GENERAL AND TECHNICAL INFORMATION

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LEADING PARTICULARS

Starting systems	Plessey IPN
Airframe group	
Fuel pump, air blower and motor unit	
Fuel pump	Gear type
Air blower	Roots type-triple lobed
Motor unit	25V d.c. series wound
HP switch and solenoid valve	refer AP 113F-0106-1
Ignition switch	refer AP 113D-1502-16
Ignition unit	refer AP 113L-0118-1
Control unit	refer AP 113D-1007-16
Engine group	
Starter motor	Turbine driven
Direction of rotation	Anti-clockwise - viewed on output shaft
Turbine	Single stage, impulse axial flow
Reduction gear	Single stage, epicyclic
Ratio	3.75 : 1
Nominal cut-out speed (output shaft)	
All groups (Mod. 2264)	10 200 rev/min
Group 23/E (Pre mod 2264)	10 200 rev/min
Group 5/E2 and 7/E (Pre mod 2264)	11 700 rev/min
Lubrication	Oil, OX-38
Capacity	100 cc
Fuel	AVPIN (NATO Code S-746, Ref.No. 34A/9423147)
Consumption at 20V d.c. motor terminal voltage	
Group 23/E	270 to 310 cm^3/s
Group 5/E2	345 to 400 cm^3/s
Group 7/E	360 to 400 cm^3/s
Safety discs (2 off)	37F/20805
Nett dry weight	
Group 5/E2 and 23/E	60 lb (27.22 kg) approx
Group 7/E	68 lb (30.84 kg) approx

Introduction

1 The IPN (iso-propyl nitrate) starting system consists of an engine mounted, turbine rotor driven, starter motor and aircraft mounted fuel and electrical components.

1.1 The starter motor rotor is driven by the gas generated by the controlled ignition of IPN fuel (AVPIN) in the starter motor combustion chamber. The resultant drive is transmitted, via an epicyclic reduction gear, to the engine.

1.2 The system operating cycle, once initiated by the engine starter button, is fully automatic. A control unit containing a timing motor, energized via a speed control switch in the starter motor gearbox, determines the sequence of operation and will shut down the system in the event of component failure or malfunction. The operating cycle is terminated, at a predetermined output shaft speed, by the speed control switch, or by a time switch in the control box.

1.3 The starter motor relies on the mono-fuel properties of the AVPIN fuel for its cperation. This fuel contains sufficient oxygen to support combustion and will decompose under high pressure and temperature conditions, such as are created in the starter combustion chamber. At normal temperature and pressure the fuel burns readily when mixed with air.

1.4 The airframe mounted equipment controls the delivery of fuel to the starter motor combustion chamber and provides a supply of air, at the commencement of the operating cycle, for scavenging purposes. An ignition unit, energized via a fuel pressure operated ignition switch and connected to the starter motor igniters, provides initial combustion of the fuel.

1.5 Pressure fuel and air for the starter motor are provided by a combined fuel pump, air blower and motor unit. The pump, supplied with fuel from a special tank in the aircraft, delivers the fuel to the starter motor via a high pressure (HP) switch and solenoid valve assembly, and the ignition switch. Blower delivery air is piped direct to the starter motor.

DESCRIPTION

Fuel pump, air blower and motor unit (fig.1)

2 A gear type fuel pump and a Roots type air blower are coupled together and driven by a 25V d.c. series wound motor. The delivery side of the blower connects with a fuel pressure operated dump valve. A gauze filter at the blower inlet prevents ingress of foreign matter. The fuel pump, is self-lubricated with fuel at inlet pressure and a drain is provided to dispose of any seepage from the gland seal. A preset pressure relief valve is mounted on the outlet side of the pump. This valve is set during manufacture and must not be disturbed.

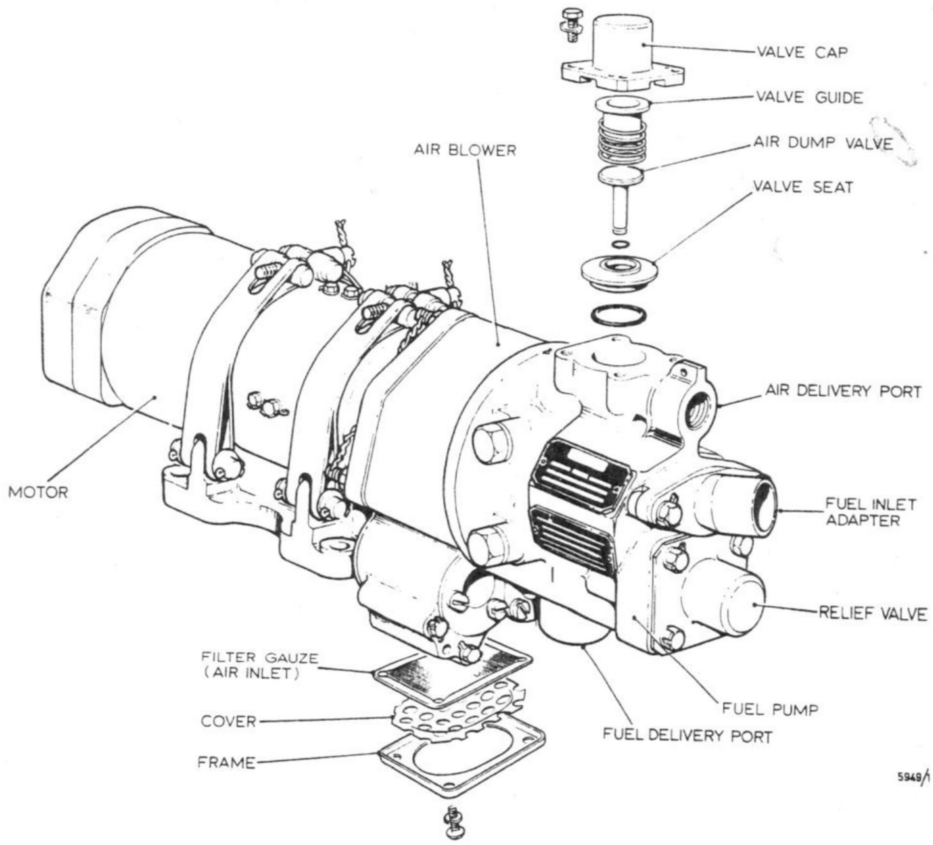


Fig.1 Typical fuel pump, air blower and motor unit

HP switch and solenoid valve assembly (fig.2)

3 The HP switch and solenoid valve, bolted together to form an assembly, are interdependent in operation and are connected electrically with the control unit. The solenoid operated valve directs the pump delivery fuel either to the starter motor, via the ignition switch, or back to the supply tank, via a non-return valve housed in the solenoid valve outlet adapter. The HP switch provides a signal at high fuel pressures, to the speed control relay in the control unit and de-energizes the ignition unit.

Ignition switch (fig.3)

4 The ignition switch senses the fuel pressure in the supply pipe to the combustion chamber and initiates the electrical supply to the ignition unit.

Ignition unit (fig.4)

5 The high frequency (HF) ignition unit, energized via the ignition switch, provides a high energy supply for the two igniter plugs in the starter motor combustion chamber. The unit incorporates a vibrator and an auto frequency transformer and produces a high rate of sparking over a wide temperature range. On systems incorporating Mod. S.889 a manually operated vent valve is fitted to the unit to facilitate restoration of atmospheric pressure within the unit in the event of ignition failure due to reduced internal pressure.

Control unit (Pre-mod S.647) (fig.5 and 10)

6 The electrical control unit incorporates a Teddington time switch and two relays operating in conjunction with the HP, ignition and speed control switches to provide automatic control of the starting system.

6.1 The time switch comprises a motor driven, coil operated clutch, a cam mechanism and five switches, A, B, D, E and F. When the motor is energized, the clutch engages the cam mechanism, and at the same time, operates switch 'A' which isolates the engine start button. The cam, driven by the motor, operates the remaining switches in timed sequence.

6.2 The relays consists of a speed control relay (R2), energized via the speed control switch in the starter motor gearbox, and a double contact, slugged relay (R1/2), energized via the ignition switch.

Control unit (Mod. S.647) (fig.5 and 11)

7 This control unit is physically and electrically interchangeable with the control unit (Pre-mod. S.647) described in para. 6. The unit incorporates a static timer to replace the Teddington time switch and the slugged relay.

Starter motor (fig.6, 7, 8 and 9)

8 The starter motor, complete with air and fuel pipes, an exhaust outlet and attaching parts, forms the engine equipment for the starting system. An atomizer, combustion chamber, nozzle plate and a rotor driven, reduction gearbox are the main basic components of the starter. The gearbox incorporates the speed cutout switch, the output shaft and the starter mounting flange, complete with captive bolts. The output shaft is splined and threaded to receive the sun gear of the engine reduction gear.

8.1 AVPIN fuel and air for scavenging are piped to the starter motor and admitted to the combustion chamber through the atomizer. The atomizer comprises a body, a sealed fuel sleeve and a housing, bolted together to retain poppet type fuel and air valves. Separate ducts, connected with an air and a fuel inlet, integral with the housing, direct the fuel and air into the combustion chamber.

