Cfm56-3 engine manual

CFM56-3 SYSTEMS Training Manual Revised April 1990 Prepared By CFM INTERNATIONAL CUSTOMER TRAINING CENTER Evendale Technical Training School GE Aircraft Engines Cincinnati, Ohio 45215 This publication is for TRAINING PURPOSES ONLY. The information is accurate at the time of compilation; however, no update service will be furnished to maintain accuracy. For authorized maintenance practices and specifications, consult the pertinent Maintenance Publications. The information (including technical data) contained in this document is the property of CFM International (General Electric Co. & SNECMA). It is disclosed in confidence and the technical data therein is exported under a U.S. Government license. Therefore, none of the information may be disclosed to other than the recipient. 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The fuel delivery system contains the main fuel pump, its filter, the servo fuel heater, main fuel/oil heat exchanger, MEC, fuel manifold and fuel nozzles. The CFM56 engine control system consists of both a hydromechanical (MEC) and electrical (PMC) components. Hydromechanical units include the main engine control, fan inlet temperature sensor (T12), HPC inlet temperature sensor (T25), hydraulic motor for the variable bleed valves (VBV), clearance control valve, and variable stator vane (VSV) actuators. The electrical units include the power management control (PMC), control alternator, fan speed sensor, fan inlet temperature (T12) sensor, and fan inlet static pressure (Ps12) (part of the PMC). Operational control of the engine is achieved by use of the power lever, fuel shutoff lever, and a PMC. The MEC is mounted on the main fuel pump and provides core speed (N2) governing in response to power lever input, and fuel limiting as modified by engine operational variables. The control automatically adjusts VSV system through external actuators and the VBV system through a gear motor. The MEC also provides signals to operate the HP clearance control system. The MEC acceleration fuel schedule is compensated for aircraft bleeds. This engine acceleration time is essentially the same with bleed on or off. The PMC operates from power delivered by the control alternator and functions to set fan speed (N1) by trimming the MEC within narrow authority limits. With PMC on, automatic calculation of takeoff N1 is accomplished from sensed fan inlet temperature and static pressure signals. The power lever signal is used to select a percentage of takeoff thrust; the selected percentage is used to establish a demanded fan speed achieved by control of fuel flow through the MEC. With PMC off, the MEC provides N2 governing. The oil system is used for lubrication and cooling of the engine bearings and gears in the transfer and accessory gearboxes. The ignition system is to produce an electrical spark to ignite the fuel/air mixture in the engine combustion chamber during the starting cycle and to provide continuous ignition during takeoff, landing, and operation in adverse weather conditions. iiiINTRODUCTION The indicating system is to verify proper and safe engine operation throughout the flight envelope. The engine is equipped with various sensors that monitor engine performance. 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This signal regulates the air flow of the 5th and 9th stage compressor bleed air to the HP turbine shroud support. Under certain takeoff conditions (above 13,800 N2) the MEC will alter this schedule through the use of a turbine clearance control valve timer. The MEC establishes a fuel flow (P7) to the fan inlet temperature sensor with a return (Pb) to the control. The differential fuel pressure (P7-Pb) is proportional to fan inlet temperature (T12). 5 FUEL DELIVERY SYSTEM Component Location 1. Fuel Pump Mounted on aft side of AGB 2. Fuel Filter Integral part of the fuel pump 3. Main Fuel/Oil Heat Exchanger Mounted on upper side of fuel pump 4. Servo Fuel Heater Mounted aft side of fuel/oil heat exchanger 5. Main Engine Control Mounted on aft end of fuel pump 7 FUEL DELIVERY SYSTEM Fuel Pump PURPOSE; The fuel pump pressurizes and circulates fuel required for combustion and fuel operated servo systems throughout the operational envelope of the engine. 