PART 1

CHAPTER 3—ENGINES AND FIRE PROTECTION SYSTEMS

Contents

CONTROLS AND INDICATORS

1. Details of the controls and indicators for the engine system in the F Mk 3 and F Mk 6 are shown in Table 1 and illustrated in Fig 1; for the T Mk 5 see Table 2 and Fig 2.

DESCRIPTION OF THE SYSTEM

General

2. The two Avon Mk 302 16-stage axial flow gas turbine engines are mounted in the fuselage, No 2 engine to the rear of and above No 1. Each engine develops approximately 12,600 lb static thrust without reheat and approximately 16,300 lb with full reheat. The main engine systems include:

- High pressure fuel system
- Reheat system
- Liquid fuel starting system
- Relighting facilities
- Engine oil system
- JPT control
- Engine anti-icing system
- Fire detection system
- Fire extinguishing system

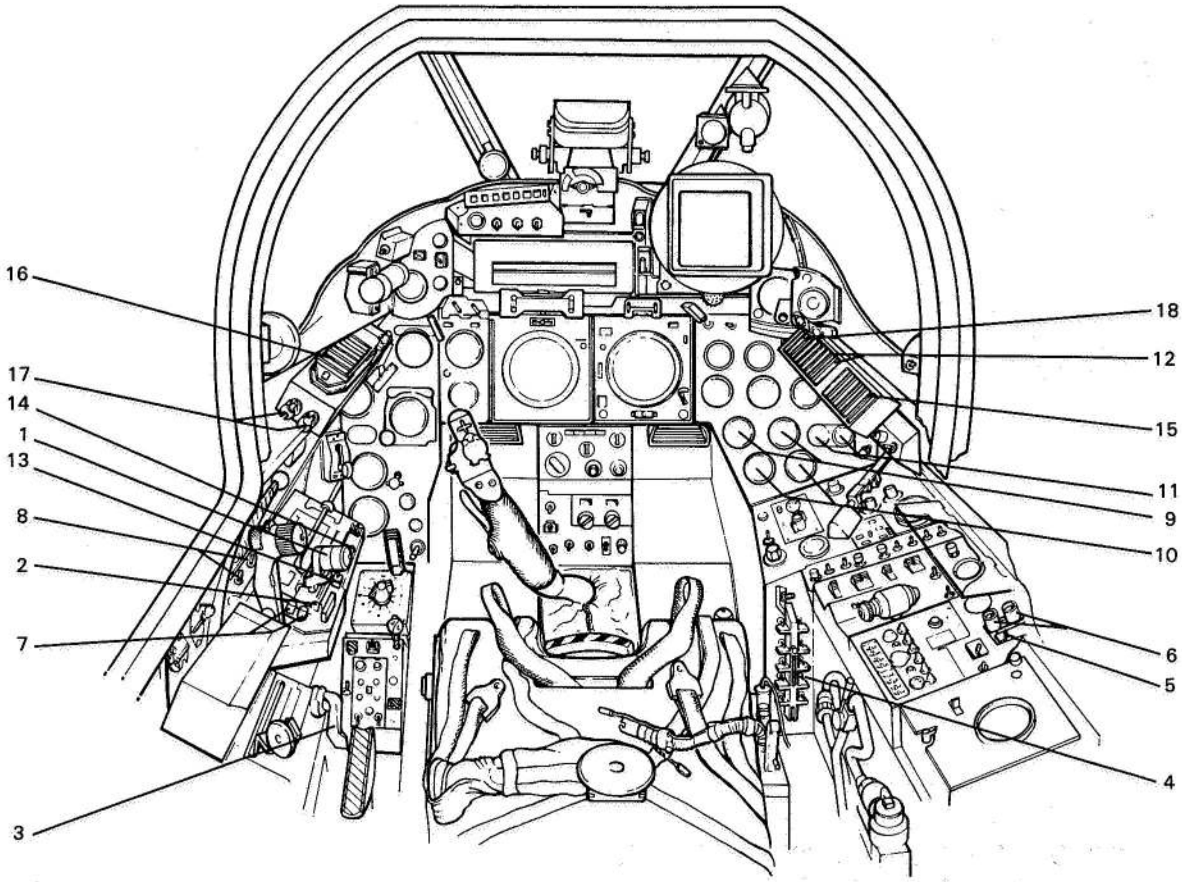
3. Each installation consists of the engine, an intermediate jet pipe and a reheat jet pipe which terminates in a variable nozzle consisting of 16 interlocking flaps. The airflow through the compressor is controlled by variable intake guide vanes and bleed valves; the intake airflow control system is fully automatic.