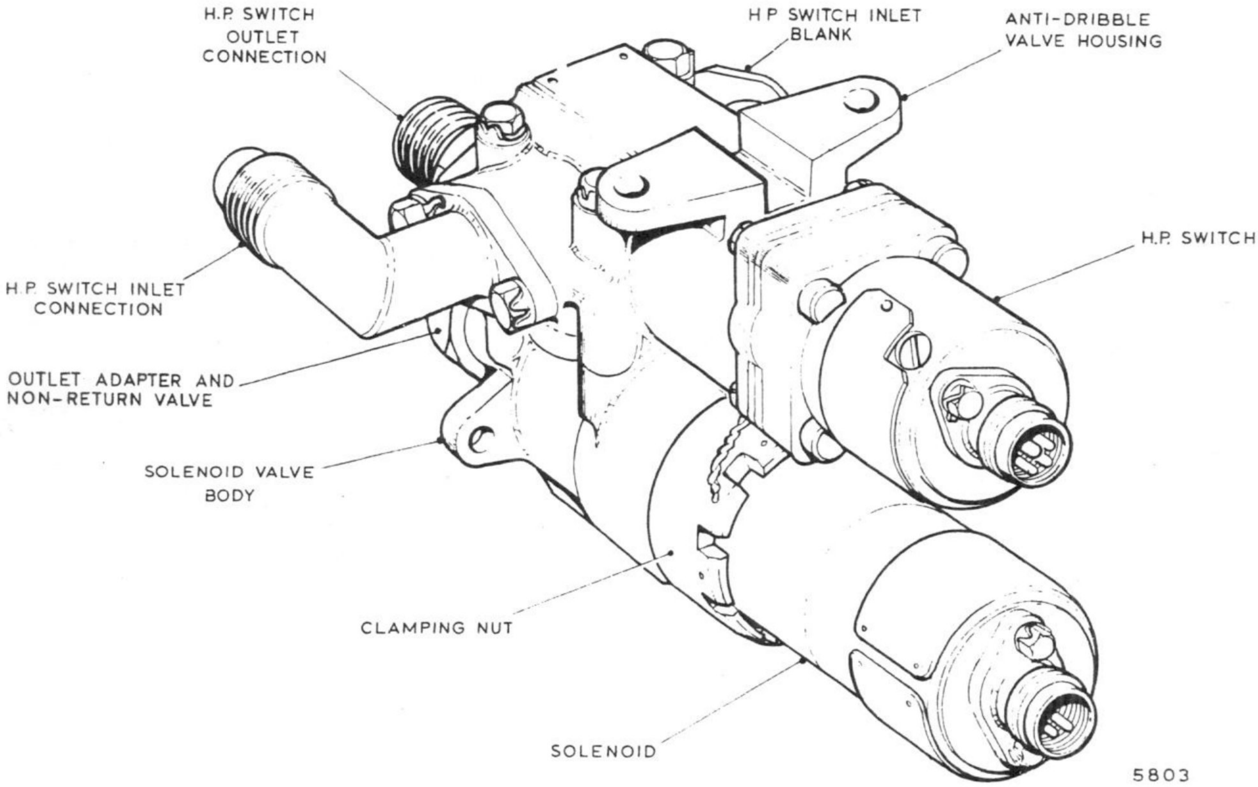


Fig.2 Typical HP switch and solenoid valve

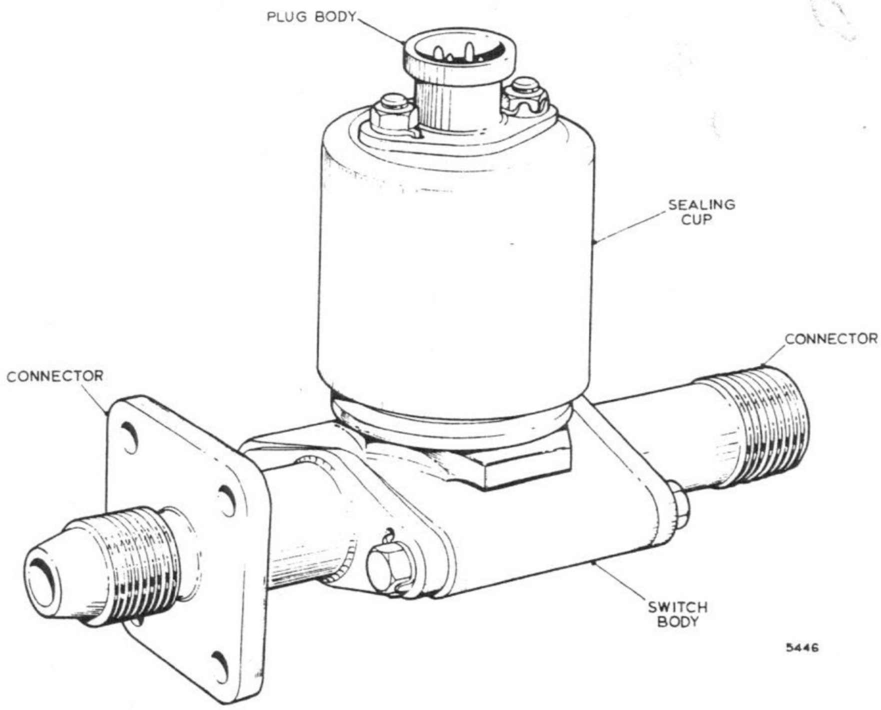


Fig.3 Typical ignition switch

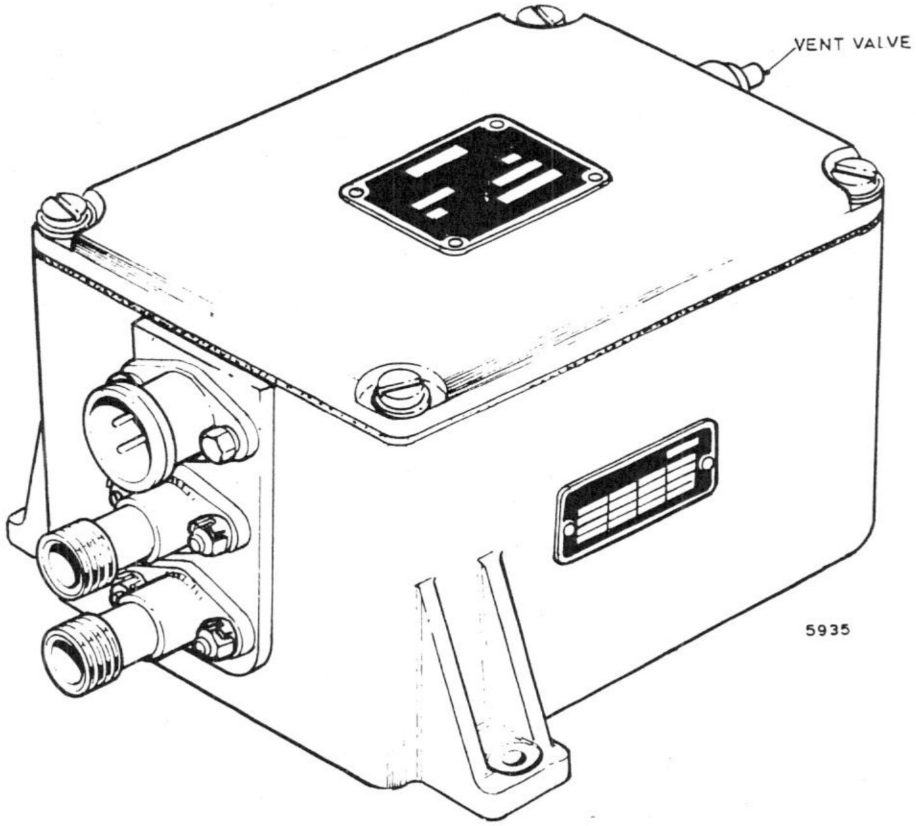


Fig.4 Ignition unit

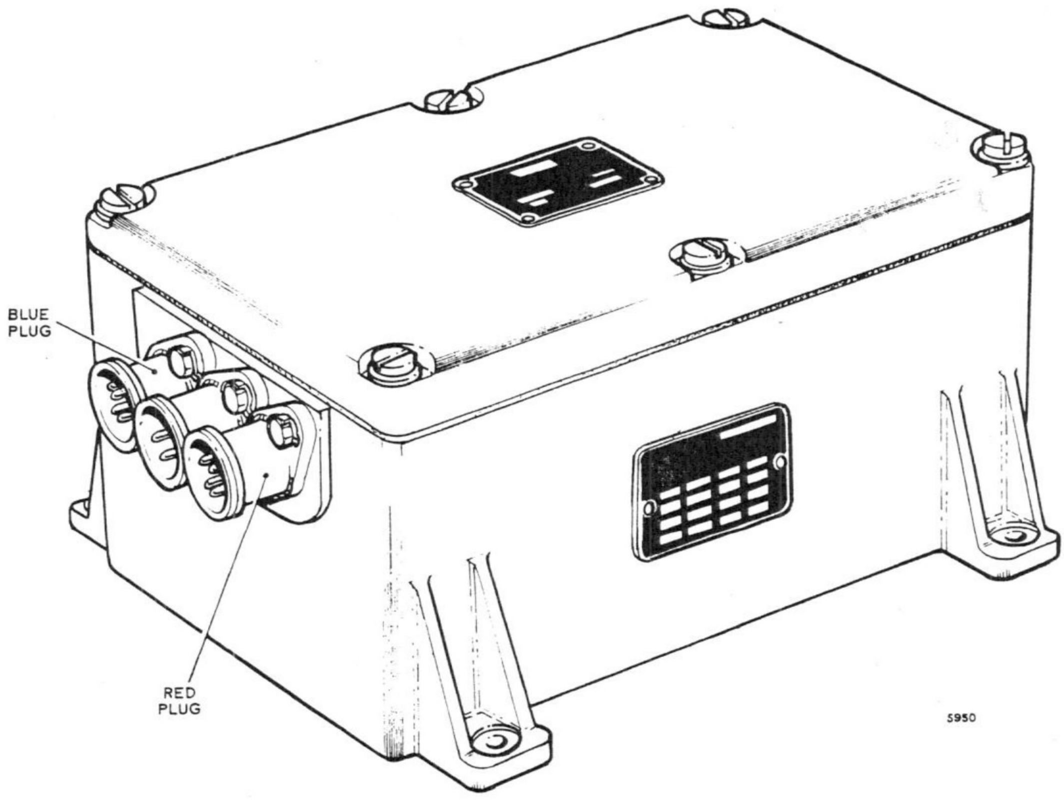


Fig.5 Control unit

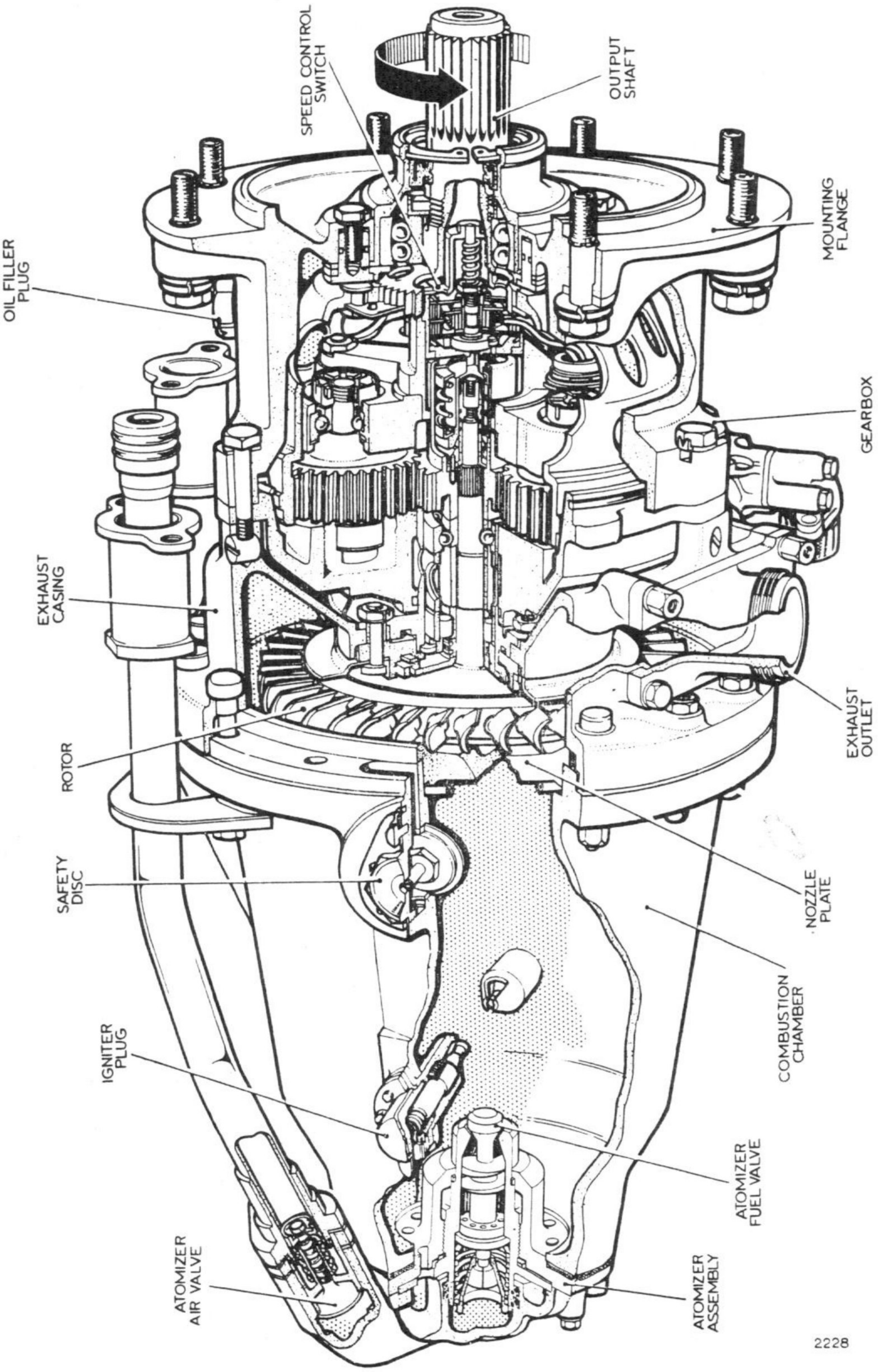


Fig.6 Typical starter motor

8.2 The air valve, comprising a spring loaded valve housed in a guide, locates in a bore in the air inlet. The valve, which is PTFE coated, functions as a non return valve and prevents loss of chamber pressure during combustion.

8.3 The fuel valve is similar in construction to the air valve but has no PTFE coating. The valve is secured in the atomizer body together with a fuel distribution sleeve and a swirl chamber. Fuel enters the swirl chamber through tangential drillings in the chamber wall and is ejected, via a nozzle, in the form of an atomized spray into the combustion chamber.

8.4 Depending on type and modification state, certain starter motors are fitted with an anti-dribble atomizer. On these starters, the fuel valve seats in the fuel delivery nozzle to provide a positive shut-off of fuel.

8.5 Incorporated in the combustion chamber are the mountings for the two diametrically opposed igniter plugs and two safety discs. Each disc, comprising a metal diaphragm clamped between two support plates on a mounting stem, is located in a holder and clamped to a seat in the wall of the combustion chamber. Should the gas pressure in the chamber exceed a predetermined safe value, the metal diaphragm will shear and the combustion gas will pass through the holder and a port in the chamber mounting flange direct to the starter exhaust. The disc mounting stem protrudes through the holder to indicate sheared disc.

8.6 A nozzle plate, clamped between the combustion chamber and the gear-box, directs the combustion gas on to the blades of the rotor, through a ring of convergent/divergent nozzles. A gas filled metal joint ring seals the periphery of the nozzle plate and a torque reaction pin, located in the chamber flange, to prevent the plate rotating. A drain hole is provided in the nozzle plate to allow any unburnt fuel in the combustion chamber to drain into the starter exhaust.

WARNINGS ...

(1) A BLOCKED NOZZLE PLATE CONSTITUTES A SERIOUS HAZARD. UNDER NO CIRCUMSTANCE MUST A STARTER BE RETURNED TO SERVICE UNTIL THE BLOCKAGE HAS BEEN CLEARED.

(2) THE COMBUSTION CHAMBER MUST BE EXAMINED, AND THE NOZZLE PLATE DRAIN HOLE AND DISCHARGE NOZZLES CLEARED, AS NECESSARY, IF ANY OF THE FOLLOWING INCIDENTS HAVE BEEN REPORTED IN SERVICE.

(a) THE FUEL PUMP, AIR BLOWER AND MOTOR UNIT FAILS TO SHUT DOWN AT THE END OF THE THREE SECOND AIR CYCLE (DURING PRIMING OR FUEL DRAINAGE CHECKS).

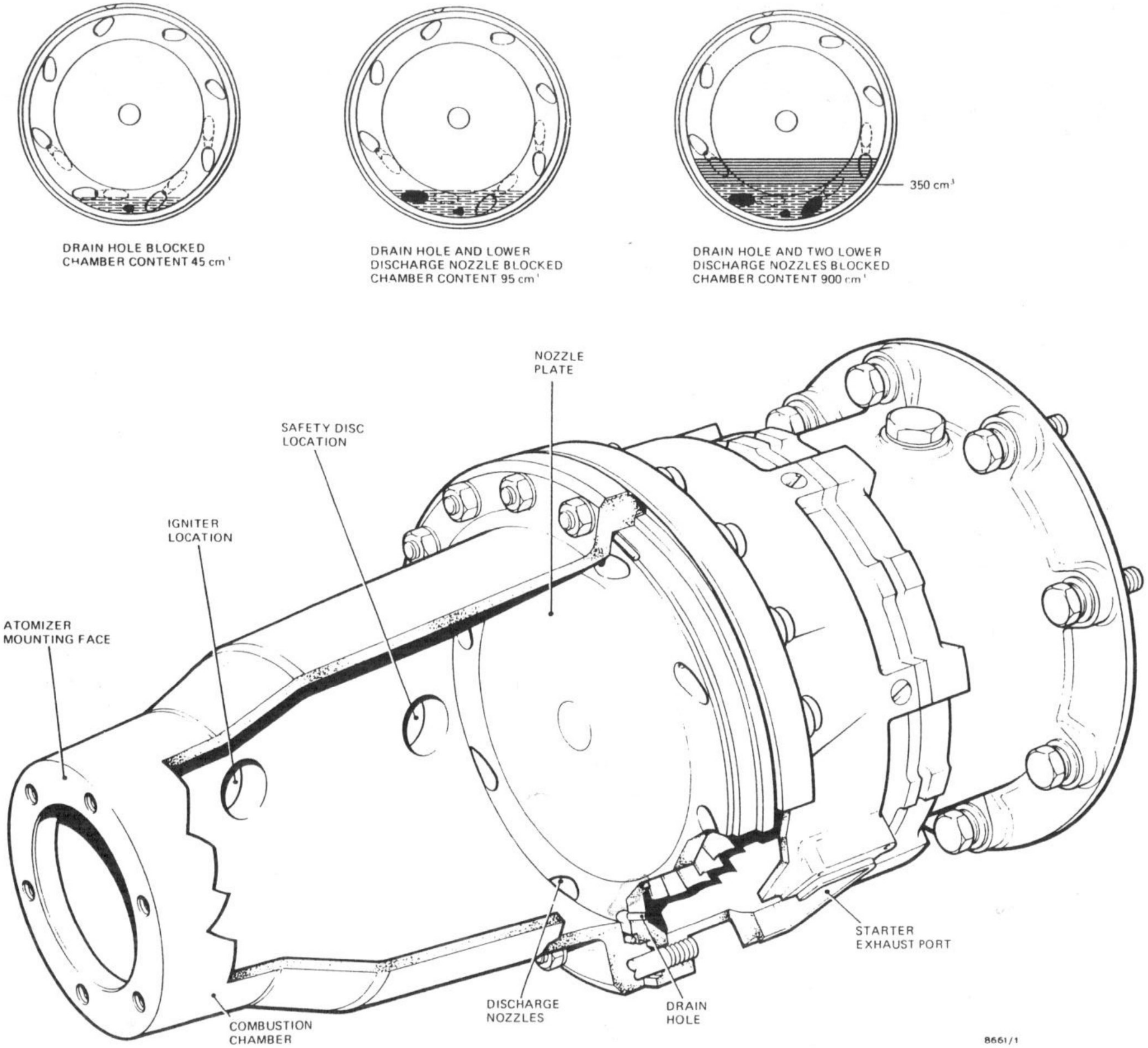
(b) MORE THAN FOUR SIMULATED STARTS ARE REQUIRED BEFORE FUEL DRAINS FROM THE STARTER EXHAUST DURING PRIMING.

(c) FAILED FUEL DRAINAGE CHECK.

(d) MORE THAN FIVE (GROUP 8 AND 23) OR SIX (GROUP 5/3) STARTER OPERATIONS, COMPRISING FUEL DRAINAGE CHECKS AND UNSUCCESSFUL ATTEMPTS TO START (WHERE COMBUSTION DOES NOT OCCUR) SINCE LAST SUCCESSFUL COMBUSTION CYCLE.

(e) REPEATED IN SITU WATER FLUSHING OF ATOMIZER AIR VALVE (GROUP 8).

(f) PRESENCE OF FUEL IN COMBUSTION CHAMBER.



WARNING...

(1) A BLOCKED NOZZLE PLATE CONSTITUTES A SERIOUS HAZARD AS IT PERMITS DANGEROUS AMOUNTS OF FUEL TO COLLECT IN THE COMBUSTION CHAMBER. UNDER NO CIRCUMSTANCES MUST A START BE ATTEMPTED UNTIL THE BLOCKAGE HAS BEEN CLEARED.

(2) IF THE FUEL CONTENT IN THE COMBUSTION CHAMBER EXCEEDS 350 cm^3 AN EXPLOSION WILL RESULT, SHOULD A START BE ATTEMPTED, CAUSING EXTENSIVE DAMAGE TO THE STARTER AND TO THE AIRCRAFT.

(3) REPEATED PRIMING RUNS, FUEL DRAINAGE CHECKS, UNSUCCESSFUL ATTEMPTS TO START (WHERE STARTER COMBUSTION DOES NOT OCCUR) OR WHERE THE FUEL PUMP CONTINUES TO RUN ON DURING PRIMING MAY DISLODGE CARBON (PRODUCTS OF COMBUSTION) WHICH CAN CAUSE BLOCKAGE OF THE NOZZLE PLATE.

Note...