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The pump housing provides mounting surfaces for the MEC and the main oil/fuel heat exchanger. The fuel pump is driven by the AGB through an arrangement of three splined shafts. The main drive shaft turns the high pressure stage gear pump, the low pressure stage shaft rotates the low pressure impeller pump, and the control drive shaft rotates the internal MEC speed governor and tachometer flyweights. 9 FUEL DELIVERY SYSTEM Fuel Pump LOW PRESSURE STAGE DESCRIPTION; FUEL PUMP Low Pressure Stage: The LP stage is a centrifugal type fuel pump that delivers a boost pressure to the HP stage to avoid pump cavitation. The fuel pump LP stage consists of a swirl inducer, an impeller and a volute. 11 FUEL DELIVERY SYSTEM Fuel Pump HIGH PRESSURE STAGE HP STAGE: The HP stage is a positive displacement type pump (gear pump). It delivers, for a given number of revolutions, a constant fuel flow regardless of the discharge pressure. The HP stage consists of a drive spur gear concentric with the main drive shaft, and a driven gear. These gears ride in bearings fitted into the gear housing. 11 FUEL DELIVERY SYSTEM Fuel Pump DESCRIPTION; FUEL/FILTERS: A replaceable filter cartridge is contained in the integral fuel filter housing. This housing has a removable cover fitted with a drain plug. The filter, located between the main oil/fuel heat exchanger and the HP stage of the pump, protects the HP stage and the MEC from particles within the fuel. The fuel circulates from the outside to the inside of the filter cartridge which has a nominal filtering capability of 20 microns. In case of a clogged filter, a bypass valve relieves fuel to the HP stage. 13 FUEL DELIVERY SYSTEM Fuel Pump DESCRIPTION; WASH FILTER: The wash filter is located at the HP stage discharge. Foreign material larger than 65 microns are prevented from entering the servo fuel flow and are washed on with the main fuel flow. The wash filter, incorporated with the pump housing, consists of a filtering element and a bypass valve. Should the filter clog, the bypass valve relieves fuel to the servo fuel heater. 15 FUEL DELIVERY SYSTEM Fuel Pump OPERATION; Fuel enters the pump inlet at aircraft boost pressure. The LP stage raises the fuel pressure and sends the LP stage output flow through the external main oil/fuel heat exchanger and then through the fuel filter. A filter bypass valve relieves LP stage output pressure directly to the HP stage. A pressure relief valve relieves a portion of the HP stage discharge flow back to the HP stage inlet if the HP stage discharge pressure exceeds a predetermined maximum. The HP stage discharges through the wash filter to the MEC. The fuel flow not required by the MEC is returned to the HP stage inlet. 17 FUEL DELIVERY SYSTEM Servo Fuel Heater PURPOSE; The servo fuel heater raises the temperature of the fuel to eliminate ice in the fuel before entering the control servos, inside the MEC. LOCATION; The servo fuel heater is mounted on the aft side of the main oil/fuel heat exchanger. 19 FUEL DELIVERY SYSTEM Servo Fuel Heater DESCRIPTION; The servo fuel heater consists of a housing with a heat exchanger core inside and a cover. The core assembly is removable. It consists of a number of aluminum alloy dimple " U " shaped tubes, inserted through a series of drilled baffle plates. The tubes are mechanically bonded to a tube plate which is profiled to the housing and end cover flanges. The core/housing assembly is designed to direct oil in four radial flow passes over the fuel filled " U " tubes. 21 FUEL DELIVERY SYSTEM Servo Fuel Heater OPERATION; The servo fuel heater is a heat exchanger using the engine scavenge oil as its heat source. The hot scavenge oil first goes through the servo fuel heater and then to the main oil/fuel heat exchanger. Within the servo fuel heater fuel from the fuel pump wash filter is heated by the scavenge oil and then goes to the MEC servos Inside the main oil/fuel heat exchanger fuel from the fuel pump LP stage cools the scavenge oil. Then the fuel goes to the inlet of the fuel filter and the cooled oil returns to the tank. 23 FUEL DELIVERY SYSTEM Main Engine Control PURPOSE; The main engine control (MEC) is a hydromechanical device that is basically a speed governor with refinements to provide automatic speed adjustments. This corrects