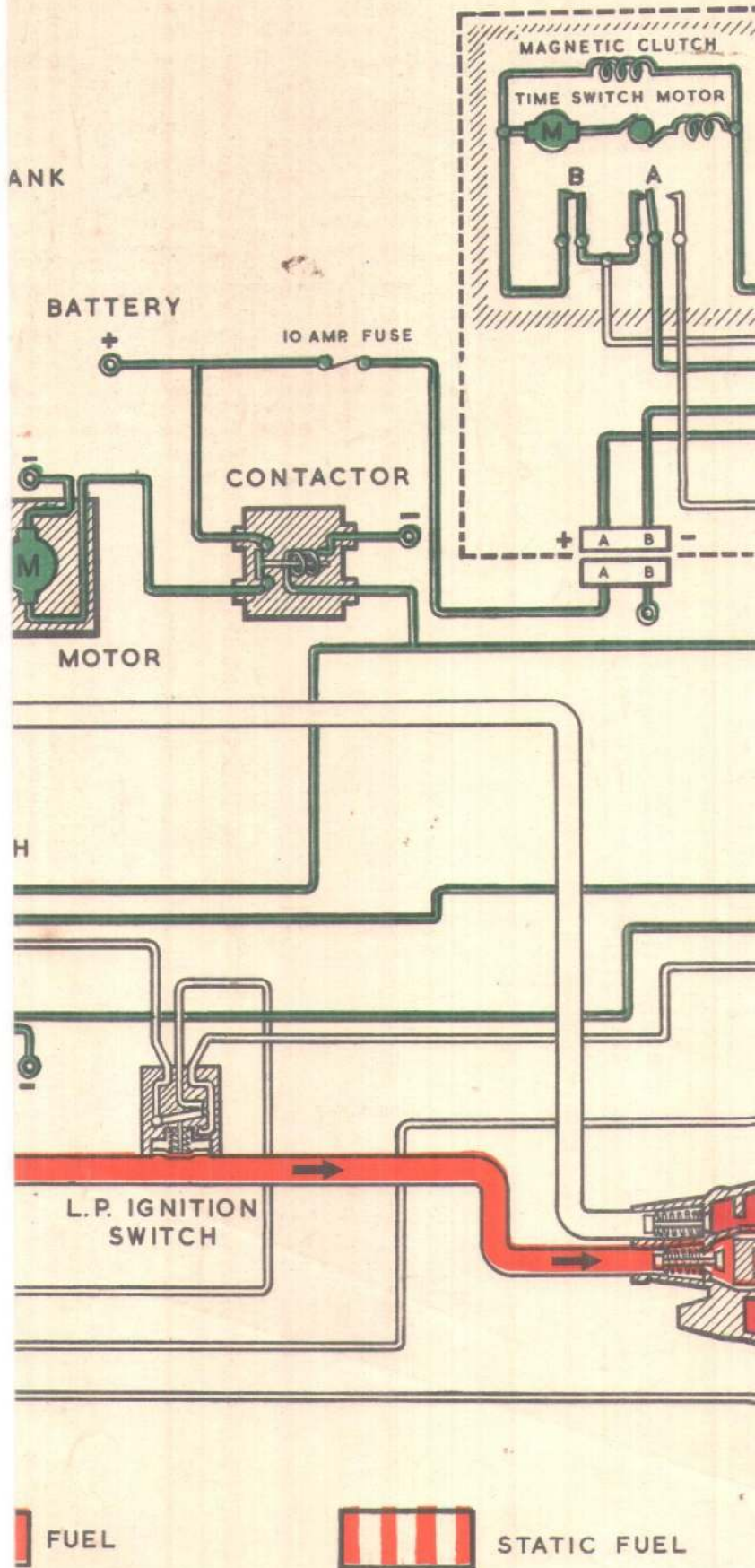
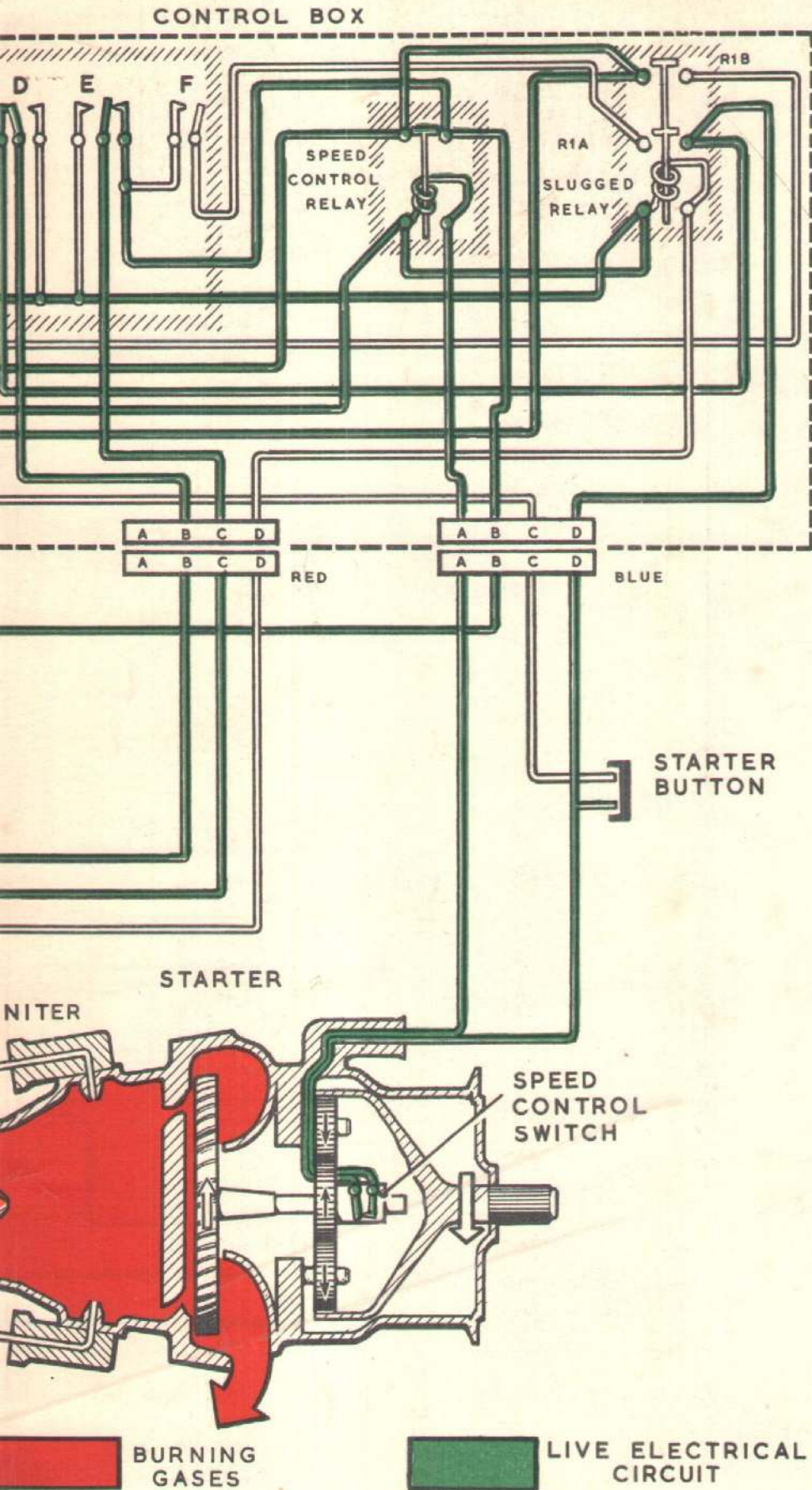


Fig. 8. Principle of operation: four RESTRICTED



stage combustion)

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