An unsuccessful attempt to start (where starter combustion does not occur) has the same effect on the IPN system and passes the same amount of fuel as a priming run or a fuel drainage check.

(4) THE COMBUSTION CHAMBER MUST BE CHECKED FOR FUEL CONTENT AND THE NOZZLE PLATE EXAMINED AND CLEARED, AS THE LAST OPERATION JUST PRIOR TO AN ATTEMPT TO START, IF ANY OF THE FOLLOWING INCIDENTS OCCUR:

(a) THE FUEL PUMP, AIR BLOWER AND MOTOR UNIT FAILS TO SHUT DOWN AT THE END OF THE THREE SECOND AIR CYCLE DURING PRIMING OR FUEL DRAINAGE CHECKS.

(b) MORE THAN FOUR PRIMING RUNS ARE REQUIRED BEFORE FUEL DRAINS FROM THE STARTER EXHAUST.

(c) FAILS FUEL DRAINAGE CHECK.

(d) MORE THAN SIX STARTER OPERATIONS, COMPRISING FUEL DRAINAGE CHECKS AND UNSUCCESSFUL ATTEMPTS TO START (WHERE STARTER COMBUSTION DOES NOT OCCUR) SINCE THE LAST SUCCESSFUL COMBUSTION CYCLE.

Fig.7 Blocked nozzle plate hazard - group 5/E2

WARNING . . .

(1) A BLOCKED NOZZLE PLATE CONSTITUTES A SERIOUS HAZARD AS IT PERMITS DANGEROUS AMOUNTS OF FUEL TO COLLECT IN THE COMBUSTION CHAMBER. UNDER NO CIRCUMSTANCES MUST A START BE ATTEMPTED UNTIL THE BLOCKAGE HAS BEEN CLEARED.

(2) IF THE FUEL CONTENT IN THE COMBUSTION CHAMBER EXCEEDS 350 cm^3 AN EXPLOSION WILL RESULT, SHOULD A START BE ATTEMPTED, CAUSING EXTENSIVE DAMAGE TO THE STARTER AND TO THE AIRCRAFT.

(3) WATER FLUSHING OF THE ATOMIZER AIR VALVE OR REPEATED PRIMING RUNS, FUEL DRAINAGE CHECKS, UNSUCCESSFUL ATTEMPTS TO START (WHERE COMBUSTION DOES NOT OCCUR) OR WHERE THE FUEL PUMP CONTINUES TO RUN ON DURING PRIMING MAY DISLODGE CARBON (PRODUCTS OF COMBUSTION) WHICH CAN CAUSE BLOCKAGE OF THE NOZZLE PLATE.

Note . . .

An unsuccessful attempt to start (where starter combustion does not occur) has the same effect on the IPN system and passes the same amount of fuel as a priming run or a fuel drainage check.

(4) THE COMBUSTION CHAMBER MUST BE CHECKED FOR FUEL CONTENT AND THE NOZZLE PLATE EXAMINED AND CLEARED, AS THE LAST OPERATION JUST PRIOR TO AN ATTEMPT TO START, IF ANY OF THE FOLLOWING INCIDENTS OCCUR:

(a) THE FUEL PUMP, AIR BLOWER AND MOTOR UNIT FAILS TO SHUT DOWN AT THE END OF THE THREE SECOND AIR CYCLE DURING PRIMING OR FUEL DRAINAGE CHECKS.

(b) MORE THAN FOUR PRIMING RUNS ARE REQUIRED BEFORE FUEL DRAINS FROM THE STARTER EXHAUST.

(c) FAILS FUEL DRAINAGE CHECK.

(d) MORE THAN FIVE STARTER OPERATIONS, COMPRISING FUEL DRAINAGE CHECKS AND UNSUCCESSFUL ATTEMPTS TO START (WHERE COMBUSTION DOES NOT OCCUR) SINCE THE LAST SUCCESSFUL COMBUSTION CYCLE.

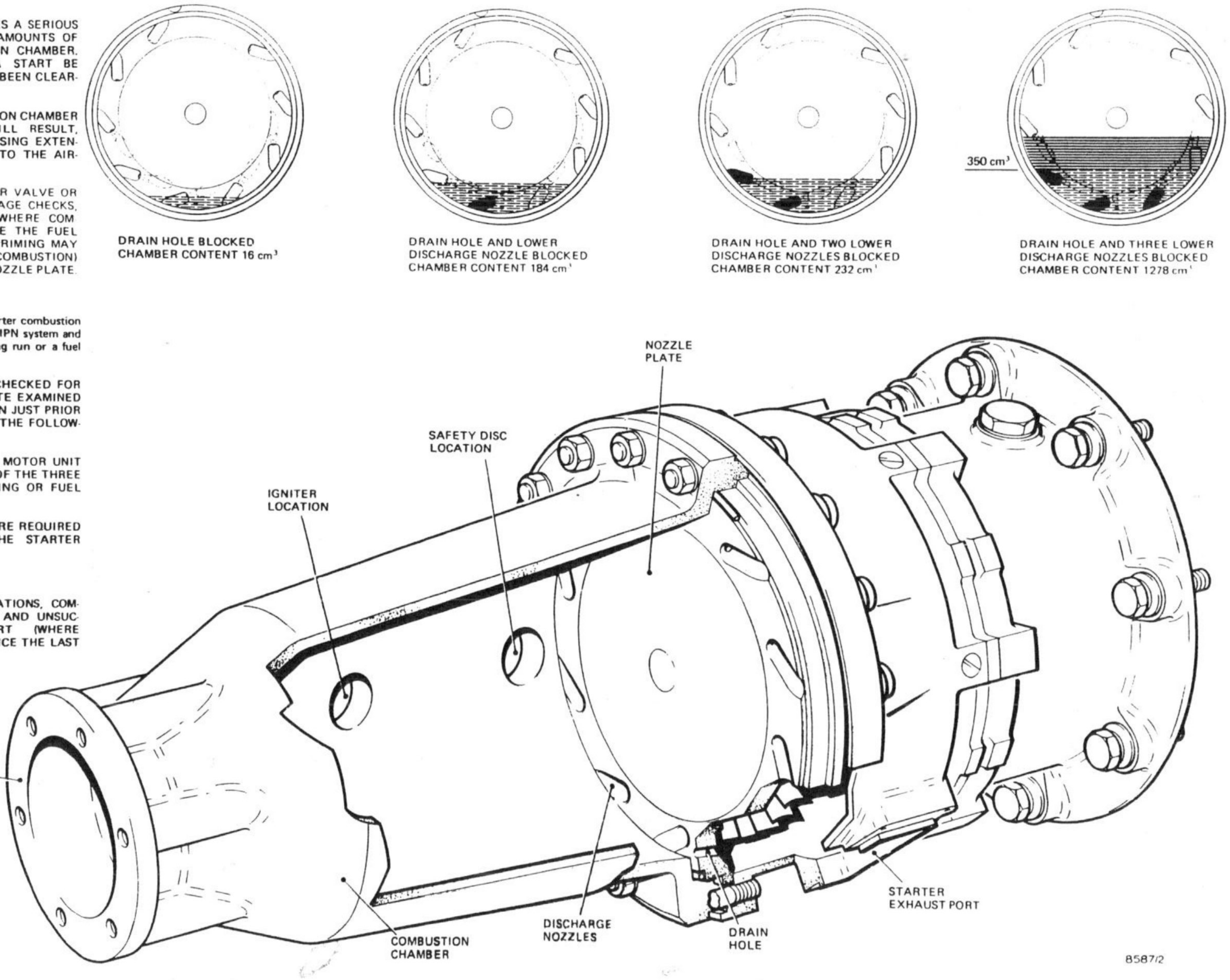
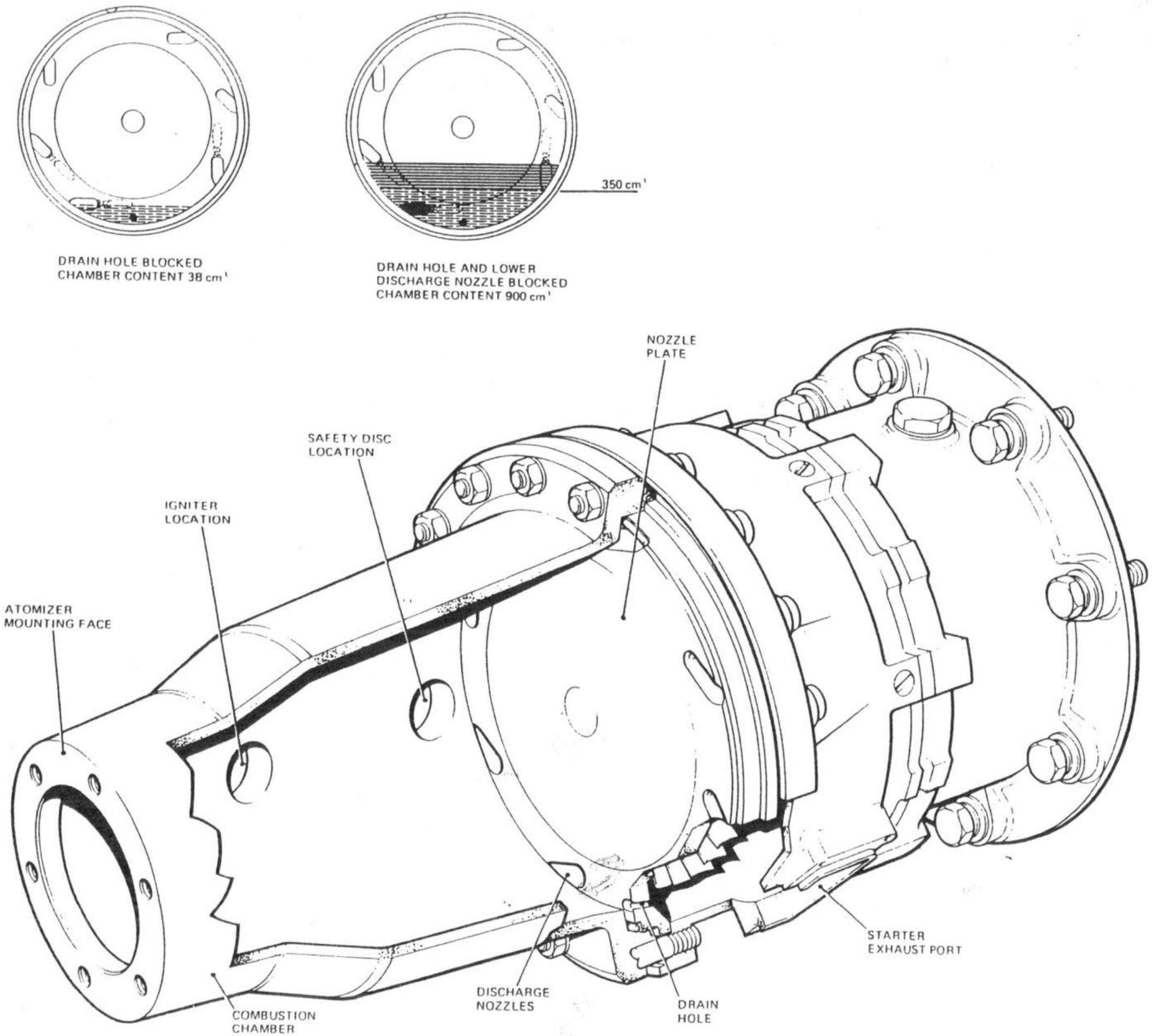


Fig.8 Blocked nozzle plate hazard - group 7/E



WARNING . . .

(1) A BLOCKED NOZZLE PLATE CONSTITUTES A SERIOUS HAZARD AS IT PERMITS DANGEROUS AMOUNTS OF FUEL TO COLLECT IN THE COMBUSTION CHAMBER. UNDER NO CIRCUMSTANCES MUST A START BE ATTEMPTED UNTIL THE BLOCKAGE HAS BEEN CLEARED.

(2) IF THE FUEL CONTENT IN THE COMBUSTION CHAMBER EXCEEDS 350 cm³ AN EXPLOSION WILL RESULT, SHOULD A START BE ATTEMPTED, CAUSING EXTENSIVE DAMAGE TO THE STARTER AND TO THE AIRCRAFT.

(3) REPEATED PRIMING RUNS FUEL DRAINAGE CHECKS, UNSUCCESSFUL ATTEMPTS TO START (WHERE STARTER COMBUSTION DOES NOT OCCUR) OR WHERE THE FUEL PUMP CONTINUED TO RUN ON DURING PRIMING MAY DISLODGE CARBON (PRODUCTS OF COMBUSTION) WHICH CAN CAUSE BLOCKAGE OF THE NOZZLE PLATE.

Note . . .

An unsuccessful attempt to start (where starter combustion does not occur) has the same effect on the IPN system and passes the same amount of fuel as a priming run or a fuel drainage check.

(4) THE COMBUSTION CHAMBER MUST BE CHECKED FOR FUEL CONTENT AND THE NOZZLE PLATE EXAMINED AND CLEARED, AS THE LAST OPERATION JUST PRIOR TO AN ATTEMPT TO START, IF ANY OF THE FOLLOWING INCIDENTS OCCUR:

(a) THE FUEL PUMP, AIR BLOWER AND MOTOR UNIT FAILS TO SHUT DOWN AT THE END OF THE THREE SECOND AIR CYCLE DURING PRIMING OR FUEL DRAINAGE CHECKS.

(b) MORE THAN FOUR PRIMING RUNS ARE REQUIRED BEFORE FUEL DRAINS FROM THE STARTER EXHAUST.

(c) FAILS FUEL DRAINAGE CHECK.

(d) MORE THAN FIVE STARTER OPERATIONS, COMPRISING FUEL DRAINAGE CHECKS AND UNSUCCESSFUL ATTEMPTS TO START (WHERE COMBUSTION DOES NOT OCCUR) SINCE THE LAST SUCCESSFUL COMBUSTION CYCLE.

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Fig.9 Blocked nozzle plate hazard - group 23/E

8.7 The gearbox consists of a mounting flange, a bearing housing and an exhaust casing, bolted together to house the rotor, the epicyclic reduction gear and speed control switch.

8.8 The rotor shaft is mounted in ball and roller bearings in the exhaust casing and carries the sun gear of the epicyclic geartrain. A labyrinth seal arrangement and a double piston ring seal, mounted on the rotor shaft, prevent gas leakage from the exhaust casing into gearbox and minimize oil loss from the gearbox. A guide plate shrouds the labyrinth and provides a heat shield for the rotor rear face.

8.9 Three saetllite gears, mounted on a fixed carrier, transmit the drive to an annulus gear mounted on the output shaft. A self-aligning, double row ball bearing supports the output shaft, and an oil seal, secured in the bearing housing, prevents the interchange of oil with the engine.

8.10 The speed control switch is mounted in a housing at the rear of the satellite carrier and is actuated by a centrifugal governor housed in the bore of the sun gear. The switch is connected, via a sealed plug between the switch and bearing housing, with a two-pin plug on the outside of the gearbox.

8.11 The gearbox is splash lubricated and receives a measured quantity of oil from the engine, on each starting cycle, from an engine mounted single-shot pump. The oil is injected into the starter gearbox via a drilling in the mounting flange.

OPERATION (fig. 10, 11, 12 and 13)

Pre-mod S.647 (fig.10)

9

9.1 On depressing the engine start button, the speed control relay (R2) is energized via the 10A fuse, switch 'A', the start button and the speed control switch in the starter motor. R2 contacts close to connect the supply to the motor contactor, and via the HP and ignition switches, to the coil of the slugged relay (R1/2). Contacts R1(A) close momentarily before R1(B) to provide a 'hold in' circuit for R2 from switch F. As contacts R1(B) close, power is supplied, via switch B, to the time switch motor and clutch coil. The clutch engages and operates switch 'A', which open circuits the starter button and provides an alternative supply to the time switch motor, by-passing contacts R1(B). The cam mechanism, driven by the time switch motor, via the clutch, commences to rotate. After 0.75 seconds, the normally open contacts of switch 'D' close to connect the positive supply to the open contact of the HP switch.