for a broad variation in engine operational eMronments and provides additional control functions to optimize engine performance. OPERATION: Engine speed control is effected by controlling fuel flow to maintain the cockpit speed setting and establishes the maximum safe fuel limit under any operating condition. The conditions (parameters) vary, and the limits vary accordingly to definite acceleration and deceleration schedules. In order for the control to determine the schedules, certain parameters such as compressor discharge pressure (CDP), compressor bleed pressure (CBP), compressor inlet temperature (CIT), fan inlet temperature (T2) and core engine speed (N2), must be sensed. The control not only senses these parameters but also amplifies and computes necessary information from the sensed information. The computed limits are compared with actual fuel flow and are imposed when the limits are approached. A pressurizing valve maintains system pressure at low flow conditions to ensure adequate fuel pressure for MEC servo operation and accurate fuel metering. The schedule for variable stator vane (VSV) position is directly fed by fuel pump high pressure (HP) to the VSV actuators to position the vanes as the schedule changes. The signal which determines the position of the VSV actuators is the result of the control computing N2 and CIT specifically for this purpose. The schedule for variable bleed valve (VBV) position is directly fed by fuel pump high pressure fuel (PF) to the VBV hydraulic motor to position the valves as a function of the VSV schedule. A thrust reverser valve overrides the thrust recover schedule whenever the thrust reverser is deployed or there is a rapid actuation of VSV towards the closed position. The MEC also generates the turbine clearance control (TCC) schedules. 24 FUEL DELIVERY SYSTEM Main Engine Control Schedule of the turbine clearance air valves is created by the output of signal pressures (TC1 and TC2) which are a function of engine speed (N2). Positive fuel shutoff operation is independent of power lever position. The MEC defines and regulates the over-speed governing pressure and ensures fuel supplied by the fuel pump to the downstream side of the pump low pressure stage. 25 MAIN ENGINE CONTROL Speed Governing System (PMCOff) PURPOSE; The speed governing system controls core engine speed (N2) as a function of power lever position (PLA) and adjusts the fuel flow (WF) as necessary to maintain the desired speed setting by the power lever (speed demand N2*). The power lever angle speed demand is biased by fan inlet temperature (T2) and fan inlet pressure (Ps12) in a manner to change core speed (N2) as necessary to produce the proper fan speed (thrust). 31 MAIN ENGINE CONTROL Speed Governing System (PMCOff) PRINCIPLE: The desired core speed N2 is compared with the actual core speed N2. The desired core speed N2* is determined by: 1. A schedule supplied by T2 and PLA. 2. A schedule depending on T2 and Ps12. The physical core speed N2 is sensed by a flyweight device. The error signal: = N2* - N2, determines the fuel metering valve position, i.e. the required fuel flow (WF). Any error signal, created when demand speed and actual speed are not equal, will result in the flyweight device (governor) repositioning the fuel metering valve as necessary to produce the demanded speed. 33 MAIN ENGINE CONTROL Fuel Limiting System PURPOSE; Apart from the operating limits governed by the mechanical integrity of its components, the engine is subject to two other limits: 1. Lower or minimum limit imposed by the risks of lean flameout. 2. Upper or maximum limit imposed by the risk of rich flameout, compressor flow instability (stall) and overheating. During transient operation, the speed governing system could cause the engine to exceed the metered fuel flow beyond the safe limits described above. The purpose of the fuel limiting system is to define and impose correct engine fuel flow limits during rapid transients including accels, decels and starts. 35 MAIN ENGINE CONTROL Fuel Limiting System PRINCIPLE: The fuel limiting system schedules acceleration and deceleration fuel flow to the engine as a function of N2, T25, Ps3, and CBP. Acceleration Example: The max. fuel flow allowed during acceleration is determined by two cams: 1. One is called the "3D cam", rotated according to N 2 and driven linearly according to T25. The cam position represents the required ratio for the fuel flow rate (WF2)/(Ps3), which varies for each N2 and T25 value. 