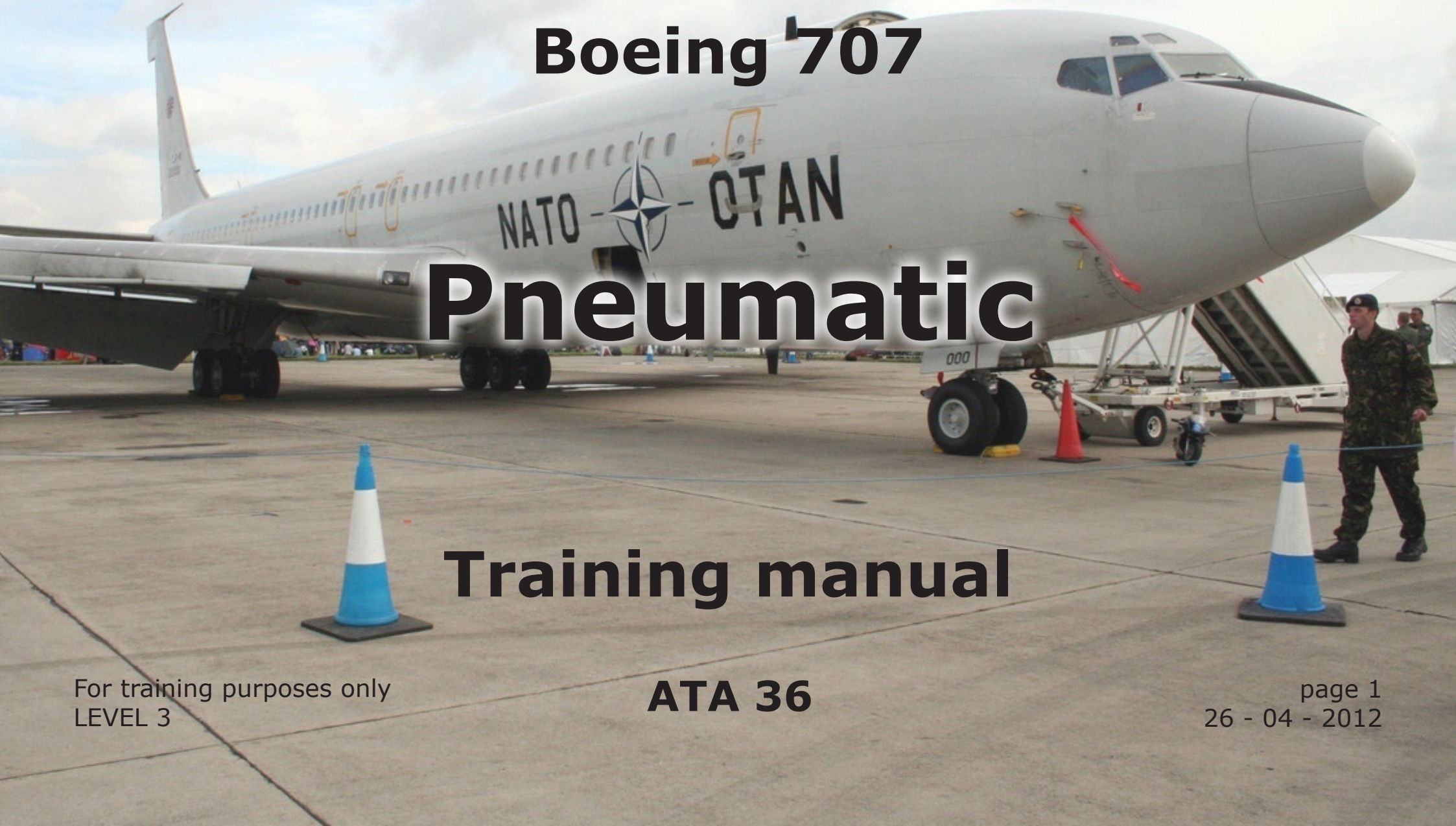
Aviation Competence Centre
First Class Education

Boeing 707

Pneumatic

Training manual



ATA 36

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1. GENERAL DESCRIPTION.

The bleed air system supplies high temperature compressed air for cabin air conditioning, pressurization and engine starting.

The main supply of high temperature compressed air is obtained from three turbocompressors, one mounted on top of each of engines 2, 3 and 4. An alternate or supplemental air supply is obtained by bleed air from the intermediate compressor case behind the 8th stage of each engine. This engine bleed air can be used to supply either the wing thermal anti-icing system manifold or the wing bleed air manifold. Shutoff valves in the ducting control the flow of air as required.

The turbocompressor is an integral turbine and compressor unit. The turbine is driven by 15th stage engine compressor air which is ducted from the diffuser case through a pressure regulator and a shutoff valve. The turbine drives the coaxial compressor which receives fresh air from an inlet on top of the engine nacelle. The compressed air flows past a surge valve outlet and through a check valve to the wing air manifold. A low pressure bleed air duct, to supply the engine starter, ties into the wing manifold duct at each engine.