9.2 Refer to fig. 12 and 13. The motor unit, energized via the contactor on selection of the start, drives the air blower and the fuel pump. Air from the blower is delivered to the starter motor via the air valve in the atomizer. The air scavenges the combustion chamber expelling any residual combustion materials to atmosphere via the nozzle plate and starter exhaust. Pump delivery fuel passes to the HP switch and solenoid valve assembly. The fuel by-passes the anti-dribble valve and is delivered to the solenoid valve which opens, under fuel pressure, and passes the fuel through the non-return valve back to the aircraft tank.

9.3 After 2.75 seconds, the normally open contacts of switch 'E' are closed to energize the solenoid valve. The valve closes, under servo action, shutting off the fuel return to the tank and resulting in an immediate rise in pump delivery pressure. This rise in pressure partially opens the anti-dribble valve (against the spring loaded push rod) and fuel passes, via the ignition switch and the fuel valve in the atomizer, to the combustion chamber. At the same time, the rising fuel pressure opens the dump valve venting the blower delivery air to atmosphere.

9.4 As fuel is injected into the combustion chamber, the ignition switch operates, de-energizing the slugged relay and energizing the ignition unit primary circuit. The resulting high frequency/high energy discharge is fed to the igniters and ignition occurs. The rapid increase in combustion chamber pressure, following ignition, causes a rise in the fuel pump delivery pressure. The higher fuel pressure, acting on the anti-dribble valve, overcomes the plunger spring and operates the HP switch to de-energize the ignition unit and provide a maintaining circuit to the speed control relay via switch 'D', by-passing the slugged relay contacts R1(A).

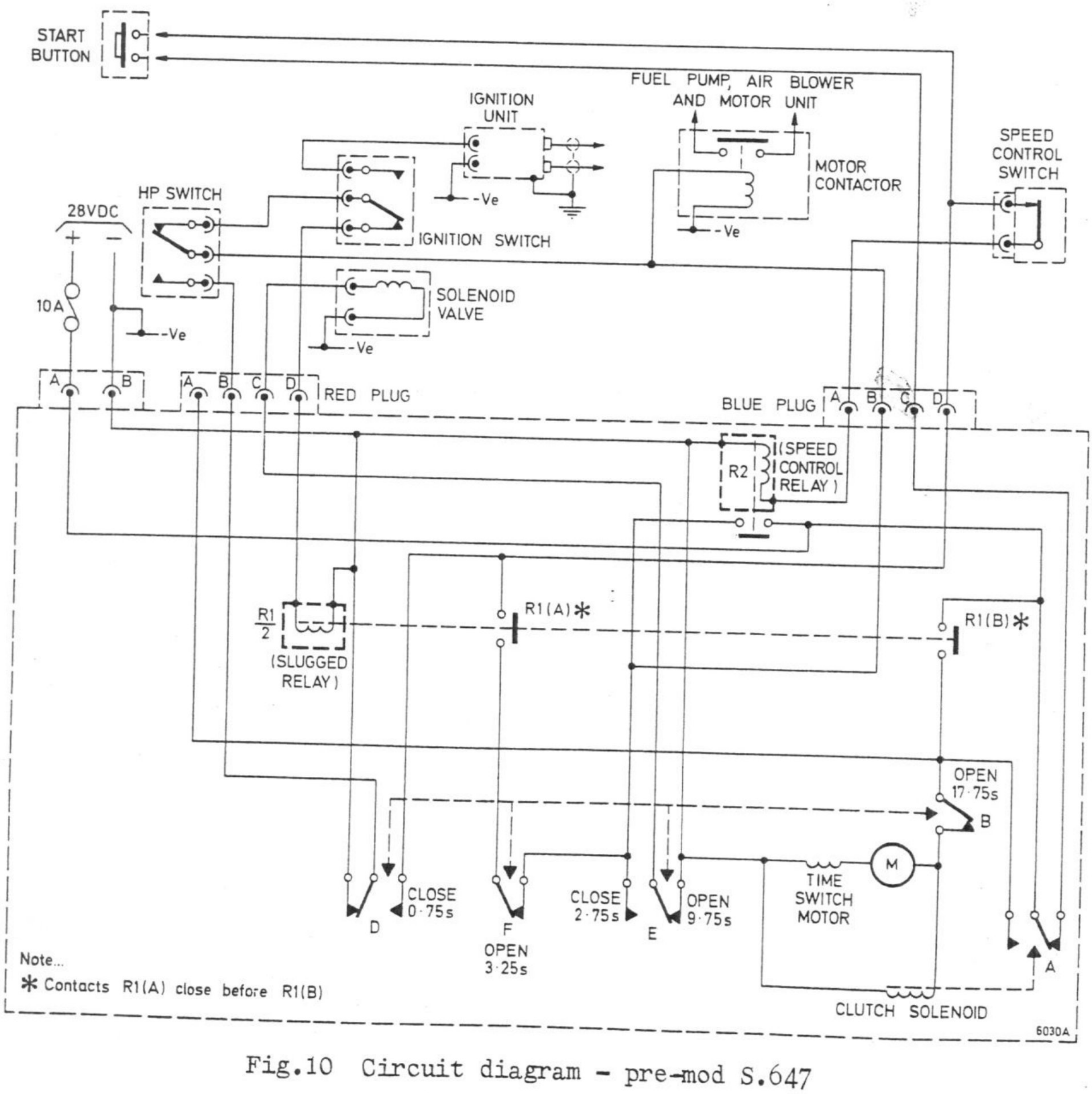

Fig.10 Circuit diagram - pre-mod S.647

9.5 If ignition of the fuel does not occur within 0.18 seconds of operation of the ignition switch, the delay opening of the slugged relay contacts R1(A) will de-energize the speed control relay and shut down the starter system. Should ignition not take place and the slugged relay fail to release, the system will be shut down by switch 'F', overriding contacts R1(A), approximately 3.25 seconds from the initiation of the start. Any fuel collected in the combustion chamber will drain to atmosphere via the nozzle plate drain hole and starter exhaust.

9.6 The combustion gas is directed through the nozzle plate on to the blades of the rotor. The resultant drive is transmitted to the engine via the reduction gear and output shaft. The rotor accelerates and, at a predetermined speed, the speed control switch operates, de-energizing the speed control relay and shutting down the starting system. Should the starter fail to reach cutout speed within 7 seconds of the solenoid valve closing, such as during an engine dead crank, switch 'E' will de-energize the solenoid valve shutting off the fuel supply to the atomizer; the HP switch interrupts the supply to the speed control relay and the motor unit stops. The control unit time switch motor operates for approximately 18 seconds, until switch 'B' is opened by the cam mechanism. The motor and clutch are de-energized and the cam mechanism returns, under the action of a coil spring, to the starting position. Switches 'D' and 'E' provide system protection in the event of a 'short circuit' condition; any attempt to initiate a start under this condition will cause the 10A fuse to blow.

<u>Mod S.647</u> (fig.11)

10

10.1 On depressing the engine start button, the positive supply from the 10A fuse is applied, via pin 'D' on the blue plug, to a 'pulse' circuit R18/C3 and, via the speed control switch in the starter motor, to the coil of relay Ra1. The pulse, applied via D20, 'switches-on' TR6 which energizes relay Ra1. Contacts Ra1/1 close to connect the supply to the motor contactor and via the HP switch, ignition switch, D24 and R11 to TR4 which 'switches-on' and short circuits C4, preventing TR5 from switching on. Simultaneously the supply is connected to the coil of relay Ra1, via D21 and the speed control switch, to TR6, via R1, R12 and D13, and to the time delay circuit RV1/R7/C2, via R1 and D27. Relay Ra1 thus 'holds-in' and capacitor C2 commences to charge.

10.2 Refer to fig.12 and 13. The motor unit, energized via the contactor on selection of the start, drives the air blower and the fuel pump. Air from the blower is delivered to the starter motor via the air valve in the atomizer. The air scavenges the combustion chamber expelling any residual combustion materials to atmosphere via the nozzle plate and starter exhaust. Pump delivery fuel passes to the HP switch and solenoid valve assembly. The fuel by-passes the anti-dribble valve and is delivered to the solenoid valve, which opens, under fuel pressure, and passes the fuel through the non return valve back to the aircraft tank.

10.3 After 2.75 seconds, the voltage on C2, applied via D23, triggers TR3 which conducts, causing TR1 to 'switch on' and relay Ra2 to energize. Under these conditions D20 is reverse biased, via D8, ensuring that, in the event of C3 allowing excessive leakage current, the control of relay Ra1 is not jeopardised. Contacts Ra2/4 provide an alternative circuit to TR3, ensuring that relay Ra2 'holds-in'. Contacts Ra2/1 connect the supply to three time delay circuits (RV5/R13/C6, RV3/R22/C5 and RV4/R14/C1) and to the solenoid valve. The valve closes, under servo action, shutting off the fuel return to the tank and resulting in an immediate rise in pump delivery

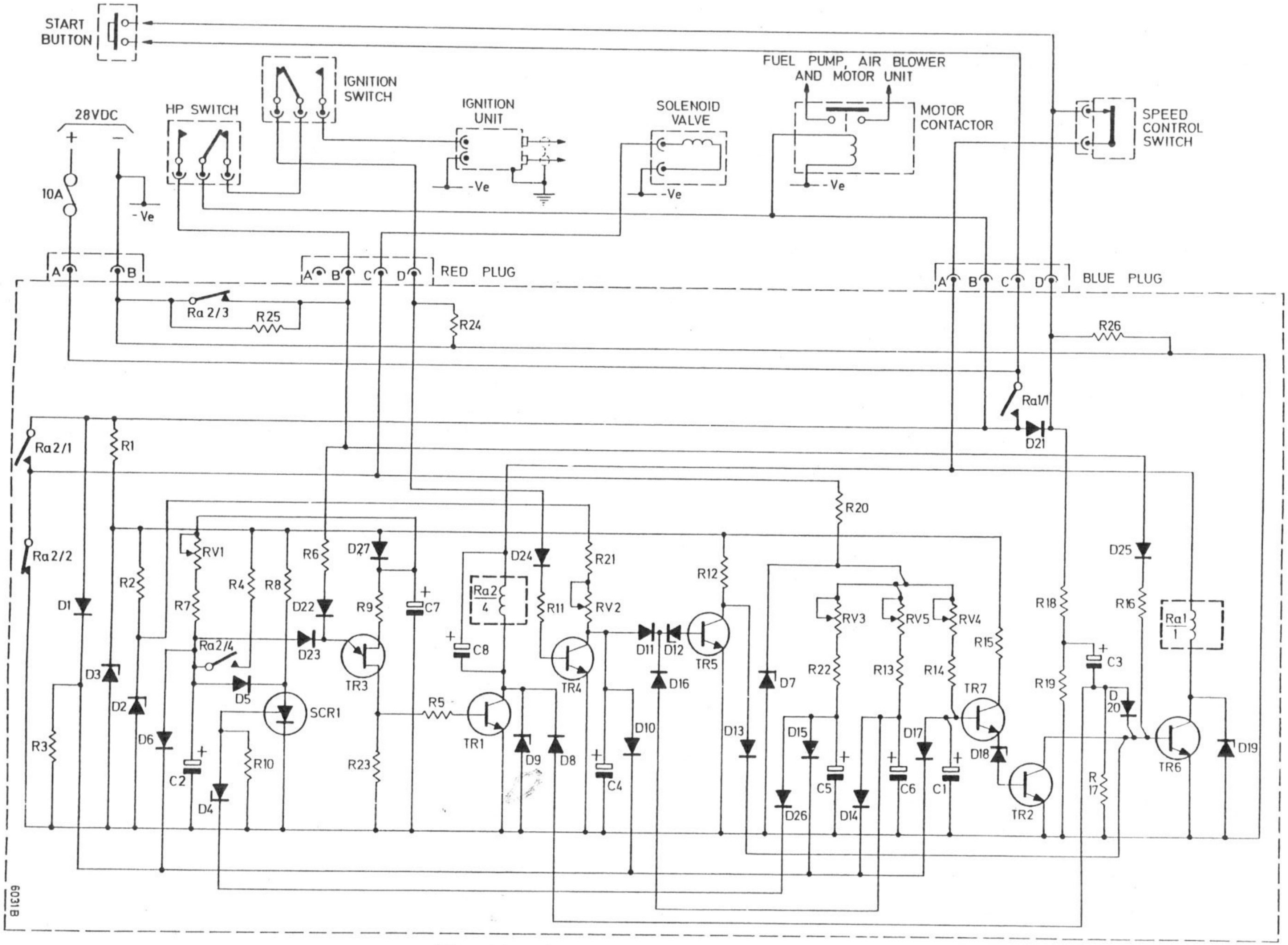

Fig.11 Circuit diagram - Mod. S.647

pressure. This rise in pressure partially opens the anti-dribble valve (against the spring loaded push rod) and fuel passes via the ignition switch and the fuel valve in the atomizer, to the combustion chamber. At the same time, the rising fuel pressure opens the dump valve, venting the blower delivery air to atmosphere.

10.4 As fuel is injected into the combustion chamber, the ignition switch operates, 'cutting off' TR4 and energizing the ignition unit. The resulting high frequency/high energy discharge is fed to the igniters and ignition occurs. The rapid increase in combustion chamber pressure, following ignition causes a rise in the fuel pump delivery pressure. The higher fuel pressure, acting on the anti-dribble valve, overcomes the plunger spring and operates the HP switch to de-energize the ignition unit and provide maintaining circuit to TR3, via R6 and D22, and to TR6, via D25 and D16. Relays Ra1 and Ra2 thus remain energized.

10.5 With TR4 'cut-off' following the operation of the ignition switch, C4 commences to charge via R21 and RV2. After 0.18 seconds, the forward voltage at D11 causes D12 to breakdown and TR5 to 'switch-on'. D13 is thus reverse biased, removing the supply from R12 to the base of TR6. Where ignition of the fuel does not occur within the delay period, relay Ra1 is de-energized and the starter system shuts down. Should ignition not take place and relay Ra1 fail to release, the system will be shut down, approximately 3.25 seconds from the initiation of the start, when the voltage on C6 is sufficient to 'switch-on' TR5, causing relay Ra1 to de-energize, as previously described. Any fuel collected in the combustion chamber will drain to atmosphere via the nozzle plate drain hole and starter exhaust.

10.6 After 0.5 seconds, from the operation of relay Ra2, the voltage at C5, applied via D26, causes D4 to breakdown and SCR1 to 'switch-on'. C2 is thus shorted and the supply, via D23, to TR3 is removed. Providing that the system is operating satisfactorily, TR3 remains biased on, via D22 as previously described.

10.7 The combustion gas is directed through the nozzle plate on to the blades of the rotor. The resultant drive is transmitted to the engine via the reduction gear and output shaft. The rotor accelerates and, at a predetermined speed, the speed control switch operates, de-energizing relays Ra1 and Ra2 and shutting down the starting system. Should the starter fail to reach cutout speed within 7 seconds of the solenoid valve closing, such as during an engine dead crank, the voltage on C1 will 'switch-on' TR7 and TR2 connecting the base of TR6 to the negative supply line. TR6 will thus 'cut-off', de-energizing relays Ra1 and Ra2. Contacts Ra1/1 open, then Ra2 contacts operate, capacitor C8 providing the 'drop-out' time delay, and the system is completely shut down. Contacts Ra2/2 and Ra2/3 close to provide system protection. The time delay circuits discharge, via the appropriate diode and R3, to ensure that the correct time sequence occurs during a subsequent start.