Table 1 — Controls and Indicators — F Mk 3 and F Mk 6

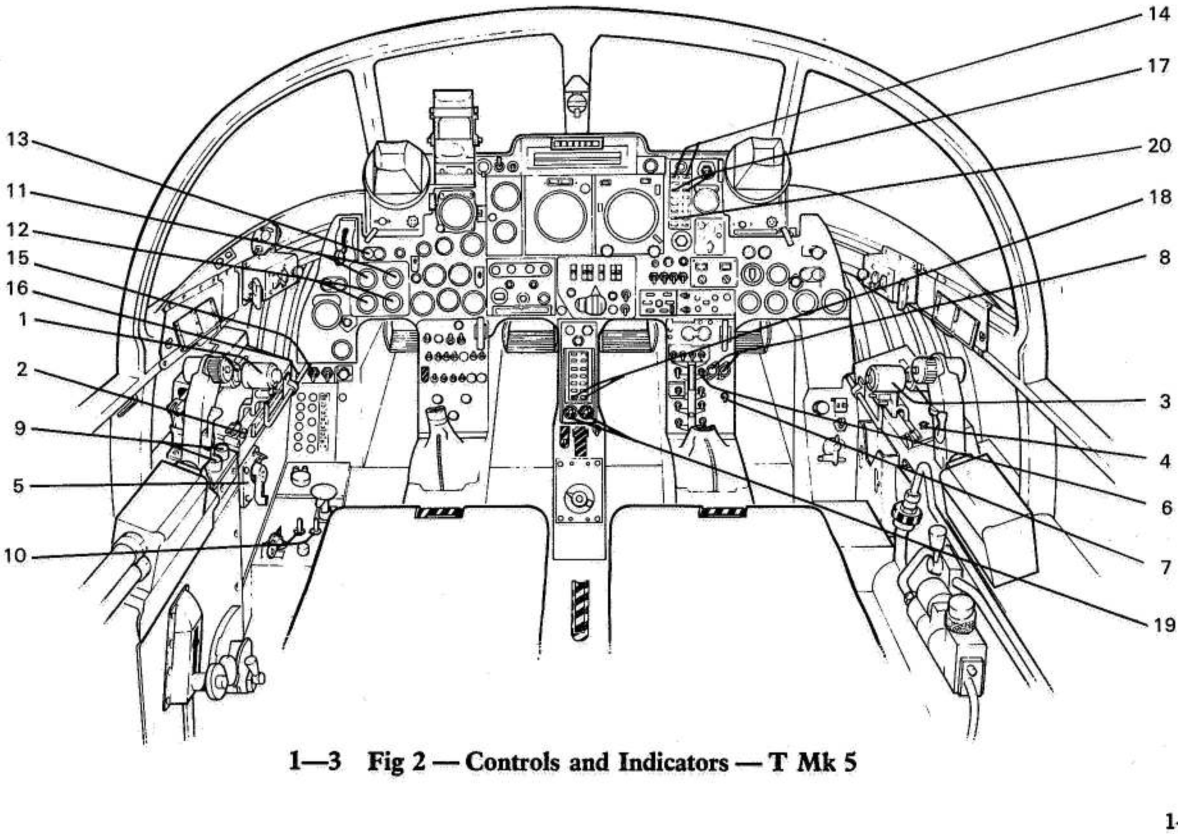
Item No	*Item*	*Markings*	*Remarks*
1	Throttles/HP cocks	HP COCKS OFF, OPEN, IDLING, THROTTLE OPEN, REHEAT. No 2 Throttle: PRESS, FAST IDLING STOP RELEASE	No 1 engine left throttle. No 2 throttle incorporates airbrake control and press-to-transmit button
2	Engine shutdown lever	SHUTDOWN	—
3	Throttle servo control	THROTTLE SERVO — ENGAGE/ DISENGAGE	See Chapter 8
4	Engine master switch	ENG MASTER	Up for on
5	Starter isolation switch	ENGINE STARTER ISOLATION	Aft to isolate
6	Engine start buttons	NO 1 — ENGINE START — NO 2	—
7	Relight buttons	NO 1 — RELIGHT — NO 2	—
8	JPT control switches	JPT CONTROL — NO 1/NO 2 — AUTO/OFF	Wire-locked to AUTO
9	RPM indicators	NO 1/NO 2 — PERCENT RPM	—
10	JPT indicators	NO 1/NO 2 — °C × 100	—
11	Nozzle position indicators	NO 1/NO 2	—
12	Oil pressure warnings	OIL 1/OIL 2	—
13	Engine anti-icing control	DE-ICING ON/OFF/RAIN DISPL	3-position switch guarded to OFF
14	Engine anti-icing MI	I/black/R	—
15	Top Temperature captions	TTC 1/TTC 2	—
16	Engine fire warnings	FIRE 1/FIRE 2	—
17	Fire extinguisher controls	F1/F2	Push buttons with integral lights
18	Ice warning caption	ICE	Inoperative