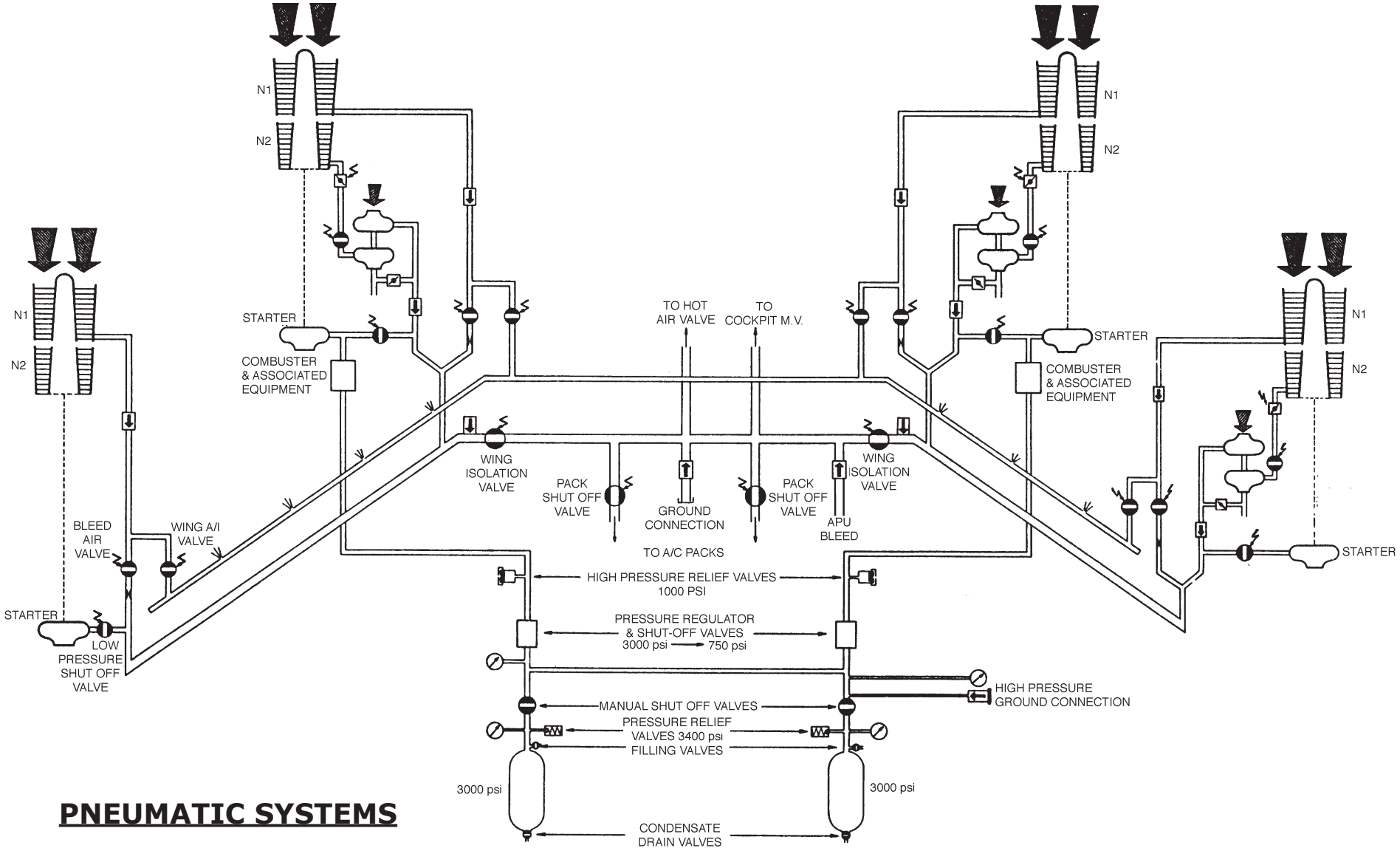
The left and right wing manifolds are connected across the fuselage by a crossover bleed air duct.

This duct contains the valves necessary to isolate each wing manifold, deliver high temperature compressed air to the air conditioning system, and receive air from a pneumatic ground supply or APU.

A wing check valve is located outboard of each wing isolation valve to balance the pressure between the wing bleed air manifold and the air conditioning distribution bay when the wing isolation valve is closed.

The turbocompressor is self-regulated. Accordingly, the automatic controls are designed to provide optimum operation at the approximate cruising altitude of the aircraft. In order to obtain the required compressor bleed air flow when the aircraft is on the ground, the left landing gear safety-switch energizes a valve which causes the control system to increase the air flow for this mode of operation.

All manual controls, indicators and warning lights for the bleed air system are located on the flight engineer's panel. Each turbocompressor has a control switch "START-STOP", tachometer and separate warning lights for low oil pressure and overspeed trip indications. The left and right wing isolation valve switches have two positions, "OPEN" and "CLOSE". Engine bleed air is controlled by "ON-OFF" switches, labeled "ENGINE BLEED AIR". The controls for the wing thermal anti-icing system are located on the pilots' overhead panel.