2. The other is the "CDP cam" rotated according to Ps3 and the ratio Ps3/CBP. A lever, in contact with the "3D and CDP cams", combines both position data in order to define the permissible fuel flow (WF1). 37 Fuel flow (WF2) is compared to the actual engine fuel flow rate (WF1). The signal resulting from WF2-WF1 limits fuel flow rate automatically during acceleration, for every point within the flight envelope. 37 MAIN ENGINE CONTROL Idling System PURPOSE; The CFM56-3 idling system is designed to produce two levels of variable idling speeds identified as "Low Idle" and "High Idle". Low Idle speed for ground use will provide a constant thrust level regardless of inlet temperature and is scheduled to produce adequate taxi thrust while minimizing noise, fuel consumption and braking effort. In flight low idle speed is scheduled to minimize fuel consumption. High Idle speed is scheduled to provide rapid recovery of takeoff thrust if required PRINCIPLE: When the PLA is at idle, the speed governing system receives an idle corrected speed signal corresponding to low or high idle. The system is designed to switch to the low idle schedule from the high idle schedule when a 28 volt DC signal is applied at a solenoid mounted on the MEC. 39 FUEL DELIVERY SYSTEM Fuel Manifold Assembly PURPOSE: The fuel manifold assembly provides the piping necessary to transfer the fuel from the fuel pump and the main engine control (MEC) across to the core engine, then along the bottom of the core and around the combustion case to the fuel nozzles. At each fuel nozzle connection and Y connection, a fuel drain is provided to protect against fuel manifold leaks. DESCRIPTION; The fuel manifold is comprised of 2 halves with a 3-piece drain manifold. The drain manifold has 15 integral and 5 removable drain tubes and join to the fuel supply manifold. The 5 unique drain tubes are to facilitate borescoping. The fuel manifold is connected to a Y-shaped supply tube at approximately the 5 and 6 o'clock positions. Each connection of the Y has an individual drain that is routed to the fuel manifold by bolts. Each manifold half incorporates 10 fuel nozzle connections, a complete fuel manifold will supply fuel to 20 fuel nozzles. 41 FUEL DELIVERY SYSTEM Fuel Nozzles PURPOSE; The fuel nozzles spray fuel into the combustion case assembly and connected to the fuel manifold. The 20 fuel nozzles deliver fuel into the combustor in a spray pattern which provides good light-off and efficient burning. DESCRIPTION: Each of the 20 fuel nozzles contains a primary and a secondary flow path, a flow divider, a check valve, fuel strainers and a dual orifice spray tip. On later engines, two or four nozzles were equipped with a richer primary fuel flow to help increase flameout margin during the start sequence. These nozzles were placed on either side of the ignition igniters at nozzle positions * & 8 (2 & 4 nozzles) and 14 & 15 (4 nozzles). In addition to their part number they are identified by a colored band around the nozzle body. OPERATION; During engine starting and at altitude low power conditions when fuel flow is equally low, the flow divider valve will close the secondary flow path thus assuring the development of system pressure high enough to produce an adequate spray pattern even at low fuel flows. The check valve in the primary flow path closes at shutdown and helps to maintain system prime. 43 HIGH PRESSURE TURBINE CLEARANCE CONTROL SYSTEM (HPTCCV) 45 HPT CLEARANCE CONTROL SYSTEM GENERAL; Operating tip clearances in the core engine are of primary importance. They not only determine steady-state efficiencies, as measured by specific fuel consumption, but have the most significant effect on transient engine performance as measured by peak gas temperatures and compressor stall margin. In a situation where thermal distortions can have a degrading effect, the blade tip clearance (running clearance) may also determine the resistance to deterioration by compensating for rapid throttle movements without compromising steady-state performance. Clearance control in the CFM56 engine is accomplished