Table 2 — Controls and Indicators — T Mk 5

Item No	*Item*	*Markings*	*Remarks*
1	Pupil's throttles/HP cocks	HP COCKS OFF, OPEN, IDLING, THROTTLE OPEN, REHEAT. No 2 throttle: PRESS, FAST IDLING STOP RELEASE	No 1 engine left throttle. No 2 throttle incorporates airbrake control and press-to-transmit button
2	Engine shutdown lever	SHUTDOWN	—
3	Instructor's throttles	HP COCKS OFF, OPEN, IDLING, THROTTLE OPEN, REHEAT	No control of HP cocks. No 1 throttle incorporates airbrake control and press-to-transmit button
4	Instructor's fast idling stop release button	—	—
5	Throttle servo control	THROTTLE SERVO — ENGAGE/ DISENGAGE	See Chapter 8
6	Engine master switch	ENGINE MASTER	Up for on
7	Starter isolation switch	ENGINE START—START/ISOLATE	—
8	Engine start buttons	ENGINE START — NO 1/NO 2	—
9	Engine relight buttons	RELIGHT — NO 1/NO 2	—
10	JPT control switches	JPT CONTROL — NO 1/NO 2 — AUTO/OFF	Wire-locked to AUTO
11	RPM indicators	NO 1/NO 2 — PERCENT RPM	—
12	JPT indicators	°C × 100	—
13	Nozzle position indicators	NO 1/NO 2	—
14	Oil pressure warnings	OIL 1/OIL 2	—
15	Engine anti-icing control	ANTI-ICING/OFF/RAIN DISPL	—
16	Engine anti-icing MI	ENGINE AND INTAKE — I/black/R	3-position switch, guarded to OFF
17	Top temperature captions	TTC 1/TTC 2	—
18	Engine fire warnings	FIRE 1/FIRE 2	—
19	Fire extinguisher controls	F1/F2	Pushbuttons with integral lights
20	Ice warning caption	ICE	Inoperative



1—3 Fig 1 — Controls and Indicators — F Mk 3 and F Mk 6



1—3 Fig 2 — Controls and Indicators — T Mk 5

Engine Fuel System

4. *Fuel Feed System.* Fuel from the low pressure fuel system is fed through a filter to the engine-driven HP fuel pump. The pump unit consists of two variable-stroke pumps in a common housing. Either pump is capable of delivering sufficient fuel for approximately 100% RPM to be attained in cold power. Pump output is fed to the burners through a fuel-cooled oil cooler and a proportional flow control unit which incorporates the combined throttle valve and HP cock. The output of the pump unit is controlled by a servo system in response to signals from the engine speed governor and the flow control system.

5. *Fuel Control System.* The fuel control system consists of the following controls:

a. *Engine Speed Governor.* The maximum RPM of the engine is controlled automatically. The governed maximum RPM, however, varies with altitude and ambient temperature and, under extreme conditions, manual control may be needed to prevent the operating limitations being exceeded.

b. *Altitude Sensing Unit (ASU).* The ASU regulates the fuel pump delivery in response to intake air pressure which varies with aircraft speed and altitude.

c. *Altitude Idling Valve.* The altitude idling valve prevents excessively low RPM when the throttle is selected to IDLING at altitude.

d. *Acceleration Control.* The acceleration control automatically limits the rate of increase in the fuel flow to the burners during rapid throttle movements.

e. *JPT Controller.* The JPT controller automatically prevents the JPT rising above the maximum limitation of 795°C providing AUTO is selected. When the maximum JPT is reached the controller trims the fuel flow to prevent a further increase in JPT. This may affect the maximum RPM attainable depending on ambient air temperature, altitude and speed. With the switch at OFF there is no automatic JPT control. The JPT control switches are normally wire locked to AUTO.

f. *Fuel Flow Limiter.* The fuel flow limiter restricts the maximum fuel flow to an engine under high intake pressure conditions, by means of a back stop on the acceleration control unit. This reduces the maximum attainable RPM at low altitude and high speed.