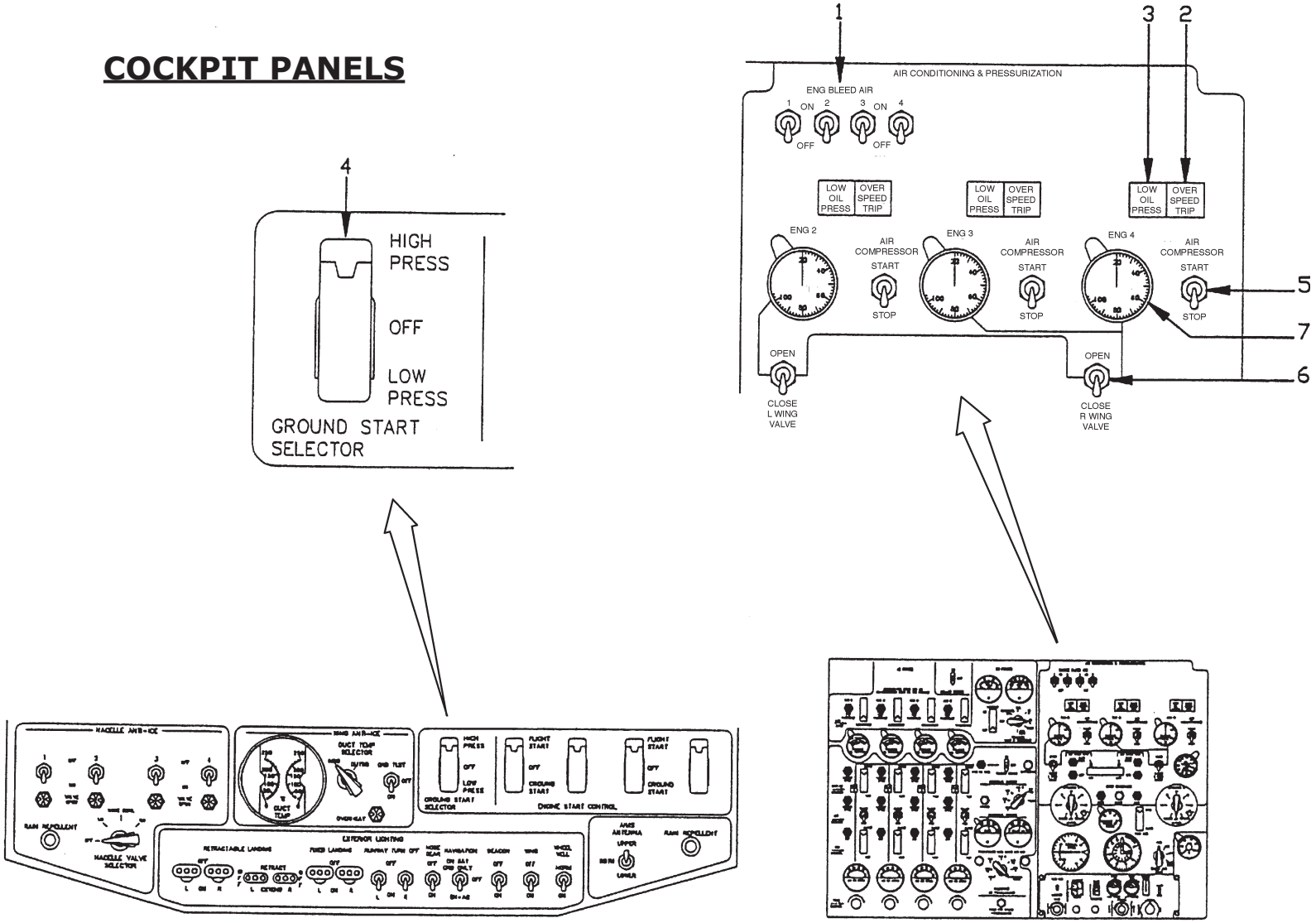


PNEUMATIC SYSTEMS

2. COCKPIT CONTROLS AND INDICATION.

CONTROL / INDICATOR	FUNCTION
1. ENGINE BLEED AIR Valve Control Switches (4)	One switch is provided for each engine. In ON position-the bleed valve is open (will be closed in OFF- position); These switches will be overridden and valves will close when the corresponding engine fire switch is pulled.
2. Turbocompressor OVER SPEED TRIP Warning Lights (3)	These warning lights illuminate when T/C speed reaches approximately 115%.
3. Turbocompressor LOW OIL PRESS Warning Lights (3)	With the warning circuit armed by T/C control switch the LOW OIL PRESS warning lights illuminate when T/C lubricating oil pressure is.too low.
4. GROUND START SELECTOR Switch	This switch, located at the pilots' overhead panel, has the positions HIGH PRESS, OFF and LOW PRESS. It controls the high pressure air regulating and shutoff valve. In the HIGH PRESS position the starter low pressure air shutoff valve is spring loaded closed and prevents high pressure air from entering the low pressure air bleed duct. The GROUND START SELECTOR switch in position LOW PRESS initiates the "full open signal" for the variable nozzles of the air-flow regulator, thus the T/C airflow will be increased if the aircraft is on the ground.
5. AIR COMPRESSOR (T/C) Control Switches (3)	These switches with positions START and STOP,springloaded in center position, are provided to control the T/C's as follows: START : Starts T/C provided., N2 bleed air is available. Overridden to stop by the following automatic T/C safety devices : - Overspeed - Overheat - Excessive or low N2 bleed air pressure Arms : - T/C's electric overspeed trip protection and warning light. - Low oil pressure warning light. STOP : Stops T/C and deactivates - T/C's electric overspeed trip protection and warning light. - Low oil pressure warning light.
6. WING VALVE L & R Control Switches (2)	These switches labeled OPEN and CLOSED are used for wing valve operation; normally positioned to OPEN,
7. Turbocompressor (T/C) Speed Indicators (3)	These indicators (provided for the turbocompressors as located on engines 2, 3 and 4) show the T/C speed in PERCENT RPM. Each indicator is marked from 20 up to 105 % in subdivisions of 2 % with numbers at 20, 40, 60, 80 and 100, and a red limit marking at 105%

COCKPIT PANELS



3. TURBOCOMPRESSOR.

3.1. Operation.

The engine compressor bleed air pressure regulator prevents N_2 engine bleed air pressure variations affecting the turbocompressor (T/C) speed.
However, pressure can be regulated only if engine RPM is high enough.

The electro-pneumatic SOV is closed automatically by several T/C protection devices.

The variable nozzles, hydraulically controlled by an airflow regulator, modulate N_2 bleed air to the turbine in order to maintain the T/C outflow practically constant. The hydraulic control power is produced by the T/C lubricating circuit. When the lubricating oil pressure drops, the variable nozzles automatically tend towards close, decreasing the T/C RPM.

The variable nozzles opening is automatically limited when the T/C RPM reach the max. design speed (topping speed).
With airplane on ground and the start selector switch on LOW position, the variable nozzles are fully opened, thus increasing the T/C outflow to allow starting of other engines in crossfeed mode.

3.2. Protection Circuits.

Overspeed Protection.
The overspeed protection device closes :

- Pneumatically the SOV,
- Electrically the SOV and the pressure regulator.

NOTE: The closure signals are locked. The T/C cannot be started any more. Manual reset on ground by pushing the reset plunger.

Overheat Protection.
The overheat protection closes : Pneumatically the SOV

NOTE: The closure signal is locked. The T/C cannot be started any more.

Excessive or Low N_2 Bleed Air Pressure at the SOV.
The protection closes : Pneumatically the SOV

NOTE: The T/C can be started again.

T/C Surge Protection.
In case of excessive compression ratio, the T/C surge bleed valve automatically opens, thus increasing the airflow through the T/C.

Comparison between Airflow from Bleed Air and Turbocompressors.
The airflow delivered by bleed air is essentially variable with engine RPM, airplane altitude, and cabin differential pressure. The influence of these factors on T/C airflow is negligeable provided :

- Engine RPM is not near idle,
- T/C RPM is below the topping speed.

NOTE : At high cabin differential pressure, the best airflow will be obtained by using T/C instead of engine bleed air.