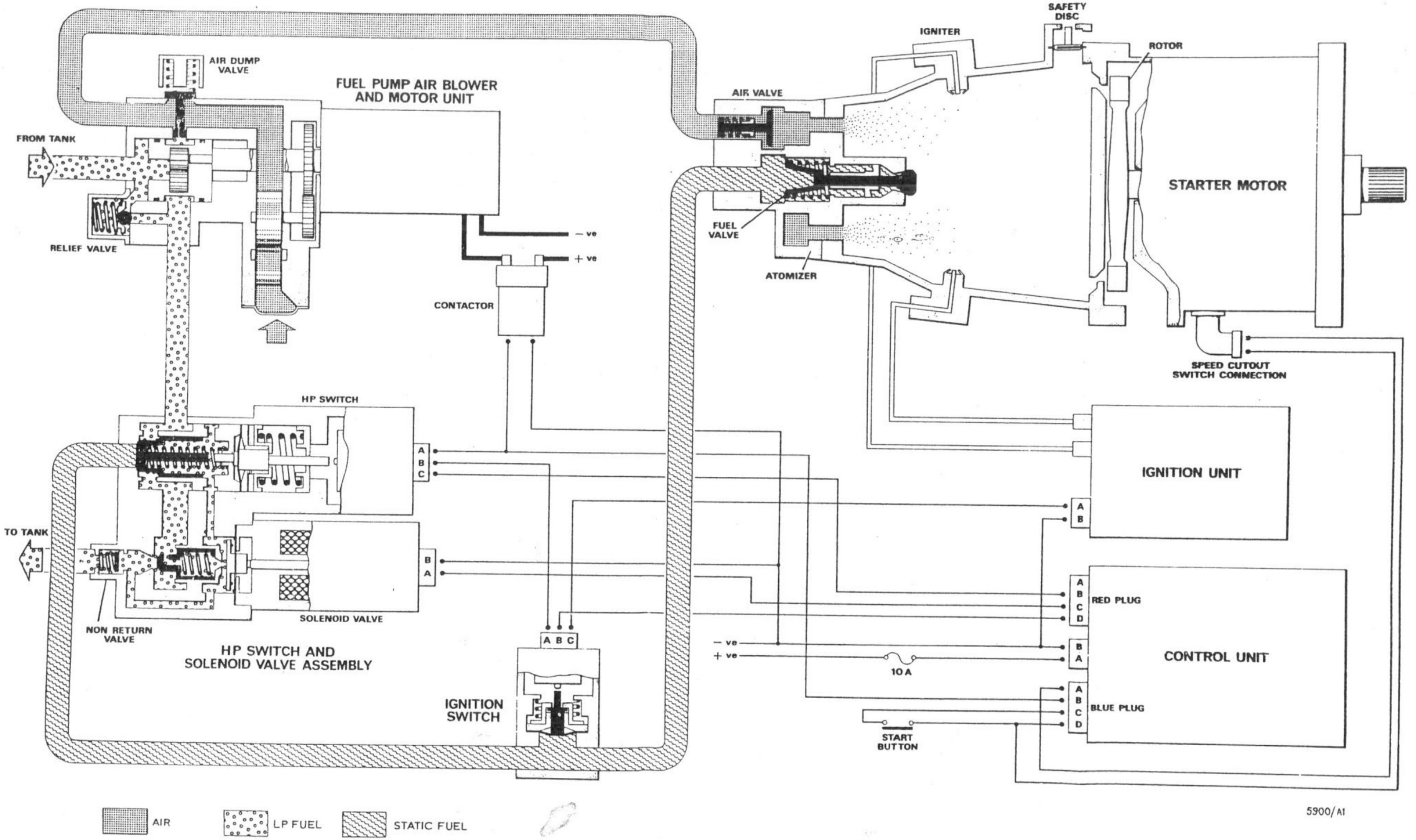

Fig.12

IPN system diagram - scavenging

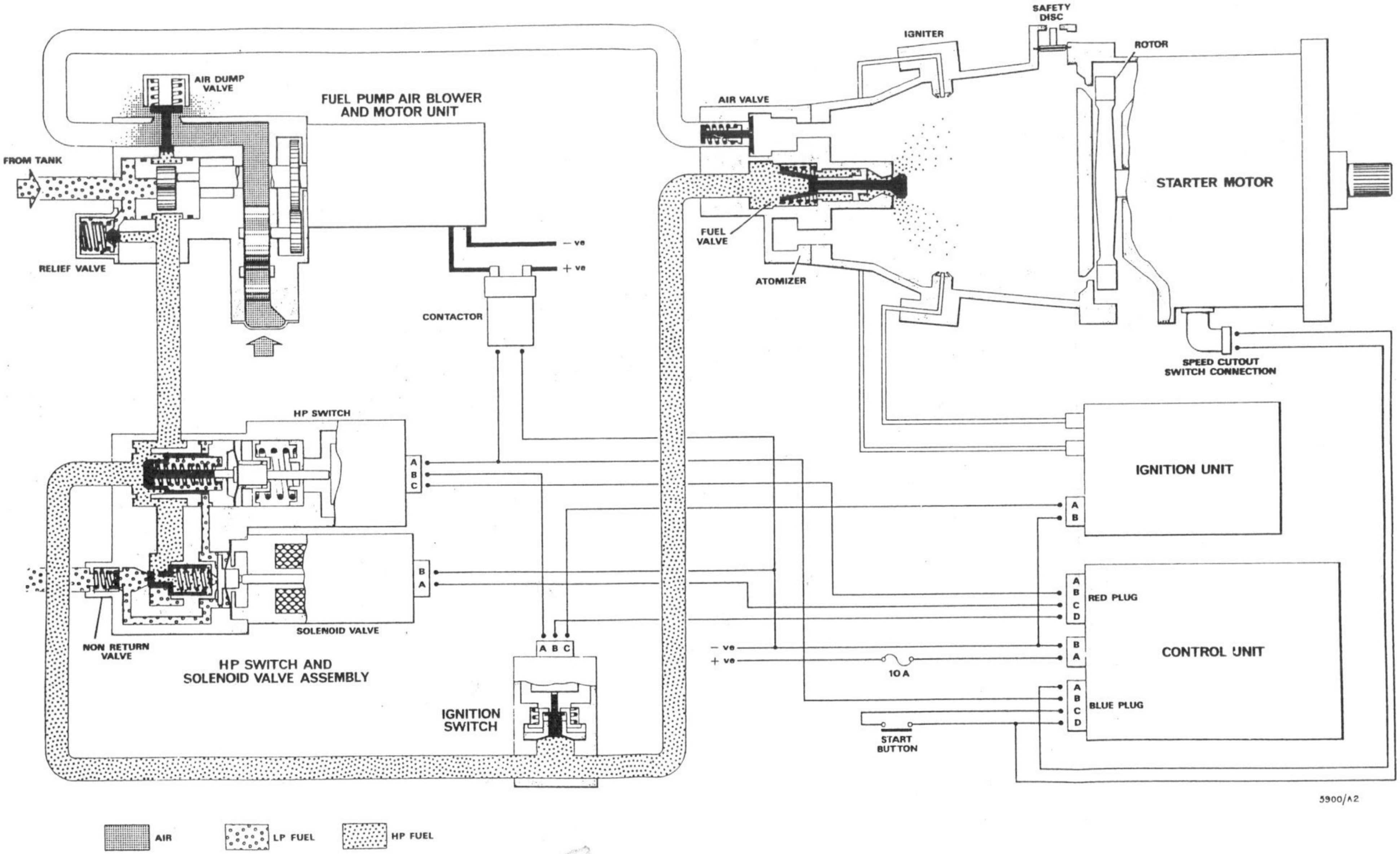

Fig.13 IPN system diagram - combustion Fig.13

SERVICING

Introduction

11 The following operations detail the procedures to be effected as a result of fault diagnosis on engine equipment. The equipment is identified by groups, details of which are given in the preliminary pages. Reference should be made to the relevant associated air publications, details of which are given in the preliminary pages, for servicing the airframe mounted equipment.

CAUTION ...

On no account should the starter motor be lifted by means of the pipes as this may result in damage.

11.1 The special tools, test equipment and materials required are listed in Table 1 and are called up in the text by the 'Table No. and Item No'.

11.2 Discard all disturbed tabwashers, O-ring seals, gaskets and locking wire on removal.

11.3 O-ring seals should be fitted in the dry condition and the exposed surface lubricated with grease, Table 1, Item 7.

11.4 During assembly lubricate all threads with grease, Table 1, Item 6.

11.5 Only those cleaning agents, listed in Table 1, or their equivalent substitutes, should be used during servicing of the IPN components.

CAUTION ...

Under no circumstances should an alkaline based cleaning agent be used.

Examine for damage and security

12

12.1 Remove light corrosion; reprotect exposed surfaces.

12.2 Tighten loose bolts, screws, nuts, etc. (refer Table 2).

12.3 Renew faulty locking devices.

12.4 Check for fuel leaks; renew faulty seals.

12.5 Examine the fuel and air pipes.

Note ...

The rigid fuel and air pipes on engine group 5/E2 are jigged on assembly, using fixture, Table 1, Item 3.

12.5.1 Fuel pipes: Smooth indentations on the tube are acceptable provided that such damage will allow the free passage of a 11/32 in diameter ball through the tube. Sharp indentations or cuts greater than 0.005 inch in depth will entail rejection of the pipe.

12.5.2 Air pipes: Smooth indentations on the tubes are acceptable provided that such damage will allow the free passage of a 7/16 in diameter ball through the tube. Sharp indentations or cuts are acceptable providing there is no evidence of leakage when the pipe is subjected to an internal air pressure of 50 lbf/in^2, using test fixture, Table 1, Item 4 or 5, and the pipe submerged in water.

TABLE 1 SPECIAL TOOLS, TEST EQUIPMENT AND MATERIALS

Item	Ref. No.	Part No.	Description
1	5G/1621	-	Insulation resistance tester
2	5QP/17447	-	Multimeter
3	-	558-1-03430	Fixture - aligning fuel and air pipes (group 5/E2)
4		558-1-03452	Test fixture, air pipe (group 23/E)
5		558-1-03453	Test fixture, air pipe (group 5/E2)
6	34B/9100528	DTD 392A	Grease ZX-13 (NATO code S-720)
7	33H/9424829	DTD 900/4298	Grease XG-250 (NATO code S-736)
8	30A/9437135	DTD 189	Locking wire 0.028 in dia (22 swg)
9	34A/9100591	DERD 2487	Oil, OX-38 (NATO code O-149)
10	-	-	Spectra spot-leak fluid
11	33C/2203584	-	Cleaning fluid, Methyl-ethyl-ketone

TABLE 2 TORQUE LOADINGS

Item		
Safety disc holder	384 lbf in	(43.39 Nm)
Atomizer securing bolts	180 lbf in	(20.34 Nm)
Igniter securing bolts	32 to 35 lbf in	(3.62 to 3.95 Nm)
Combustion chamber securing nuts/bolts	216 lbf in	(24.41 Nm)
Fuel pipe-to-atomizer nuts/bolts	100 lbf in	(11.30 Nm)
Air pipe-to-atomizer nuts/bolts (groups 5/E2 and 23/E)	170 lbf in	(19.21 Nm)
Air hose securing bolts (group 7/E)	180 lbf in	(20.34 Nm)
Gearbox to exhaust casing bolts	100 lbf in	(11.30 Nm)
Exhaust outlet securing bolts	108 lbf in	(12.20 Nm)

REMOVAL AND INSTALLATION

Safety disc(s) (fig. 14, 15 16 and 17)

13

13.1 Unlock and remove the locking screw.

13.2 Remove the star locking washer, then remove the disc holder.

13.3 Remove and discard the disc from the holder.

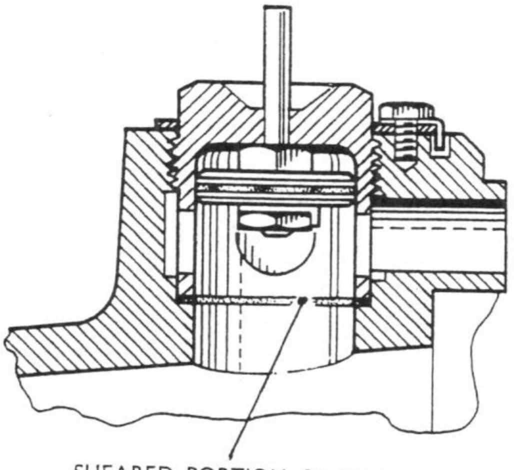

Fig.14 Sectioned view of sheared safety disc

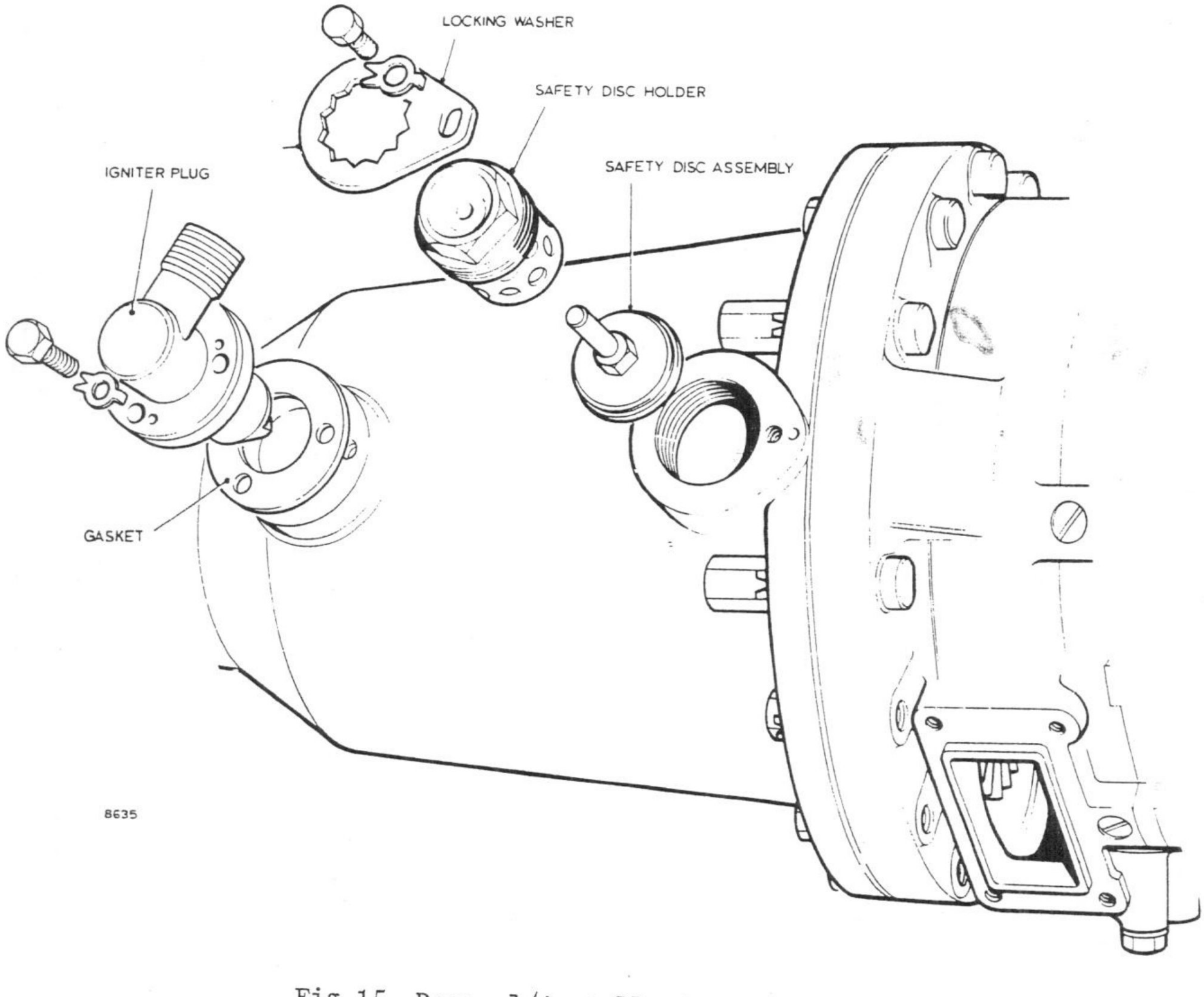

Fig.15 Removal/installation of igniter and safety disc - group 23/E

13.4 Remove and discard the sheared outer edge of the disc from the seating in the combustion chamber, then remove any carbon from the seating.