Oil System

6. Each engine has its own independent integral oil system of 12·5 pints capacity. One pressure and five scavenge engine-driven pumps maintain a continuous circulation through a fuel-cooled oil cooler and filter to the engine bearings and gears.

7. *Oil Pressure Warning.* A pressure switch is fitted in the oil system of each engine. If the oil pressure drops below 20 PSI the pressure switch closes and an OIL 1 or OIL 2 warning appears on the AWP. The oil warning light should go out by 45% RPM after starting.

Throttles/HP Cocks

8. In the F Mk 3 and F Mk 6 there is one throttle box on the left console. In the T Mk 5 the pupil's throttle box is similar in operation and position to the controls in the single-seat aircraft and a second throttle box is provided for the instructor on the right console. The instructor's throttle box in the T Mk 5 is slaved mechanically to the pupil's throttle box except that two solenoids in the pupil's unit are electrically connected to microswitches in the instructor's unit to permit reheat control and right throttle movement below the fast idle stop from the instructor's controls. The differences in operation of the instructor's throttle box are given in para 10.

9. *Normal Throttle Box.* The throttle lever and HP cock for each engine are combined in one control. The left throttle controls the No 1 engine and the right the No. 2.

a. *HP Cock.* When the throttle is fully back the HP cock is closed; when the lever is set forward to the IDLING position the HP cock is open. A stop at the IDLING position prevents rearward movement of the throttle lever; to select HP COCKS OFF the SHUTDOWN lever at the rear of the throttle box must first be pressed forward.

Note: When flying with No 2 engine shut down, forward movement of the throttle in the HP cock range could cause the idling stop to be depressed which would allow the No 1 throttle lever unrestricted movement through IDLING to HP COCKS OFF. To prevent this an additional stop ensures that the No 2 throttle is held positively at the HP COCKS OFF position until cleared by the operation of the PRESS FAST IDLING STOP RELEASE.

b. *Fast Idle.* On the No 2 throttle a fast idling stop prevents the No 2 engine being throttled back below approximately 58% RPM until the PRESS FAST IDLING STOP RELEASE is operated.

c. *Reheat.* Reheat power is obtained by first selecting maximum cold power and then rocking the throttle to the left and moving it forward to maximum reheat position. Once the reheat is lit, the throttle may be moved back from maximum reheat through the maximum cold power position to a mechanical stop at approximately 96% RPM. Reheat is cancelled by rocking the throttle to the right at any point between the maximum cold power position and the mechanical stop.

10. *Instructor's Throttle Box.* On the instructor's throttle box in the T Mk 5 the left throttle lever controls the No 1 engine and the right the No 2. The instructor's throttle box differs in operation from the normal throttle box in the following respects:

a. *HP Cock.* Although the throttles can be moved forward from HP COCKS OFF, it is not possible to select HP COCKS OFF from IDLING.

b. *Fast Idle Stop.* To reduce the No 2 throttle below the fast idle position, the button on the inboard side of the throttle box is pressed while continuing to throttle back. The system is electro-mechanical and requires a 28 volt DC supply to operate.

c. *Reheat.* To select reheat, the lever on the front of the throttle conrol lever must be 'lifted' whilst continuing to move the throttle forward into the reheat range. Reheat is cancelled by throttling back to the minimum reheat mechanical stop (approximately 96% RPM) and lifting the lever, which then allows further throttle movement into the cold power range.

Note: Using the instructor's controls, it is only possible to cancel reheat from the minimum reheat mechanical stop position.

Engine Starting System

11. Each engine has a separate iso-propyl-nitrate (Avpin) liquid fuel starter. A common 3-gallon fuel tank is fitted in the fuselage spine which supplies both starters with sufficient Avpin for a total of six starts. The gases drive the starter turbine which is connected to the engine through a reduction gearbox. Pressing the starter button with the starter isolation switch in the START position initiates a timed sequence of operations as follows:

a. The starter motor combustion chamber is scavenged by compressed air which is supplied by a combined fuel/air pump.

b. A fuel charge is pumped into the combustion chamber.

c. The mixture of fuel and air is ignited by two high frequency igniter plugs and combustion is sustained by the decomposition of the injected fuel.

d. The starter turbine turns the engine and at the same time the engine ignition plugs are energised to light up the engine.

e. When the engine reaches self-sustaining RPM, a switch operates to shut down the starter system.