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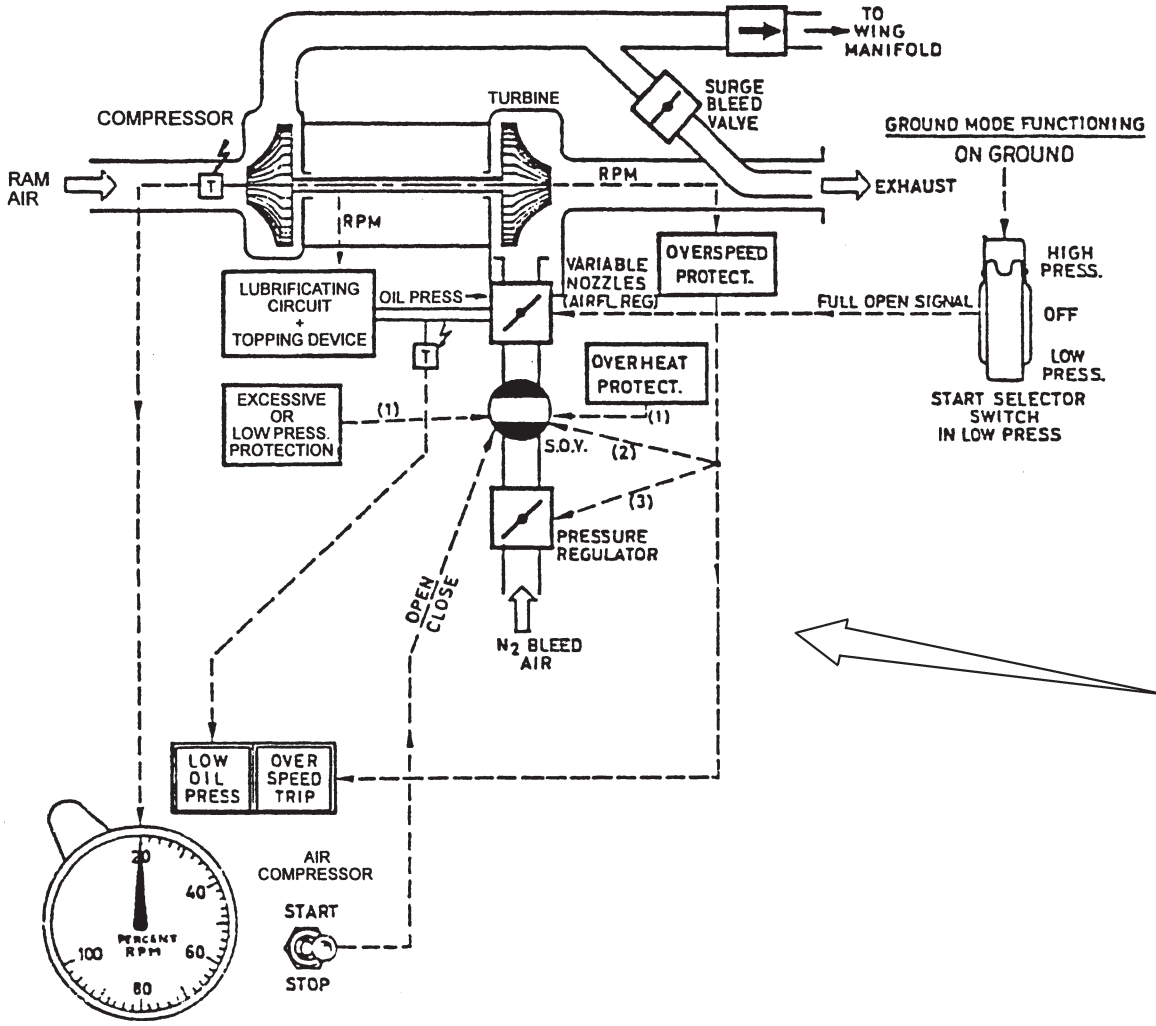
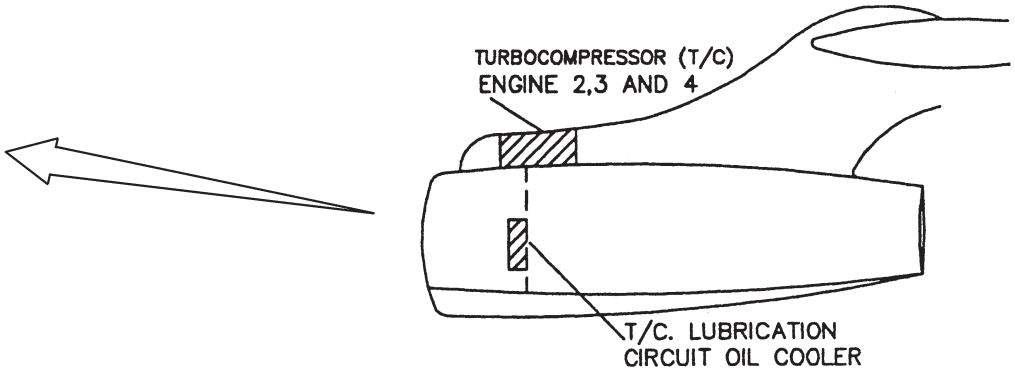


CLOSE SIGNALS
(1) PNEUMATIC SIGNAL
(2) PNEUMATIC & ELECTRICAL SIGNAL
(3) ELECTRICAL



TURBOCOMPRESSOR

4. OPERATION.

4.1. Normal Operation.

When the turbocompressor "START-STOP" switch is moved to the "START" position, and released, power is supplied to the overspeed switch and to the turbocompressor flow control valve when the flow control relay is energized. At the same time, a momentary contact directs power to energize the opening circuit of the latch type solenoid assembly in the differential pressure regulator and shutoff valve assemblies.

When the opening circuit to the differential pressure regulator is momentarily energized, the switcher is positioned to direct control air to the top of the actuator piston and vent the spring-loaded side to atmosphere.
The permanent magnets, in the solenoid assembly, hold the switcher in this position when the solenoid is de-energized. Control air, supplied by engine bleed, is delivered to the switcher through a filter and the reference pressure regulator. This air passes through the switcher to the top of the piston chamber and pushes the piston down to open the butterfly valve. Air from the spring-loaded side of the piston is vented to atmosphere through the sensing selector valve and the switcher.

The reference pressure regulator regulates the control pressure to the switcher. This limits the inlet air pressure to the turbine to 76 (±6) psig.
The downstream sensing selector valve opens at a predetermined value and allows downstream air pressure to be sensed on the springloaded side of the actuator piston. Sensing the downstream air pressure gives a modulating action to the butterfly.

If the closing circuit of the normally-open differential pressure regulator is energized, through actuation of the overspeed control, the switcher is positioned to direct control air pressure through the sensing selector to the spring-loaded side of the actuator piston and vent the opposite side of the piston to atmosphere. This action closes the butterfly valve.

When the "START-STOP" switch is moved to the "STOP" position,
and released, power is cut off from the overspeed switch and the turbocompressor flow control valve.

The compressor airflow controller and speed-topping control position the turbine variable area nozzle vanes which govern the speed of the turbocompressor assembly.

The ground mode flow control valve, when energized, bleeds the high static air pressure line which runs from the pressure sensing probe to the airflow controller. The resultant pressure differential across the flow control diaphragms regulates the control oil pressure to the hydraulic actuator to open the variable area nozzle vanes.

This ensures an adequate supply of compressed air for starting the other engines of the aircraft. The high and low pressures from the static air pressure sensing probes establish, a pressure differential across one of the flow control diaphragms to lift the hydraulic piston and bleed actuator control oil back to the sump. The pressure differentials, sensed through the compressor inlet air sensing line in the inlet duct and the high and low air pressure sensing lines from the downstream static pressure probes, position the hydraulic piston to govern the action of the hydraulic actuator.
When compressor discharge airflow drops below the required value, the piston is moved down to close the hydraulic bleed valve and allow the hydraulic actuator to increase the opening of the variable area nozzle vanes. This increase in flow of engine bleed air to the turbine wheel increases the speed of the, turbocompressor.

When compressor discharge airflow is above the required value, the piston is moved up to open the hydraulic bleed valve and cause the actuator to decrease the opening of the variable area nozzle vanes. This decrease in flow of engine bleed air to the turbine wheel decreases the speed of the turbocompressor.