Note ...

Care must be exercised to avoid damaging the seating during this operation.

Install the safety disc(s)

14

14.1 Position the safety disc, stem first, in the holder.

14.2 Apply an even coating of grease, Table 1, Item 6, to the threads of the holder then assemble the holder to the combustion chamber and torque tighten to the specified figure.

14.3 Position the star locking washer, aligning the locking screw hole, on the holder and secure with the locking screw and tabwasher.

14.4 Fully tighten the screw and lock.

Igniter plug(s) (fig. 15, 16, 17 and 18)

Remove the igniter plug(s)

15

15.1 Note the angular relationship of the igniter cap to the combustion chamber, then unlock and remove the securing bolts.

15.2 Remove the igniter plug, then remove the gasket.

Note ...

Two 2BA tapped holes are provided in the body flange for extraction purposes.

15.3 Secure the plug body to the plug cap with the transportation nuts and bolts.

Install igniter plug(s)

16

16.1 Ensure that the igniter mounting face in the combustion chamber is clean and free from carbon deposits.

16.2 Remove the transportation nuts and bolts, then separate the plug cap from the plug body.

16.3 Position the gasket on the plug body, then insert the body with the earth electrodes positioned at right angles to the starter axis as shown in fig.18.

16.4 Position the plug cap, orientated as noted in para. 15.1 (refer fig. 15, 16 and 17) in the body and secure with the bolts and tabwashers.

Note ...

Apply a thin coating of grease, Table 1, Item 6, to the thread of each bolt.

16.5 Torque tighten the bolts to the specified figure.

16.6 Lock the bolts by bending up the tabwashers.

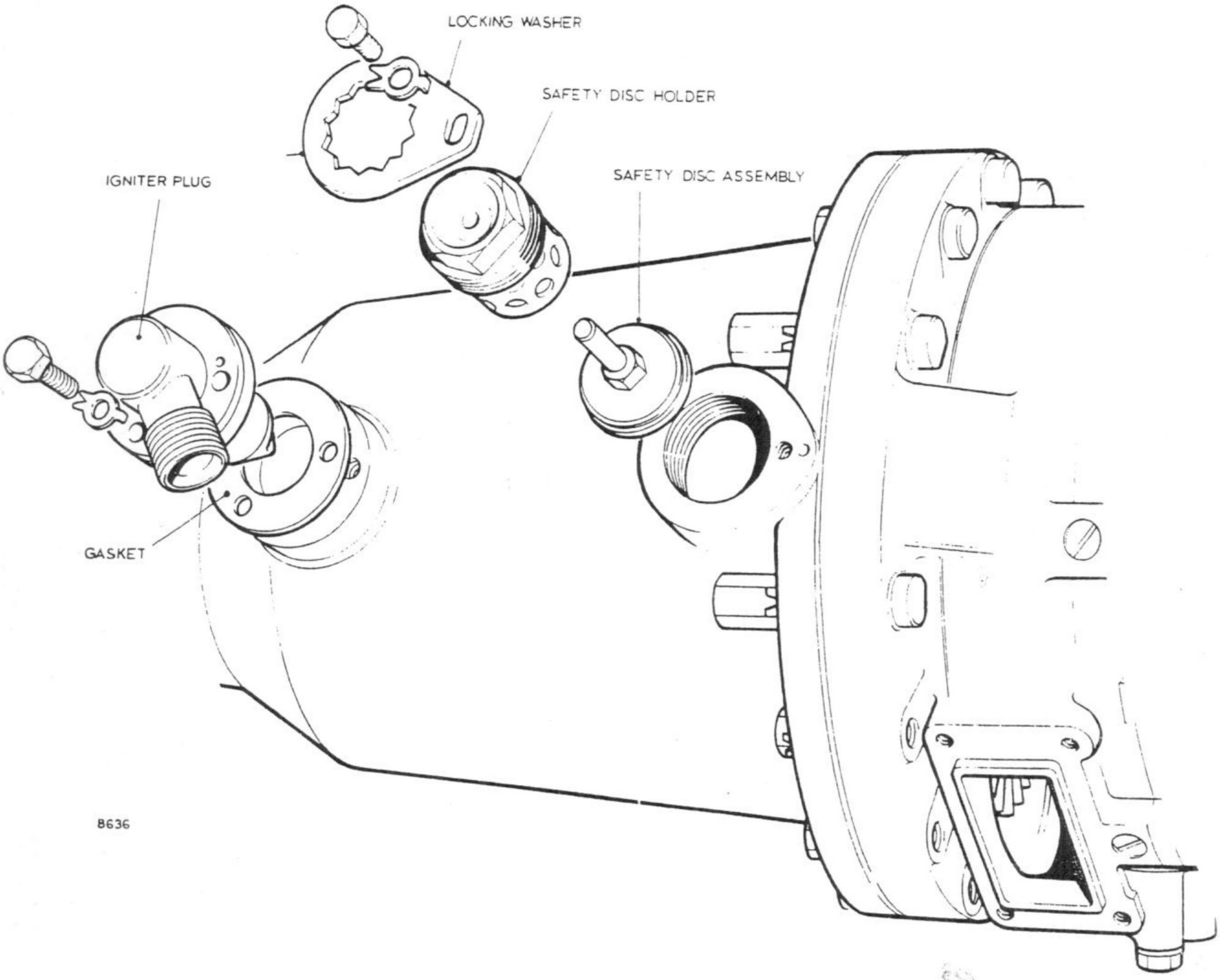

Fig.16 Removal/installation of igniter and safety disc - group 5/E2

Atomizer (Group 23/E) (fig. 19)

Remove the atomizer

Note ...

The securing bolts for the atomizer and for the fuel and air pipes are lifed to the starter and must be retained with the starter motor.

17

17.1 Unlock and remove the nuts and bolts securing the fuel pipe.

17.2 Unlock and remove the nuts and bolts securing the air pipe.

Note ...

On pre mod 2278 units, identify the air pipe securing bolts to their location to facilitate assembly.

17.3 Unlock and remove the bolts securing the atomizer, then withdraw the atomizer from the combustion chamber.

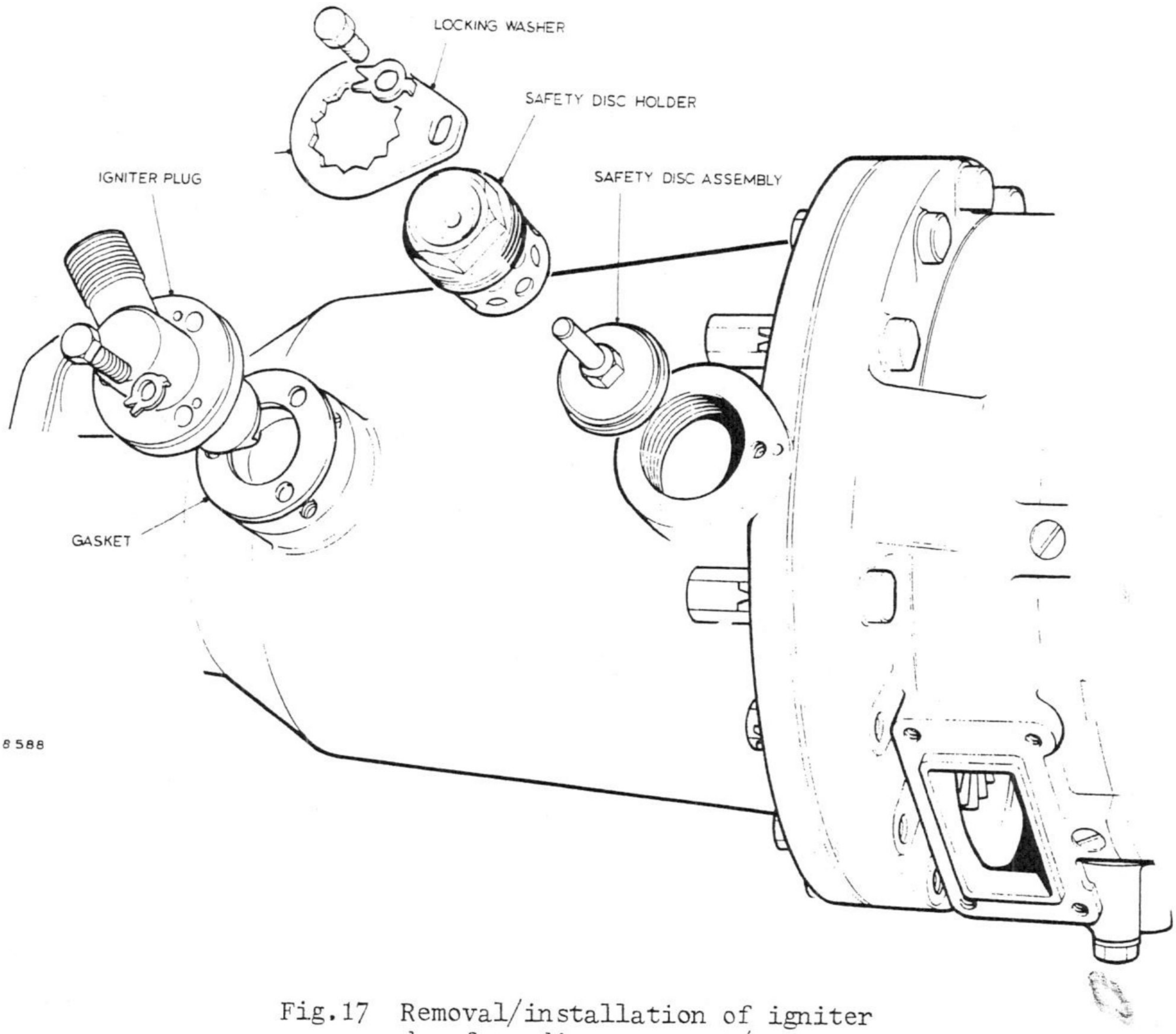

Fig.17 Removal/installation of igniter and safety disc - group 7/E

17.4 Remove and discard the atomizer gasket.

17.5 Remove and discard the internal O-ring seals from the fuel and air pipe sleeves.

17.6 Fit the fuel inlet sleeve, air valve and atomizer dust covers and secure with the nuts, bolts and distance pieces.

Install the atomizer

18

18.1 Check that the nozzle plate drain hole and nozzles in the combustion chamber are completely clear then, using a suitable suction type cleaner, remove any loose carbon from the chamber; recheck the drain hole and nozzles.

18.2 Remove the transit nuts and bolts securing the dust covers to the fuel and air valve sleeves.

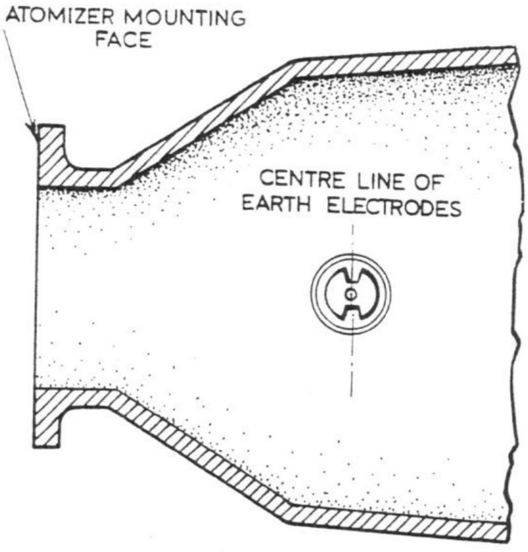

Fig.18 Orientation of igniter plugs

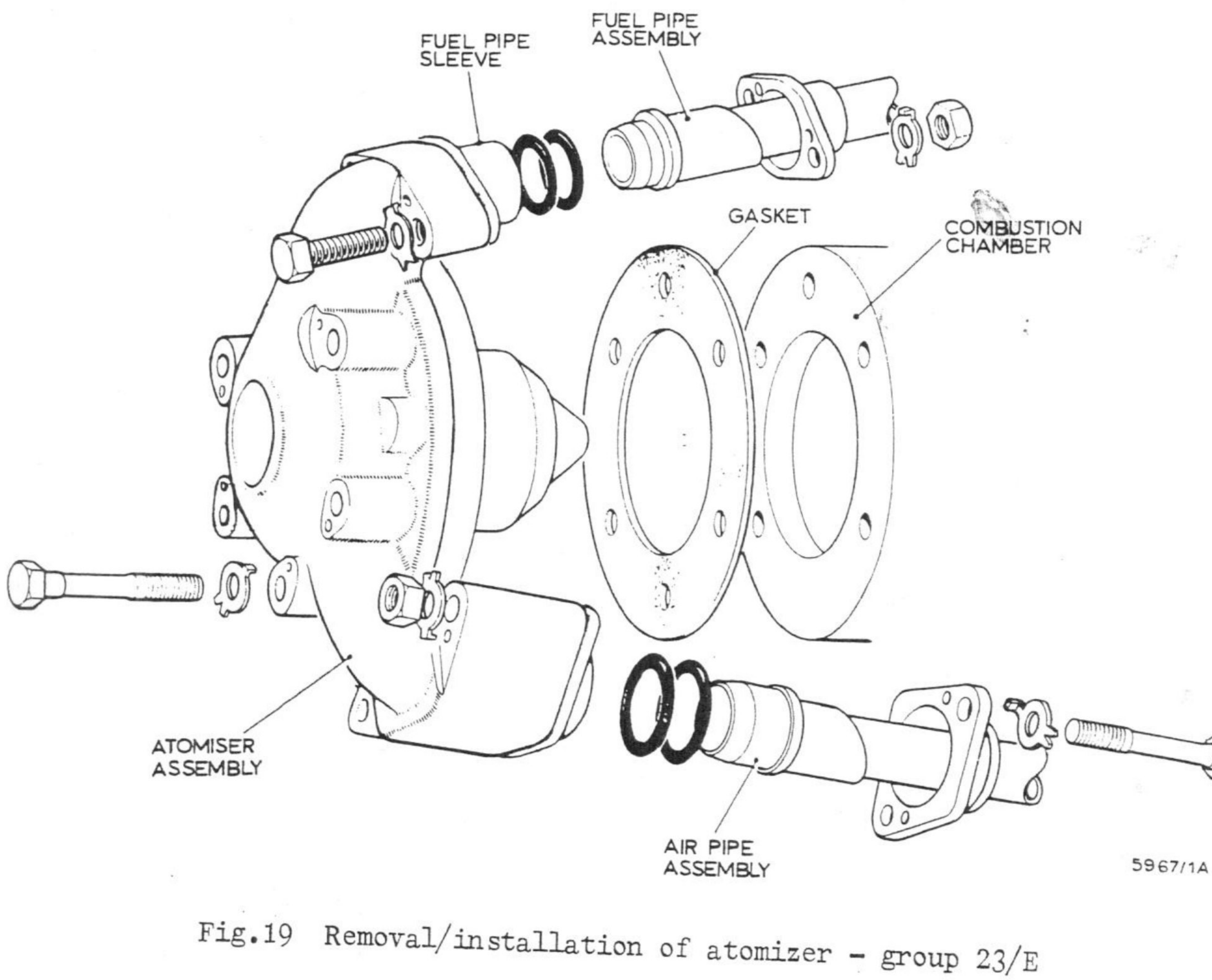

Fig.19 Removal/installation of atomizer - group 23/E

18.3 Remove the transit nuts and distance pieces securing the atomizer dust cover, then remove the cover.

CAUTION ...

On no account must the transportation bolts retaining the dust covers be used to secure the atomizer to the starter and/or the fuel and air pipes.