12. *Failures to Start.* If an engine fails to start, limitations are imposed on subsequent attempts to start depending on the type of failure. The limitations are as follows:

a. *Starter Motor Failure.* If starter combustion does not occur ('A' failure) or if combustion occurs for less then one second ('B' failure) there is no indication of engine rotation on the RPM gauge. Wait at least one minute before the next attempt to start to allow the Avpin fuel to drain from the starter combustion chamber. A maximum of three attempts may be made after 'A' or 'B' failures.

b. *Engine Rotates but Fails to Light.* If, after a normal starter combustion cycle, the engine fails to reach self-sustaining speed, the engine is to be allowed to stop turning before a further starting attempt is made. Close the HP cock immediately the failure is certain and in any case before the RPM have reduced to 10%. After this failure, heat soakage of the starter may prejudice the next start attempt. Therefore, the interval between the first and second attempts should be as close as possible to one minute. A maximum of two such attempts are to be made, after which a cooling period of 60 minutes is to be allowed before investigation or a further starting attempt is made. The cooling requirement is considered satisfied if the second permitted starting cycle results in an engine start and the engine is allowed to run for 15 minutes.

c. *No Rotation.* If the engine fails to rotate after a normal starter combustion cycle, a further attempt to start is not to be made. Examination or investigation is not to be made in the vicinity of the engine starter until a cooling period of 60 minutes has elapsed.

WARNING: An engine starting button is not to be pressed when the engine is rotating (either in the air or on the ground).

13. *Starter Isolation Switch.* A starter isolation switch renders both starter buttons inoperative when ISOLATE is selected. The engine relight system is not affected by the position of the starter isolation switch.

Relighting System

14. With the ENG MASTER switch on, pressing the relight button bypasses the normal starting sequence to energise the ignition unit and operate the high energy igniter plugs of the associated engine. Pressing the relight button for two seconds also energises a time switch which allows the ignition system to run for

approximately 30 seconds after the relight button is released. Providing the undercarriage is selected up, both relighting circuits are energised whenever the armament firing trigger is pressed.

Jet Pipe Nozzle

15. The variable position nozzle is controlled by eight screw jacks which are driven and synchronised by an annular gear. An air motor, powered by engine compressor bleed air, drives the annular gear in response to mechanical inputs from an air motor control unit (AMCU). Gas stream pressure provides the nozzle opening force and the nozzle is closed or held fixed by the annular gear. One part of the AMCU controls nozzle position in the cold power range; the remainder is associated with reheat operation.

16. *Cold Power.* To improve engine handling and to give a lower SFC in the cruise range, the nozzle area is slightly increased at lower RPM under the automatic control of an engine-mounted, RPM-sensitive switch operated from the engine speed governor. The nozzle is partly opened in the cruise position from IDLING up to 97% RPM when it closes and remains closed up to maximum cold power. When throttling back, the nozzle remains closed until 89% RPM. It is therefore possible to be in cruise or closed nozzle between 89% and 97% RPM. These RPM values are sea level figures; the changeover RPM tend to increase directly with an increase in altitude.

17. *Reheat.* With reheat engaged, the nozzle area varies with throttle lever movement from part open at minimum reheat to fully open at maximum reheat.

18. *Nozzle Position Indicator.* Each nozzle position indicator displays two arcs, the lower for the cold power range and the upper for the reheat range of nozzle operation. A specific mark at the end of each arc indicates the maximum cold power and maximum reheat position, ie nozzles closed and fully open respectively.

Reheat System

19. Reheat augments engine thrust by injecting fuel to burn surplus air aft of the turbine in the reheat jet pipe. Combustion of the injected fuel raises the temperature and velocity of the exhaust gases, increasing the thrust. Fuel consumption with reheat in operation, especially at medium and low altitude, is extremely high; it is more than double the consumption at maximum cold power.

20. Fuel for the reheat system is taken from the aircraft low pressure fuel system and fed to the reheat burners by an air turbine pump which is driven by compressor bleed air. The reheat burners form three concentric rings. The two inner rings are fed from one pipe which supplies the fuel required at low reheat selections. At high reheat power, fuel is supplied to all three rings of the burner.