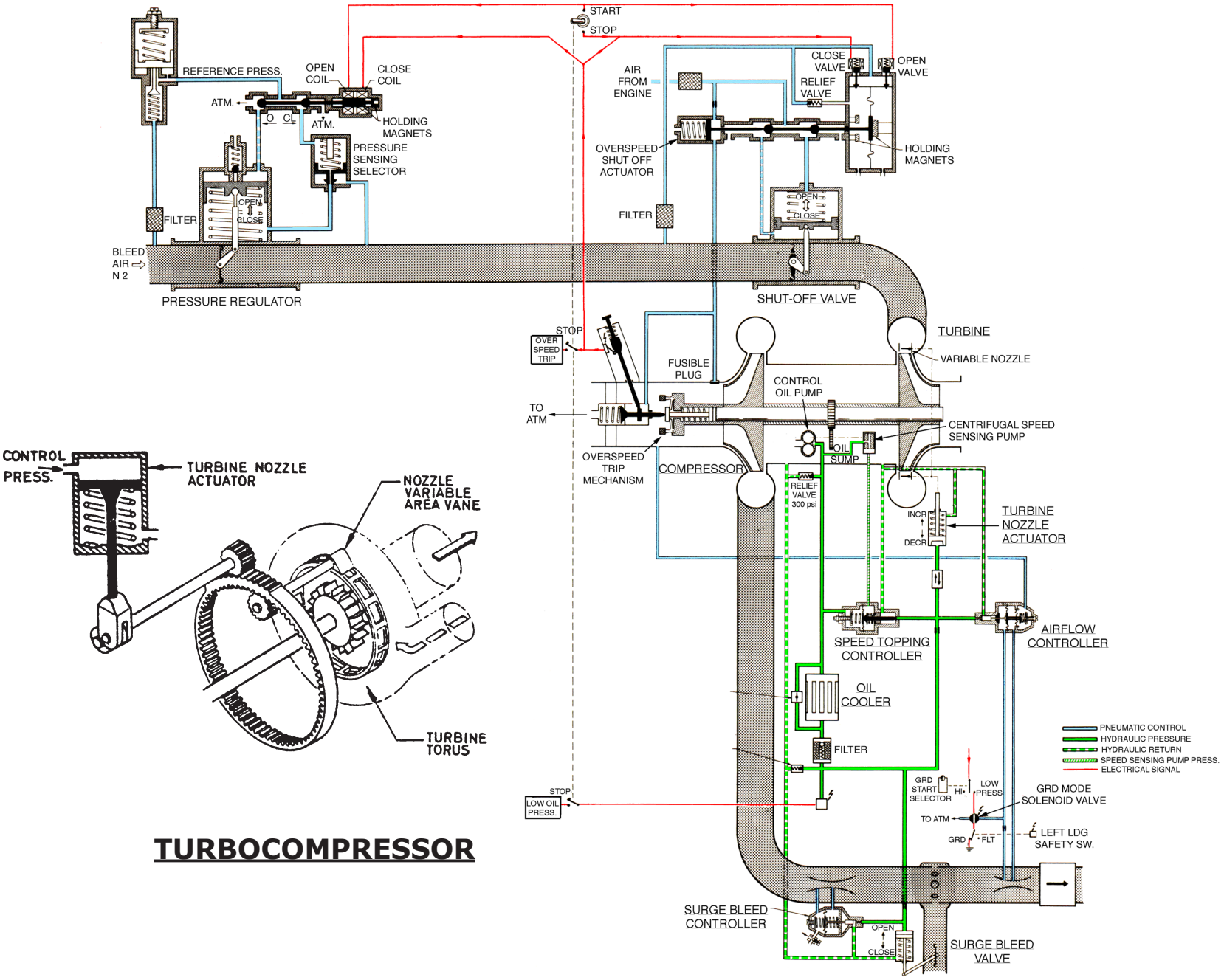
When the speed of the turbocompressor reaches the specified limit of 47,000 (±1000) rpm, oil pressure created by the centrifugal oil pump opens the hydraulic bleed valve in the speedtopping control. Opening of this bleed valve overrides the action of the flow controller and limits the amount of hydraulic pressure to the hydraulic actuator. This limiting of pressure results in limiting the opening of the variable area nozzle vanes, thus controlling the maximum speed to the turbocompressor.

The surge bleed control senses a pressure differential from the high and low static air pressure probes in the compressor outlet duct that is proportional to compressor discharge airflow. Normally, this pressure differential is such that the surge bleed valve is closed. When the compressor discharge pressure approaches a surge condition, where the discharge air flow pressure rises rapidly and the flow rate is decreased, the pressure differential across the diaphragm of the surge bleed control causes the bleed valve to open. With the bleed valve opened, control oil pressure decreases on the high pressure side of the piston in the surge valve actuator and allows the spring-loaded piston to open the butterfly valve. When the butterfly valve opens, compressor discharge air is ducted to atmosphere in an amount necessary to relieve the back pressure wave and prevent buildup of a compressor surge condition.

The overspeed shutoff mechanism will operate to prevent overspeeding of the turbocompressor in the event of failure of the normal operating controls. The flyweight device on the end of the compressor shaft will contact and open the overspeed trip poppet valve at an overspeed trip setting of 55,500 (±1500) rpm.

When this occurs, the manual reset plunger is released to lock the poppet valve in the open position and close the overspeed switch. Opening of the overspeed trip poppet valve permits the control air pressure on the high-pressure side of the spring-loaded diaphragm in the overspeed to escape to atmosphere. The overspeeds servo valve under servo influence of the diaphragm spring, then moves the pneumatic switcher of the shutoff valve assembly to direct control air to close the shutoff valve. Closing of the overspeed switch energizes the closing circuits to the differential pressure regulator valve and the shutoff valve and also completes the circuit to the overspeed trip warning light . The manual reset plunger cannot be repositioned in flight. If the overspeed shutoff mechanism is' inadvertently operated on the ground, the reset plunger must be repositioned before operation of the unit can be resumed. If the mechanism has operated as a direct result of turbocompressor overspeed, the turbocompressor assembly must, be replaced.

CAUTION: DO NOT USE SIMULTANEOUSLY BLEED AIR AND TURBOCOMPRESSOR ON THE SAME ENGINE DURING WING ANTI-ICING SYSTEM OPERATION.



TURBOCOMPRESSOR

4.2. Abnormal Operation.

Turbocompressor fails to start, LOW OIL PRESSURE light on.

- -Check engine throttle setting; increase if necessary
- -Check CB "TURBOCOMPR, VALVES & LTS- (P5)
- -Move the T/C switch to STOP, then to 'START" again, wait until LOW OIL PRESS light extinguishes before releasing switch.

T/C "LOW OIL PRESS" light illuminates.

a. RPM indicator shows zero.

- Move T/C switch on START.
- If trouble persists: Move T/C switch on STOP

b. RPM indicator low or erratic.

- Move T/C switch on STOP

c. RPM indicator normal

- Move T/C switch on STOP
- If needed, may be switched ON again regardless of "LOW OIL PRESS Light".

The T/C "OVERSPEED TRIP" and "LOW OIL PRESS" lights illuminate.