18.4 Position the gasket, aligning the bolt holes, on the atomizer, then check that the internal O-ring seals in the fuel and air pipe sleeves are fully located in their grooves.

CAUTION ...

Pre-mod 2278: The air pipe securing bolts are very similar to the atomizer securing bolts and must not be used to secure the atomizer. Prior to assembly, identify and separate the two air pipe securing bolts; the bolts are slightly longer than the six atomizer bolts and have a shorter land under the bolt head.

18.5 Assemble the atomizer, interposing the gasket and engaging the fuel and air pipes, to the combustion chamber, and secure with the bolts and tabwashers; torque tighten the bolts to the specified figure, then lock by bending up the tabwashers.

Note ...

The bolts should be tightened evenly, in turn, to avoid distortion of the housing.

18.6 Secure the air and fuel pipes with the nuts, bolts and tabwashers, then torque tighten the nuts to the specified figure.

Note ...

Tabwashers are located under the nuts and the head of the bolts.

18.7 Lock the nuts and bolts by bending up the tabwashers.

Atomizer (Group 5/E2) (fig. 20)

Remove the atomizer

Note ...

The securing bolts for the atomizer and for the fuel and air pipes are lifed to the starter and must be retained with the starter motor.

19

19.1 Remove the bolts and washers securing the fuel and air pipes to the atomizer, then withdraw the pipes from the atomizer housing.

19.2 Remove the shims and record the thickness to facilitate re-assembly.

19.3 Remove and discard the ACA seals.

19.4 Unlock and remove the bolts securing the atomizer, then withdraw the atomizer from the combustion chamber.

19.5 Remove and discard the atomizer gasket.

19.6 Fit the fuel inlet port, air valve and atomizer dust covers and secure with the nuts, bolts and packing pieces.

Install the atomizer

CAUTION ...

The atomizer to be installed must be the same modification standard as that removed.

20

20.1 Using a suitable wire brush, loosen the carbon in the combustion chamber then, using a suitable suction type cleaner, remove the loose carbon from the chamber.

20.2 Check that the nozzle plate drain hole and nozzles are completely clear.

20.3 Remove the transit nuts and distance pieces securing the atomizer dust cover, then remove the dust cover.

CAUTION ...

On no account must the transportation bolts, retaining the dust covers, be used to secure the atomizer to the starter motor and/or the fuel and air pipes to the atomizer.

20.4 Position the gasket, aligning the bolt holes, on the atomizer, then assemble the atomizer aligning the fuel and air ports to the pipes, and secure with the bolts and tabwashers.

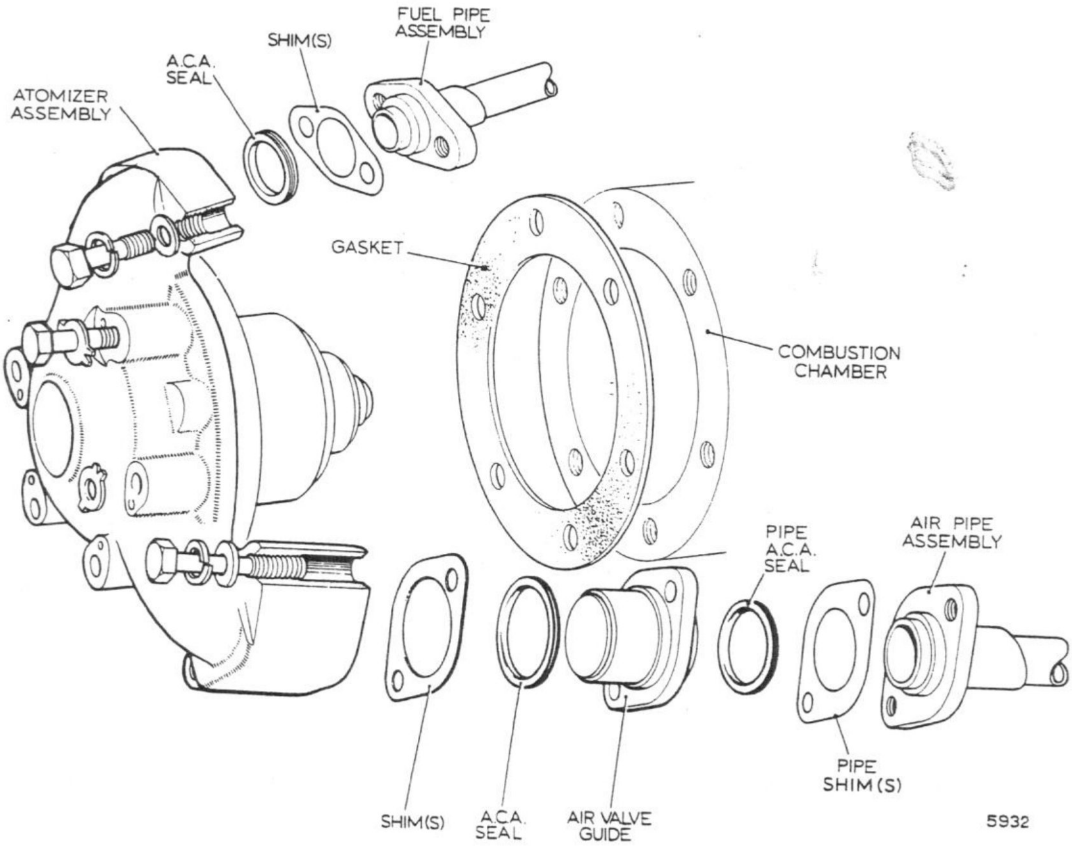

Fig.20 Removal/installation of atomizer - group 5/E2

20.5 Torque tighten the bolts to the specified figure.

Note ...

The bolts should be tightened evenly, in turn, to avoid distortion of the housing.

20.6 Fit the fuel pipe (pre-mod 2279)

Note ...

On Mod. 2279 units, the actual dimensions, engraved on the pipe end fittings and on the atomizer housings, may be used, together with the thinnest section of the ACA seal, to obtain the required nip of 0.014 to 0.016 in (0.36 to 0.41 mm) on the ACA seal.

20.6.1 Remove the transit nuts and bolts securing the dust cover to the fuel inlet port.

20.6.2 Inspection check

20.6.2.1 Examine the new ACA seal for burrs and minor damage, paying particular attention to the seal lip.

20.6.2.2 Using crocus grade abrasive paper, lightly lap the faces of the ACA seal.

20.6.3 Select the fuel pipe shim(s)

20.6.3.1 Determine the difference between the maximum and minimum thickness of the ACA seal, then add 0.015 in (0.38 mm) record the figure obtained as dimension X.

20.6.3.2 Position the ACA seal on the fuel pipe, then insert the pipe to the inlet port.

20.6.3.3 Holding the pipe firmly in position, measure the gap between the pipe flange and the housing; record the figure obtained as dimension Y. Remove the pipe.

Note ...

Ensure that the gap is equal at both bolt holes.

20.6.3.4 Subtract dimension X from dimension Y, then select shim(s) to within ± 0.001 in (0.025 mm) of the figure obtained.

20.6.4 Locate the ACA seal and the selected shim(s) on the pipe, then reassemble the pipe.

20.6.5 Secure the pipe with the retaining bolts, plain washers and spring washers; do not tighten the bolts at this stage.

20.7 Fit the air pipe

20.7.1 Remove the transit nuts and bolts securing the dust covers to the air valve, then remove the dust cover.

20.7.2 Remove the air valve and shim(s).

20.7.3 Determine the difference between the maximum and minimum thickness of the ACA seal, then add 0.011 in (0.28 mm); record the figure obtained.

20.7.4 Position the ACA seal and shim(s) on the air valve, then assemble the valve to the air inlet port.

20.7.5 Holding the valve body firmly in position measure the clearance between the valve flange and the housing; this should be within 0.001 in (0.025 mm) of the figure recorded in sub-para 20.7.3. Adjust the thickness of the shim(s) to suit.

20.7.6 Determine the difference between the maximum and minimum thickness of the air pipe ACA seal, then add 0.011 in (0.28 mm); record the figure obtained.

20.7.7 Position the shim(s) and the ACA seal on the air pipe, then insert the pipe in the air valve.

20.7.8 Holding the pipe firmly in position measure the clearance between the valve and pipe flanges; this should be within 0.001 in (0.025 mm) of the figure recorded in sub-para 20.7.6. Adjust the thickness of the shim(s) to suit.

20.7.9 Secure the pipe with the retaining bolts, plain and spring washers, do not tighten the bolts at this stage.

20.8 Check the alignment of the pipe(s)

20.8.1 Remove the blanking caps from the pipe couplings, then assemble the starter to a slave engine or the fixture, Table 1, Item 3.

20.8.2 Utilizing the clearance around the pipe to atomizer bolt holes, align the free ends of the pipes as near as possible to the engine or fixture mounting blocks, then torque tighten the pipe retaining bolts to the specified figure.

20.8.3 Where the free ends are not in line, firmly grasp the pipe at both ends then, ensuring that no strain is applied to the flanged joint, set the pipes to suit.

Note ...

Ensure that there is a minimum clearance of 0.050 in (1.27 mm) all round, between the pipe and the pipe guard.

20.8.4 Remove the starter from the engine.

20.9 Leakage check

20.9.1 Apply an air pressure of 20 lbf/in^2 (1.38 bar) to the fuel pipe.

20.9.2 Using Table 1, Item 10, or suitable equivalent, coat the fuel pipe-to-atomizer joint and check for leaks; leakage is unacceptable. Release the air pressure.

20.10 Secure the pipe couplings with the blanking cap and bolts, then tie the O-ring seals to their respective couplings.

Atomizer (Group 7/E)

Remove the atomizer

Note ...

The securing bolts for the atomizer and for the fuel and air pipes are lifed to the starter and must be retained with the starter motor.

21

21.1 Unlock and remove the bolts securing the dust covers to the fuel and air valves; remove the air valve sleeve locking plate.

21.2 Unlock and remove the bolts securing the atomizer, then remove the atomizer; remove and discard the atomizer gasket.

21.3 Fit the air valve sleeve locking plate, then fit the fuel and air valve dust covers and secure with the bolts.

21.4 Fit the atomizer dust cover and secure with the bolts, distance pieces and nuts.

Install the atomizer

CAUTION ...

The atomizer to be installed must be of the same modification standard as that removed.

22

22.1 Using a suitable wire brush, loosen the carbon in the combustion chamber then, using a suitable suction type cleaner, remove the carbon from the chamber.

22.2 Check that the nozzle plate drain hole and nozzles are completely clear.

22.3 Remove the transit nuts and distance pieces securing the atomizer dust cover, then remove the dust cover.

CAUTION ...

On no account must the transportation bolts retaining the dust covers be used to secure the atomizer to the starter motor and/or the fuel and air hoses to the atomizer.

22.4 Position the gasket aligning the bolt holes on the atomizer then, ensuring that the end plate fitting is still aligned to the combustion chamber, assemble the atomizer to the end fitting.

Note ...

The air valve is positioned adjacent to the speed control cable plug.

22.5 Secure the atomizer with the bolts and tabwashers; torque tighten the bolts to the specified figure.

Note ...

The bolts should be tightened, evenly, in turn, to avoid distortion of the housing.

22.6 Lock the bolts securing the fuel and air valve dust covers.

Fuel and air pipe(s) (Group 23/E) (fig. 21)

Remove the pipe(s)

23

23.1 Remove the atomizer as detailed in para. 17.

23.2 Unlock and remove the screws securing the damaged pipe(s), then remove the pipe(s).

Install the pipe(s)

24

24.1 Fit the O-ring seals to the connecting block, then insert the pipe(s) in the block and secure with the tabwashers and screws.

24.2 Fully tighten the screws and lock by bending up the tabwashers.

24.3 Fit the atomizer as detailed in para. 18.

<u>Fuel and air pipe(s) (Group 5/E2)</u>

Remove the pipe(s)

25

25.1 Remove the blanking cap(s) from the pipe coupling(s).

25.2 Unlock and remove the bolts securing the pipe guard(s), then remove the guards, packing washer(s) and nut(s).

25.3 Remove the bolts and washers securing the pipe(s) to the atomizer, then remove the pipe(s).

25.4 Remove the shim(s) and record the thickness to facilitate reassembly.

25.5 Remove and discard the ACA seal(s).

25.6 Remove the bolts and spring washers from the pipe coupling(s).

25.7 Remove the air valve.

Note ...

This operation should only be effected when renewing the air pipe.

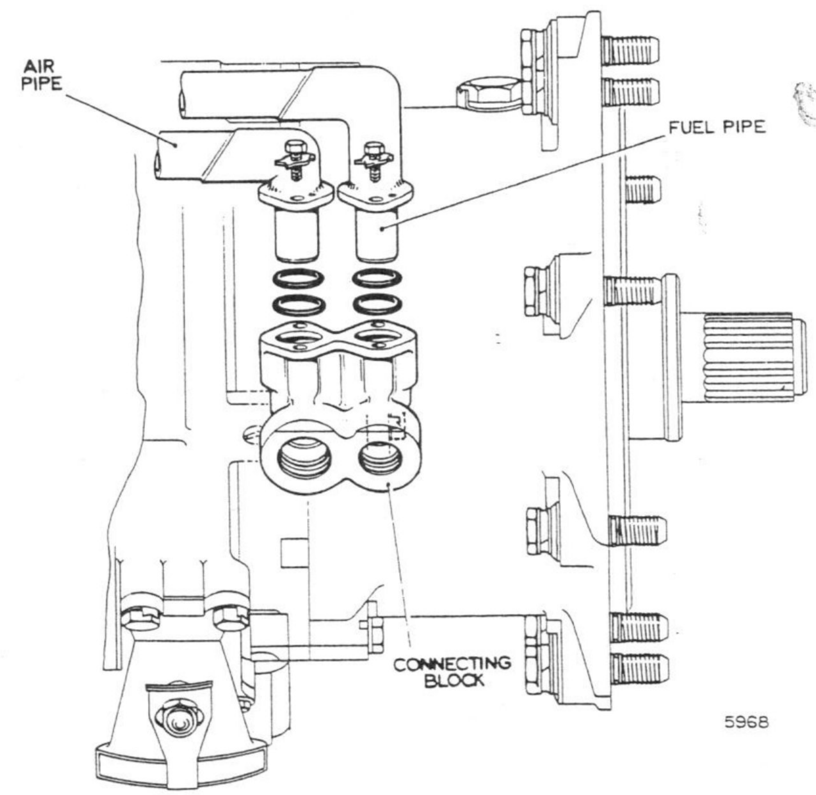

Fig.21 Removal/installation of fuel and air pipes - group 23/E

25.7.1 Remove the air valve from the atomizer, then remove the shim(s); record the thickness to facilitate reassembly.

25.7.2 Remove and discard ACA seal.

Install the pipe(s)

26

26.1 Assemble the pipe(s) to the atomizer as detailed in para. 20.6, 20.7 and 20.8.

Note ...

The free end(s) of the pipe(s) are positioned parallel to the axis of the starter.

26.2 Align the packing washers and guard(s) to their respective bolt holes in the combustion chamber flange and secure with the bolts, tab-washers and nuts; torque tighten the bolts to the specified figure.

Note ...

The bolts are inserted from the gearbox side of the flange.

26.3 Secure the pipe couplings as detailed in para. 20.10.

Exhaust outlet assembly (Group 5/E2)

Remove the exhaust outlet assembly

27

27.1 Unlock and remove the bolt securing the exhaust outlet assembly and the ignition lead clip assembly.

Note ...

Note the location of this bolt to facilitate reassembly.

27.2 Unlock and remove the bolts securing the exhaust outlet assembly.

Install the exhaust outlet assembly

28

28.1 Using feeler gauges, check the exhaust outlet flange mounting face for distortion; the face must be flat to within 0.001 in (0.025 mm).

Note ...

The mounting face may be lapped, as necessary, to remove distortion provided that the flange thickness, measured at the bolt hole spot faces, is not less than 0.250 in (6.35 mm).