21. *Reheat Selection.* Reheat is always to be selected from the maximum cold power position by moving the throttles smoothly and quickly forward to the maximum reheat position. Below 35,000 feet the nozzles open fully with a momentary pause at an intermediate position. Above 35,000 feet, reheat lighting reliability is improved by automatically delaying the full opening of the nozzles until the reheat is lit and stable. After selecting maximum reheat the nozzles open to the intermediate position, the reheat lights and the nozzles hold the intermediate position for 15 seconds, after which the nozzles open to the maximum reheat position. Monitor JPT during reheat selection since a low JPT is the most reliable indication of reheat failure to light. During reheat light-up (or cancellation), there may be a transient RPM overswing (5-second limit) to 106%.

22. *Reheat Ignition.* Reheat is ignited by the 'hot streak' method. A metered quantity of fuel is injected into one of the engine flame tubes where it ignites, passes through the turbine and then ignites a further quantity of fuel injected into the intermediate jet pipe. This streak of burning fuel continues aft and lights the fuel spray from the reheat burners.

23. *Throttle Handling.* In the reheat range, movement of the throttles is to be made slowly and smoothly apart from the initial selection. Reheat is fully variable between the maximum and minimum available. Movement of the throttle lever changes the nozzle area and thus the pressure ratio across the turbine. This change of pressure ratio is sensed by the reheat fuel control unit which positions a throttle valve to increase or decrease reheat fuel flow to restore the pressure ratio.

24. *Top Temperature Control (TTC) Captions.* The TTC 1 and TTC 2 captions on the AWP indicate the correct working or malfunction of the reheat system. When reheat is selected the TTC captions come on, indicating initiation of the reheat systems, and go out when the 'hot streak' starts.

25. *Reheat Cancellation.* If the nozzles remain open after reheat cancellation a substantial loss of thrust in cold power occurs.

Note: The instructor's throttles in the T Mk 5 differ in some aspects; see para 10.

Reheat Malfunctions

26. The TTC caption comes on after hot streak initiation if reheat fails to light or if reheat is lit and automatic cancellation occurs. The following faults cause automatic cancellation:

Failure to light
Reheat extinction
Maximum JPT exceeded by 60°C (JPT controller in AUTO)
FUEL 1 or FUEL 2 caption

27. When reheat is tripped the appropriate TTC caption comes on and the nozzle closes. The TTC caption is extinguished by moving the associated throttle into the cold power range. Reheat may be re-selected after automatic cancellation but, if the system trips again, no further reheat selection is to be made. If automatic cancellation does not occur after a TTC caption comes on, select the throttle of the affected engine to full cold power to close the nozzle and regain full cold thrust.

28. If a TTC caption comes on when reheat is not selected, a DC power supply failure to the reheat system is indicated and the nozzle moves automatically to the cruise position. Reheat cannot be initiated on an engine which has a lit TTC caption.

29. When reheat is selected, a time switch is started so that, if reheat fails to light, a time delay of between 3·5 and 7 seconds occurs (depending on the cause of failure) before automatic cancellation and closure of the nozzle. If reheat fails to light within 5 seconds, cancel the selection, wait 2 seconds and re-select. If reheat again fails to light and the aircraft is within the recommended lighting envelope (Part 3, Chapter 3), further attempts are unlikely to be successful and the reheat system should be considered unserviceable.

30. If a fault other than failure to light occurs, the TTC caption appears 2 seconds before the reheat is tripped. This delay was introduced to prevent reheat extinction when firing missiles. If a TTC caption comes on and normal conditions are restored within 2 seconds, the reheat remains lit and the TTC caption goes out.

31. *Throttle Seizure in Reheat.* If a throttle seizes in the reheat range, apply force to the throttle lever. This force stretches a telescopic rod in the reheat control run allowing the gate switch to be reached; reheat then cancels and the nozzle closes. The throttle lever then operates normally in the cold power range but it is recommended that reheat is not used again during that flight.

Anti-Icing Systems

32. *General.* Protection against icing is provided by three systems. They are all controlled by one switch which operates a DC relay common to all systems. Operation of the systems is confirmed by a magnetic indicator. Two hot air systems protect the engine and intake duct lip, and an electrically-powered Spraymat system protects the leading edges of the upper and lower radome struts and areas about the engine duct bifurcation. When the engine anti-icing switch is selected to DE-ICING ON (ANTI-ICING, T Mk 5), the DC relay operates to power both engine systems, the intake duct lip protection and the Spraymat systems.

33. *Engine Anti-Icing.* On each engine, hot air tapped from the compressor is directed via an electrically-operated gate valve to flow into the front bearing support struts, the intake guide vanes, the starter fairing and the starter exhaust pipe. The air then passes into the engine.