- Move T/C switch on STOP

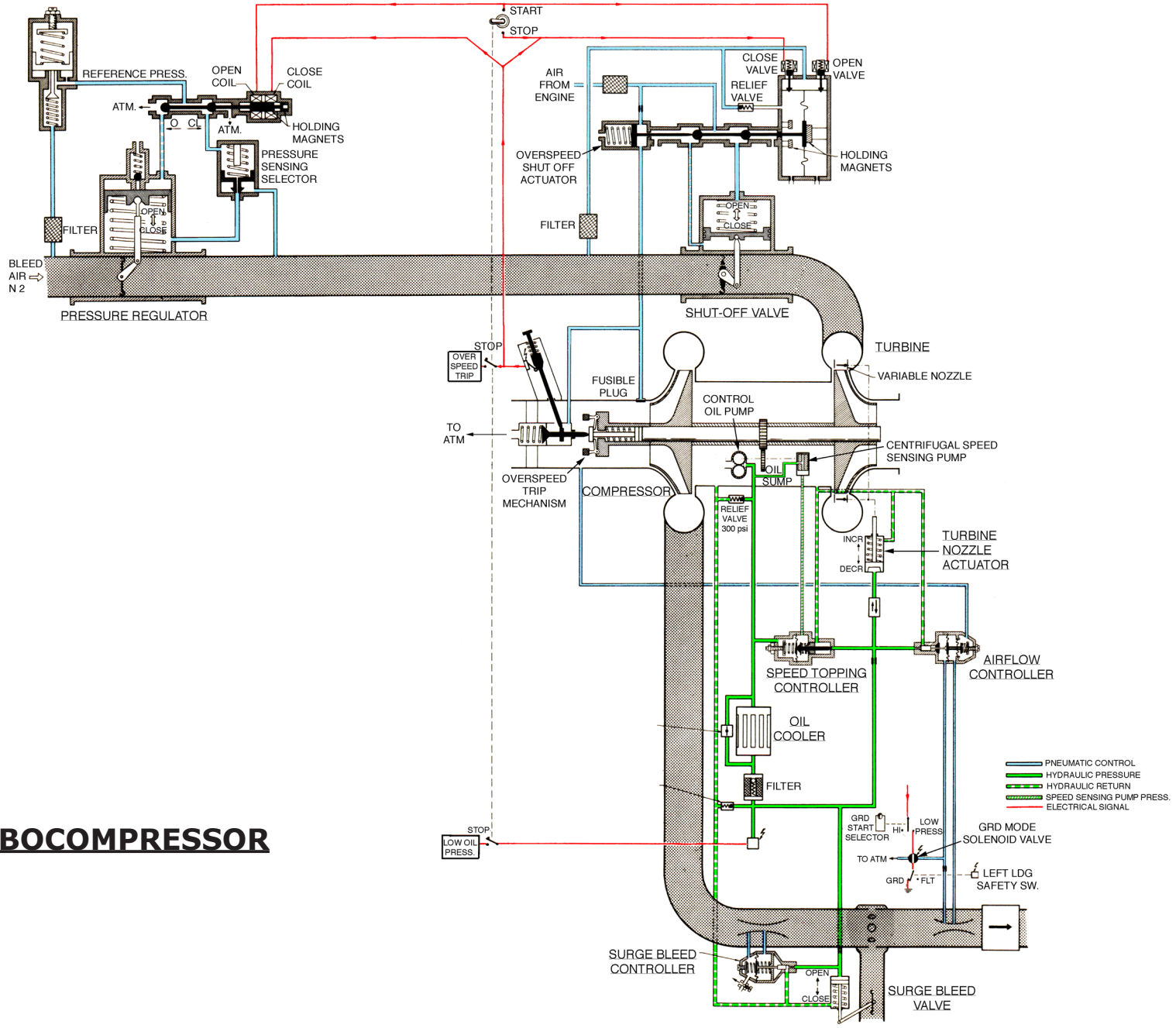
In flight, the T/C cannot be stopped by control switch.

a. The T/C functions normally.

- Move T/C switch on START to rearm the electric overspeed protection.
- Stop other T/C if necessary.