28.2 Assemble the exhaust outlet assembly to the starter motor turbine unit exhaust casing and secure with the bolts and new tabwashers. Torque tighten the bolts to the specified figure and bend up the lock tabs.

28.3 Position the ignition lead clip assembly on the exhaust outlet assembly and secure with the bolt and new tabwasher. Torque tighten the bolt and bend up the lock tabs.

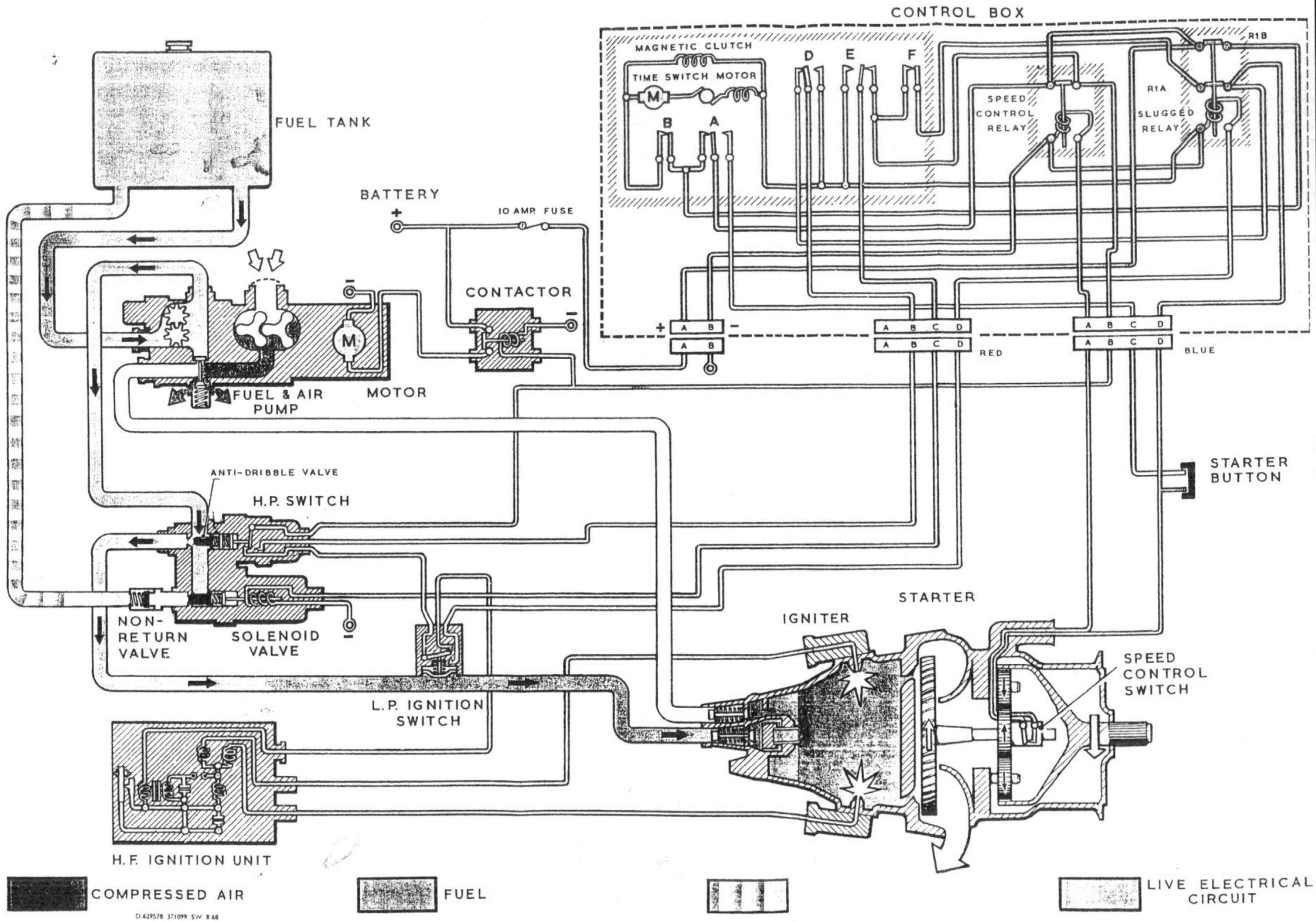

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Fig.7C Principle of operation: third stage (ignition)

2230C

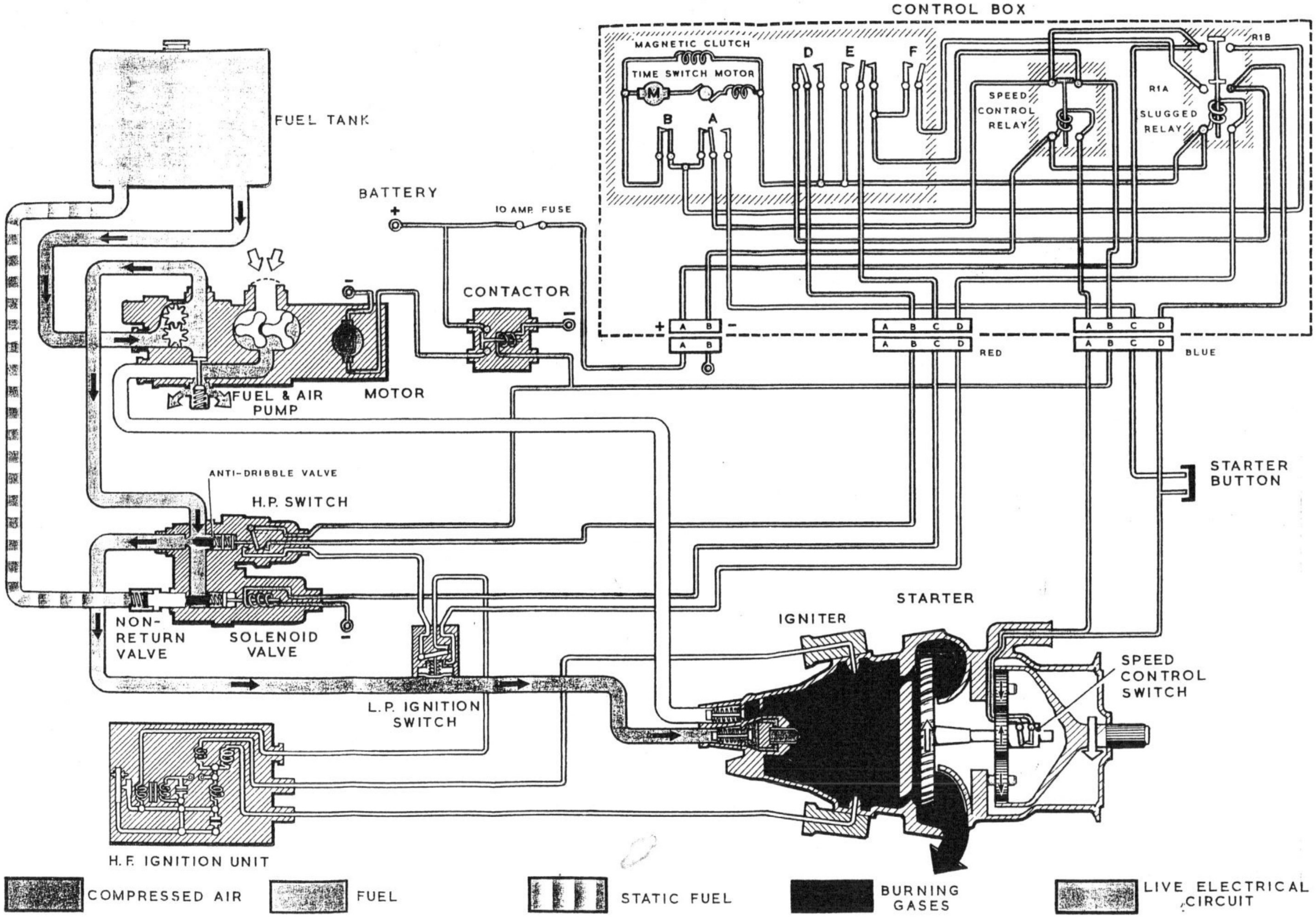

Fig.7D Principle of operation: fourth stage combustion)

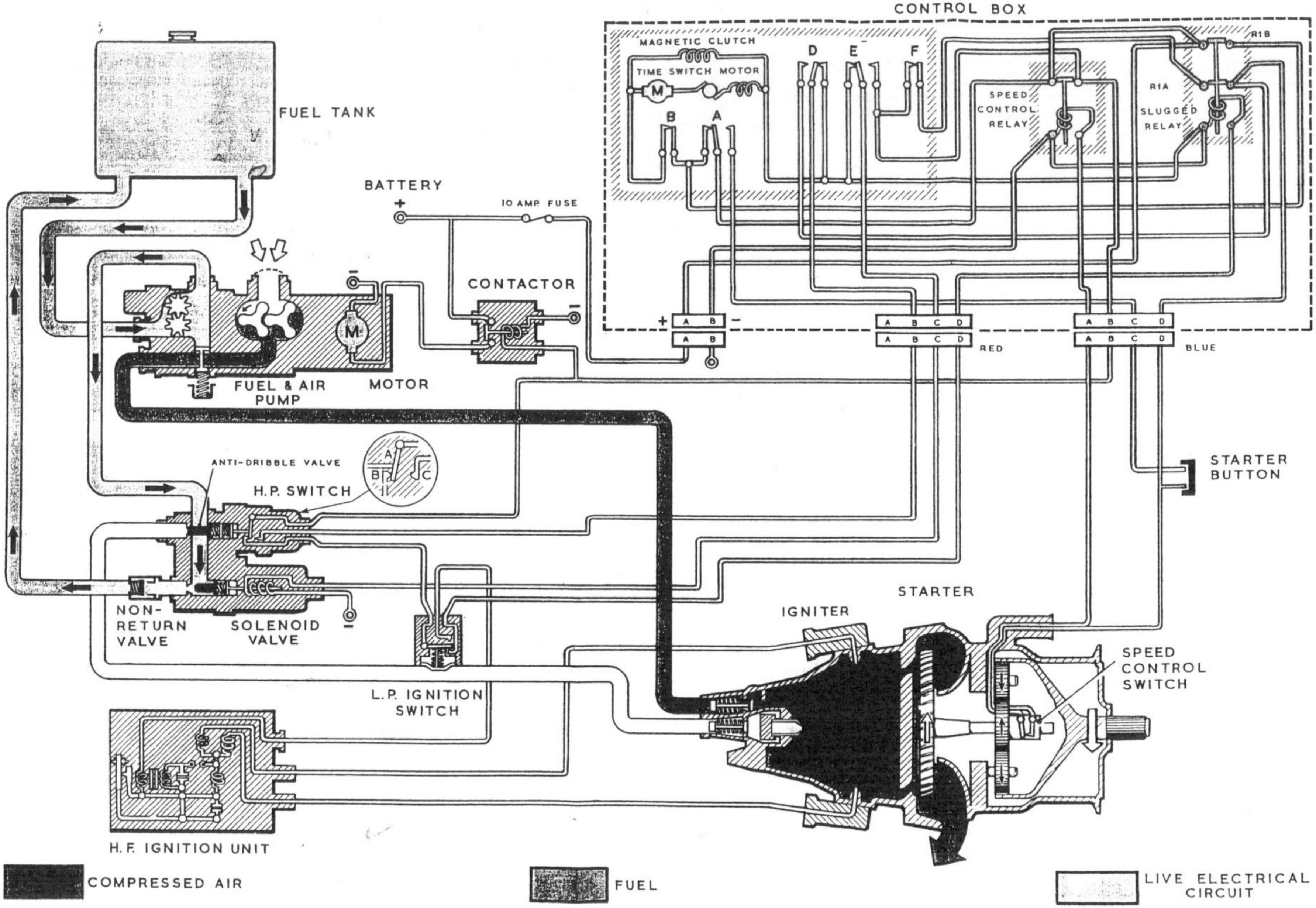

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Fig. 7A Principle of operation: first stage (scavenging)

2230A

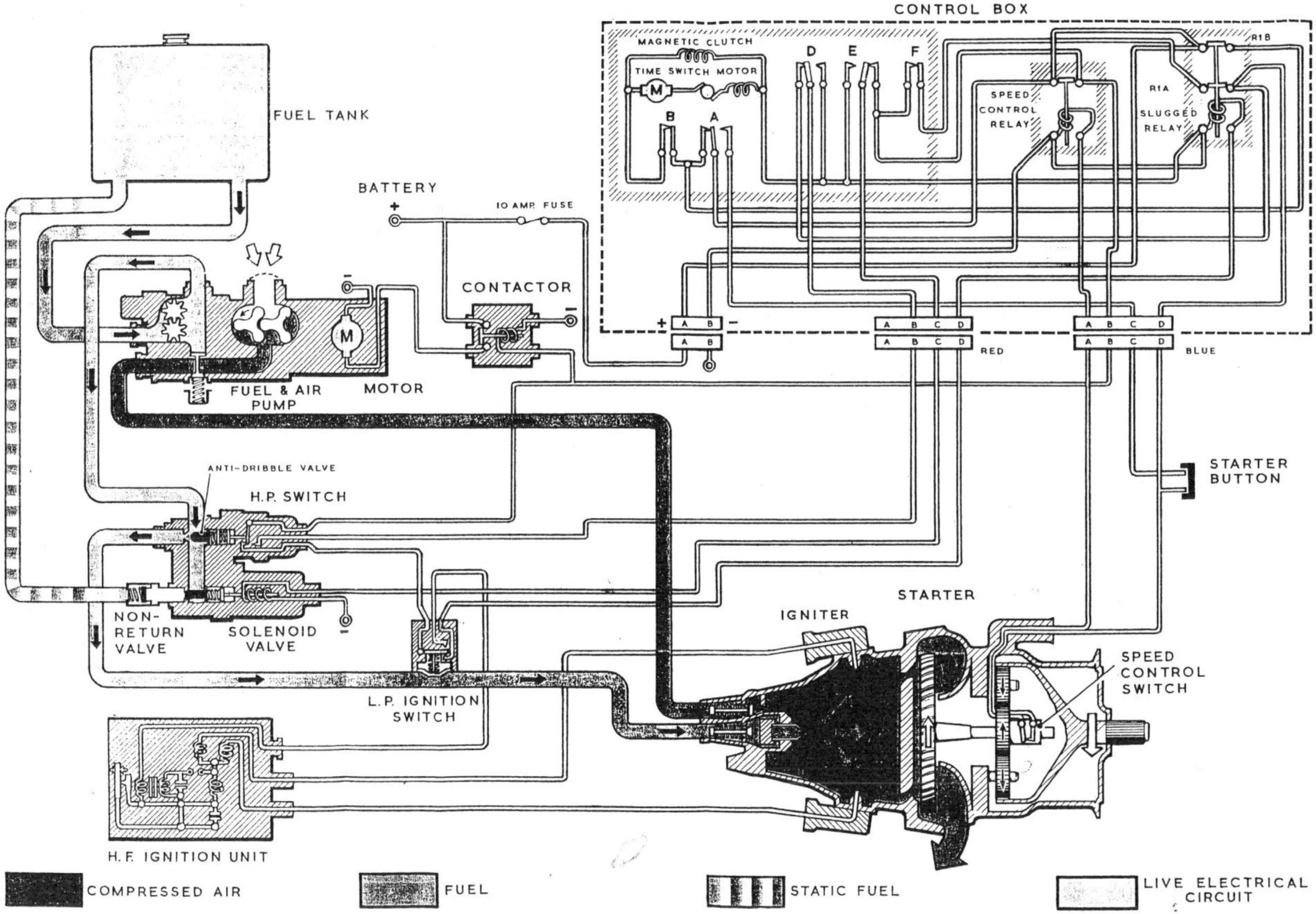

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Fig.7B Principle of operation: second stage (injection)

2230B