34. *Duct Lip Anti-Icing.* Compressor bleed air from each engine, controlled by an electrically-operated butterfly valve, is fed to a manifold and divided to flow through sections of the duct lip and escape through small vents into the duct.

35. *Spraymat Anti-Icing.* The leading edges of the upper and lower radome struts and the areas about the engine duct bifurcation are protected by the Spraymat system. Power for the heating is provided from the 200V, 3-phase, 400 Hz AC supply which is controlled by the anti-icing switch and by an automatic temperature controller within the system.

WARNING: The temperature controller in the Spraymat system is ineffective when the engines are not running. To prevent damage, an AC supply is not to be connected to the aircraft with the DE-ICING ON (ANTI-ICING, T Mk 5) position selected whilst the engines are at rest.

36. *Temperature and Pressure Switches.* Downstream of the duct lip butterfly valve are two switches which protect the system against excessive temperatures and pressures. Operation of either switch trips the DC relay common to all three anti-ice systems and they stop operating. The temperature-sensing switch is self-resetting and the systems are regained when the temperature drops. However, the pressure-sensing switch is not self-resetting and, if the switch operates, no anti-ice protection is available until the switch is reset on the ground.

37. *Magnetic Indicator (MI).* A switch in the duct lip butterfly valve controls the indication of the engine anti-icing MI. The switch operates in the last few degrees of the valve's opening or closing movement, indicating I when the systems are on and black when the systems are off or automatically shut down. When the engine anti-icing control switch is moved to the RAIN DISPL position, the MI shows R to indicate that the rain dispersal system is in operation (see Chapter 11). It is therefore not possible to have the rain dispersal and anti-icing systems working concurrently.

Ice Warning System

38. The ice warning system is inoperative and the ICE caption of the AWP is therefore redundant.

Engine Fire Protection System

39. *Fire Zones.* Each engine bay is divided into two fire zones by a fire-wall between the engine compressor section (zone 1) and the turbine and exhaust section (zone 2). The space surrounding the jet pipes of both engines is zone 3 and it is separated from the other zones by vertical and horizontal fire-walls. Each fire zone has a separate ventilating system. The diagram at Fig 3 shows the T Mk 5 engine fire protection system which is similar to the F Mk 3 and F Mk 6 systems.

40. *Fire Extinguishers.* Two dual-headed methyl bromide fire extinguishers are installed in the fuselage. The left extinguisher serves each zone 2 and the right extinguisher each zone 1. There is no extinguisher for zone 3. Extinguisher operation is effected by pressing either of two indicator/extinguisher buttons on the SWP. When either button is pressed, both extinguishers are completely discharged into zones 1 and 2 of the appropriate engine bay. Telltale indicators, one on each side of the ventral tank refuelling light on the left side of the fuselage, show a reddish-brown colour if the extinguishers have been discharged electrically.

41. *Extinguisher Discharge.* Each extinguisher is fitted with an over-temperature safety device which causes the contents to discharge overboard should the temperature in the vicinity of the bottle exceed approximately 175°C. Two indicators, one left and one right, located just aft of the No 1 engine longeron, show green when no discharge has occurred. If the contents of a bottle are released overboard, the green indicator cover is blown off and a bright red bowl under the cover is disclosed.

42. *Fire Detection.* An FFFD fire detection system is fitted in all three fire zones. There is a separate fire-wire circuit for each engine bay and two circuits, one to each jet pipe, in zone 3. The elements are connected to the input channels of a relay unit which controls the relevant warnings on the SWP. The INSTRUMENT MASTER switch must be on for the detection circuits to be operative.