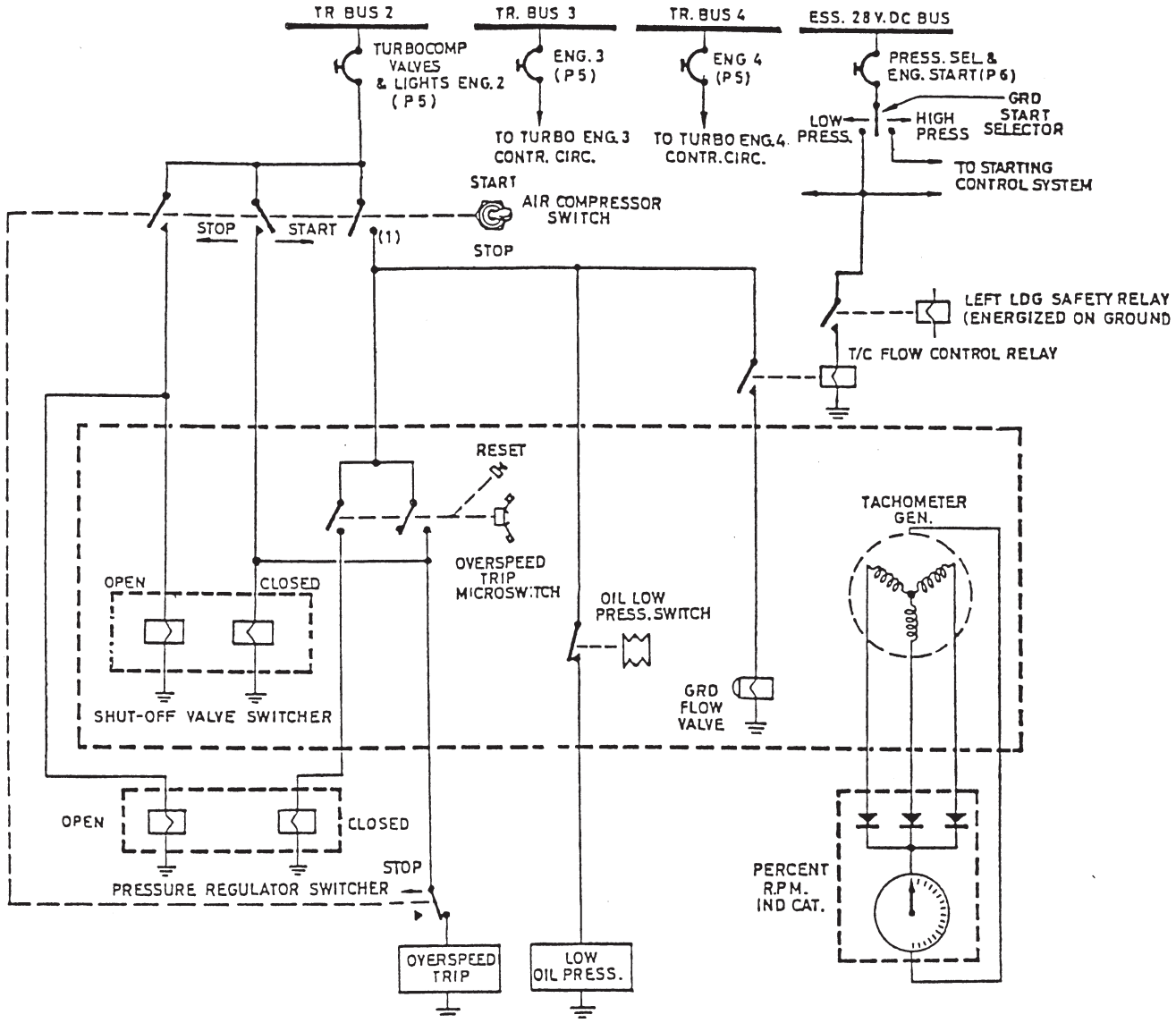
b. The T/C functions abnormally

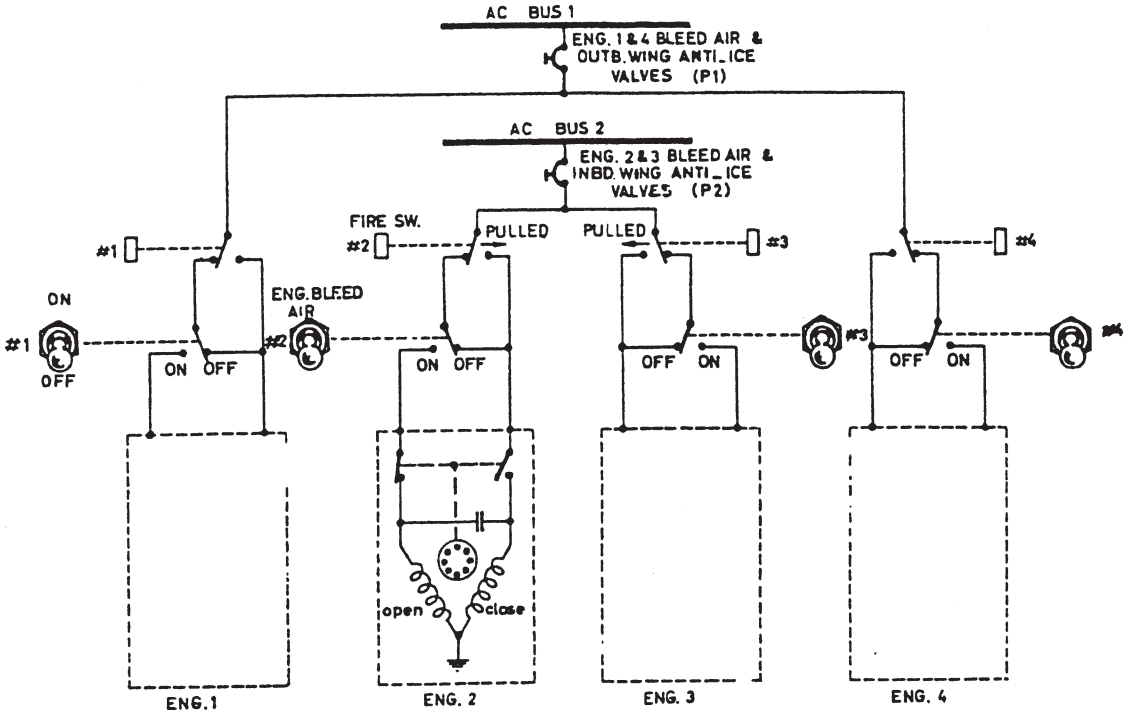
- Move T/C switch on START to rearm the electric overspeed protection.
- At pilot's discretion : Stop the T/C by cutting momentarily or definitively the corresponding engine.



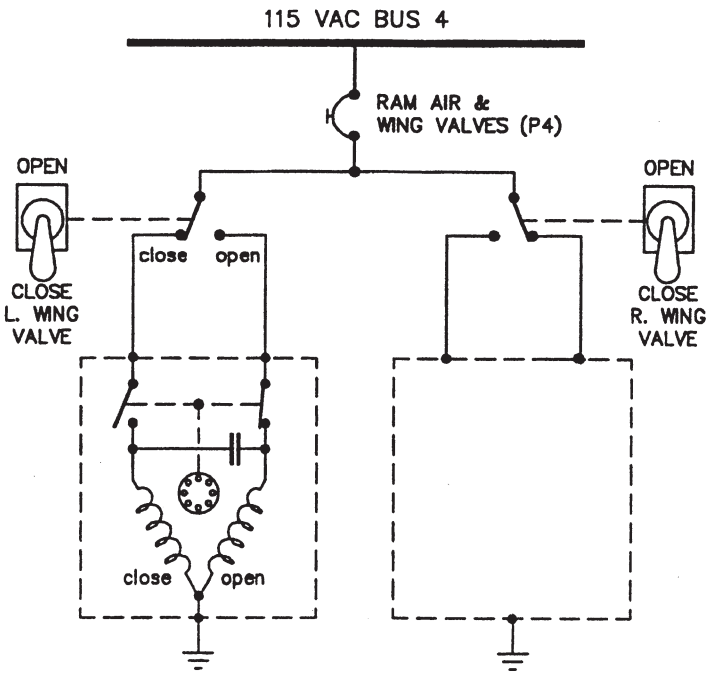
TURBOCOMPRESSOR

TURBOCOMPRESSOR ELECTRICAL SCHEMATIC

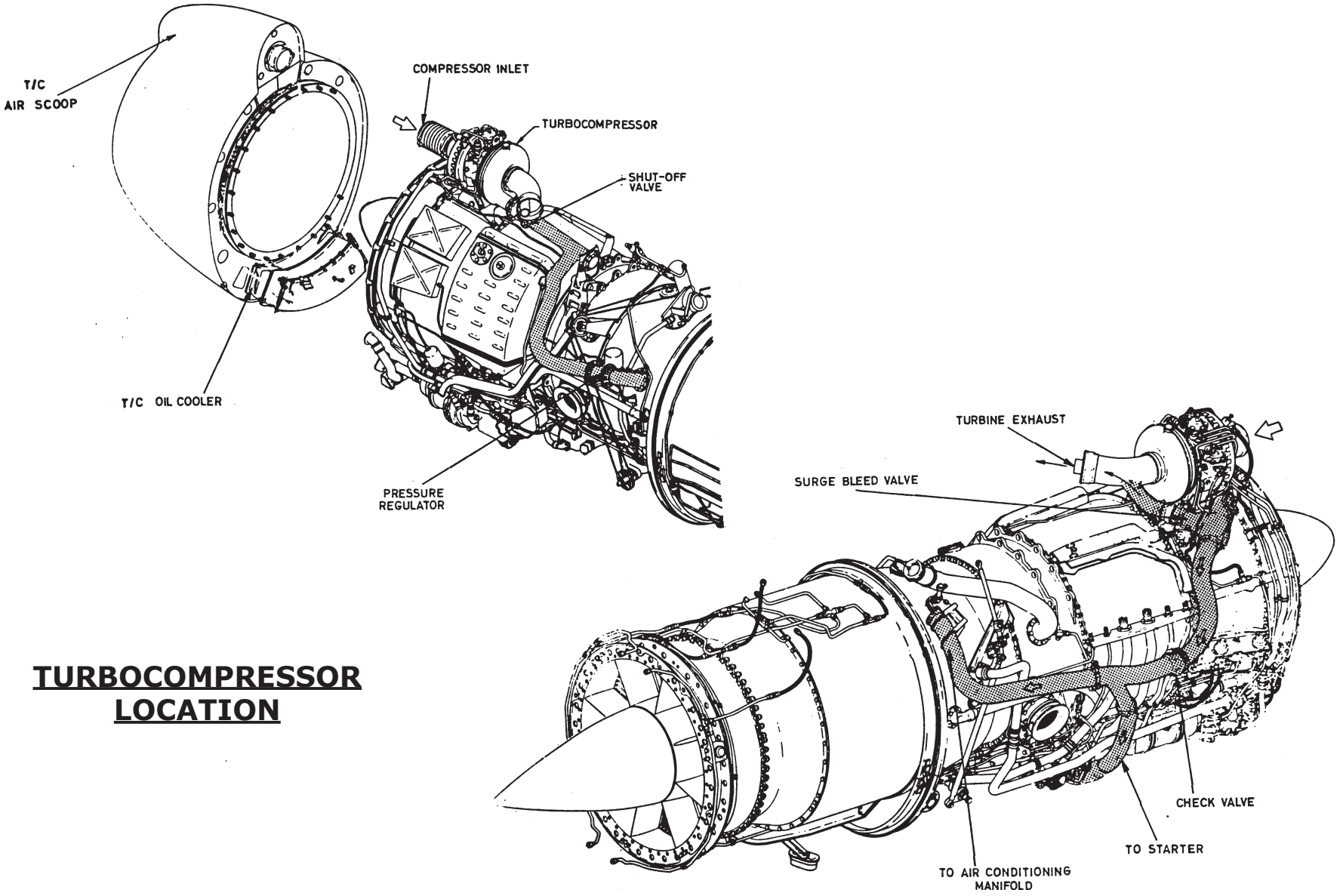




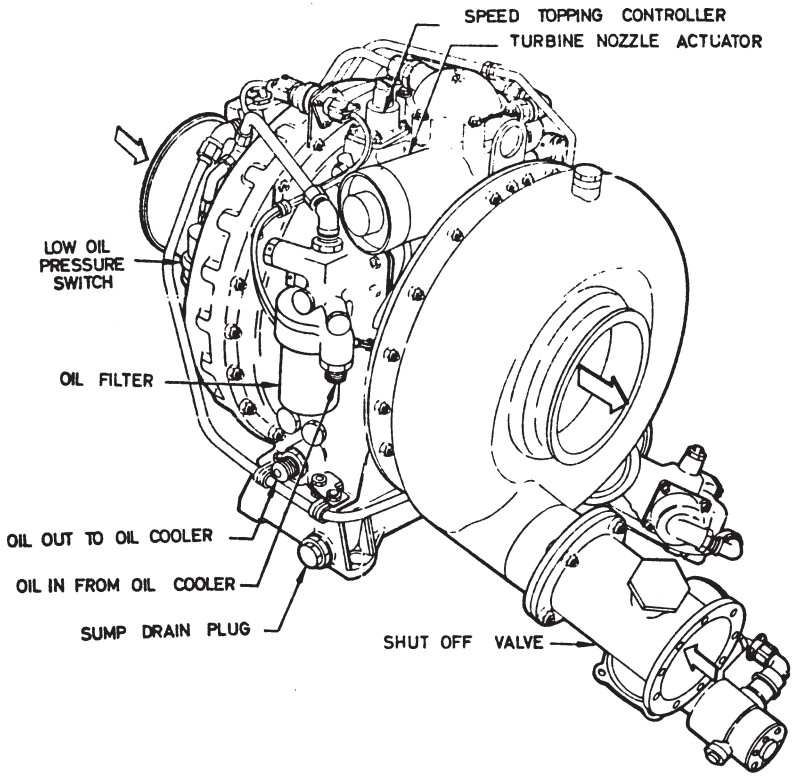
ENGINE BLEED AIR VALVES

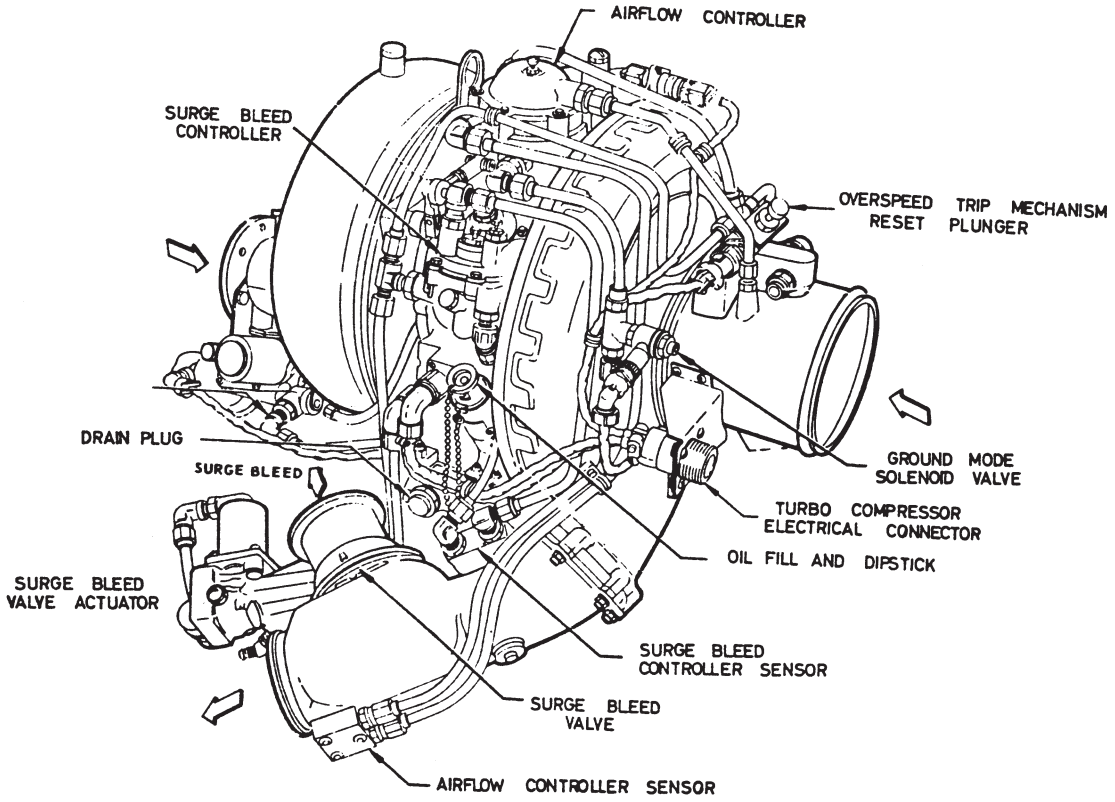


WING ISOLATION VALVES



TURBOCOMPRESSOR LOCATION





TURBOCOMPRESSOR

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