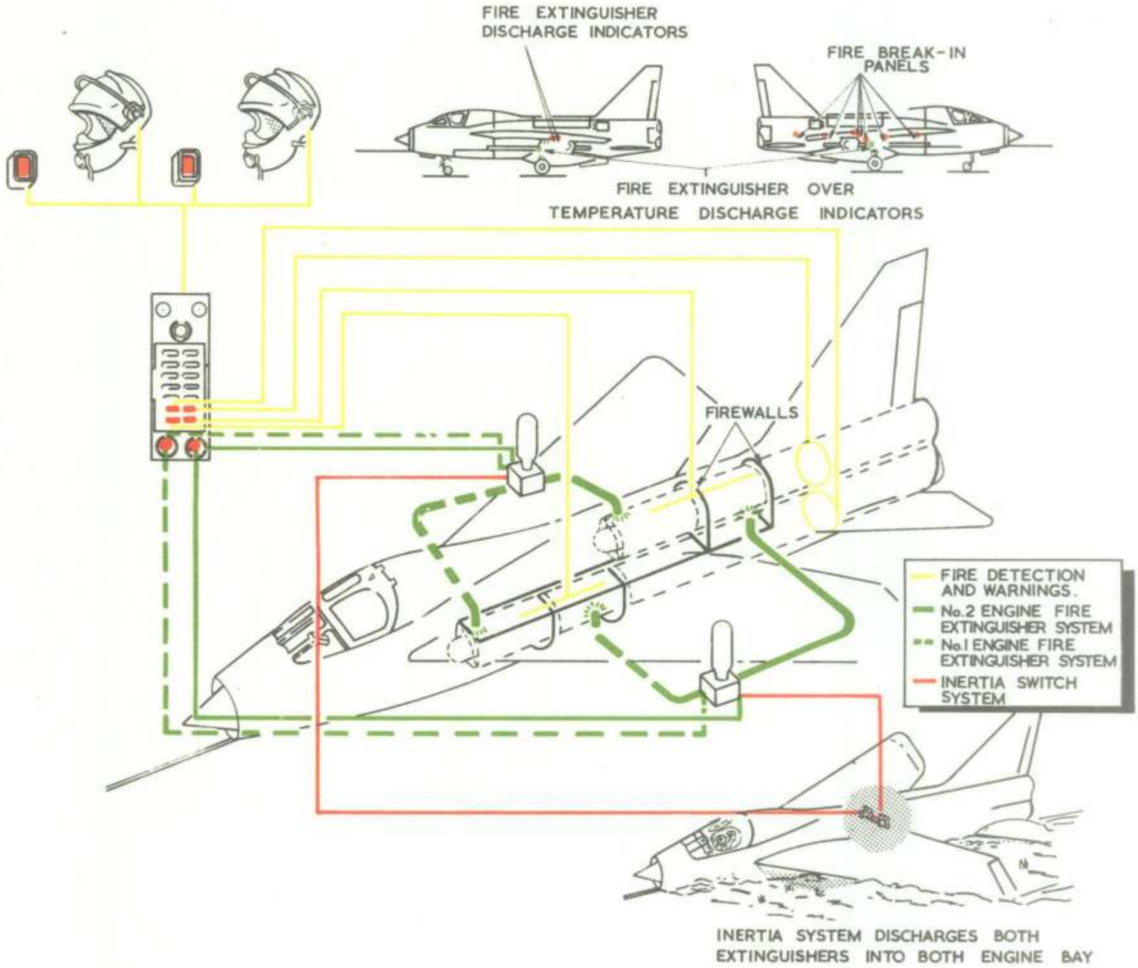
43. *Electrical Power Sources.* The system is supplied with 115V, 3-phase, 400 Hz AC from the Essential Instruments busbar which has a standby supply from the type 100A inverter. Thus, a warning initiated on one AC source is continued if changeover to the other source occurs, with a momentary interruption at the instant of changeover. Because of this interruption, cancelled attention-getters are reactivated if their originating warning is still present at the time of changeover.

44. *Fire System Testing.* The system is tested by pressing the T button on the SWP. Unserviceability is shown by the warning captions failing to come on or failing to go out when the T button is released. The system should not be tested in the air owing to the possibility that a fire warning, triggered by the test facility, may remain on when the T button is released even though the system is serviceable. Testing is done before engine start (with AC on line) and immediately after landing when optimum conditions for moisture contamination of the firewire are experienced.

45. *Fire Warnings.* Warning of fire in zone 1 or 2 of the No 1 engine is given by a FIRE 1 warning on the SWP, the operation of the F1 light in the fire extinguisher button and the operation of the attention-getters. Warning of a fire in zone 1 or 2 of No 2 engine is given by a FIRE 2 warning on the SWP, the operation of the F2 light in the fire extinguisher button and the operation of the attention-getters. Warning of excessive temperature or fire in zone 3 is given by the illumination of a RHT 1 and/or RHT 2 warning on the SWP and by the operation of the attention-getters.

46. *Inertia Crash Switches.* Two inertia crash switches are in circuit with the fire extinguisher system. If both crash switches operate, both extinguishers are discharged into zones 1 and 2 of each engine. The crash switches also isolate certain electrical supplies (see Part 1, Chapter 1).

47. *Fire Drills.* Part 4, Chapter 2 discusses in detail the procedures to be followed after fire in the air, and the FRC contain the drills.



1—3 Fig 3 — Fire Protection System

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