by a combination of mechanical designs. The system has 3 principle elements: passive structural control, rotor center cooling, turbine active clearance control. The first element, passive structural control, is achieved by the use of material in the compressor and turbine shroud support to ensure dimensional changes in the shroud and blades closely follow that of the rotor. The second element involves forced cooling of the core engine rotor. The use of low pressure booster discharge cooling air, which is a low and relatively stable temperature source, provides an effective cooling air supply to both compressor and turbine rotors with a small performance penalty. This cooling results from fixed passages and involves no control devices. The net effect is a reduction in HPC system clearances both during transient and steady-state operation. The third element of the system is the automatic control of the tip clearance between the HPT blades and the stationary tip shrouds. Bleed air from the 5th and 9th stages of the HPC is used to either cool or heat the HPT shroud support structure to optimize blade tip clearances, both transient and steady-state. In addition, the low pressure turbine is continuously cooled by fan air. Turbine clearance control is maintained within a rugged, one piece casing to maintain concentricity and clearance control. The turbine casing is cooled so that close clearances can be maintained under all operating conditions. 47 HPT CLEARANCE CONTROL SYSTEM PURPOSE: The CFM56 engine high pressure turbine (HPT) clearance control system uses high pressure compressor (HPC) bleed air through stages 5 and 9 to obtain maximum steady-state HPT performance and to minimize exhaust gas temperature (EGT) transient overshoot during throttle bursts. Air selection is determined by fuel pressure signals from the main engine control (MEC). The bleed air is ducted from the valve to a manifold surrounding the HPT shroud. The temperature of the air controls the HPT shrouds relative clearance to the HPT blade tips. DESCRIPTION; The clearance control system ducts HPC bleed air from the 5th and 9th stage air to the HPT shrouds to control the thermal expansion of the shroud support structure. The combination of valve positions can result in any of the following 3 combinations of air flow to the HPT shroud area: stage 5 air flow only, stage 9 air flow only, a combination of 5th and 9th stage air. OPERATION; After engine start and with the engine at ground idle power setting, the air flow to the HPT shroud is from the HPC stage 9 bleed. When the throttle is advanced or retarded to change the core engine speed, the air flow is regulated to maintain the optimum HPT shroud to blade tip clearance. The air flow selection for various steady-state power settings is roughly as follows: (1) (2) Idle Cruise (3) Climb (4) Take-Off - 9th stage air - 5th stage air - Combination of 5th and 9th stage air - 9th stage air 49 HPT CLEARANCE CONTROL SYSTEM OPERATION; An orifice, located in the 9th stage air extraction line between the valve and compressor casing extraction manifold, reduces the 9th stage air pressure being extracted to prevent 9th stage air introduction into the 5th stage of the compressor when both valves are open (during climb power). When the engine is shut down, the hydraulic actuator valve rods are retracted, closing the 5th and opening the 9th stage air valves During operation fuel circulates through the valve, to or from the MEC depending upon the pressure differential of the 3 control pressures and the orifice in the hydraulic actuator piston. Pressure relationship is PB < PCR < Pc. 51 HPT CLEARANCE CONTROL SYSTEM HPTCCV Timer PURPOSE: During takeoff, the HPTCCV Timer modifies the operation of the High Pressure Turbine Clearance Control Valve. This modified operation during takeoff stabilizes the HPT rotor/stator which helps to maintain turbine efficiency, and reduce transient EGT overshoot. DESCRIPTION; The timer is located on the left side of the fan case at the 10 o'clock position. The timer consists of a latching valve and return spring, a timer piston and return spring, and two maximum selector valves. The latching valve allows actuation of the timer only once per engine cycle (i.e. startup to shutdown). The timer piston provides the sequencing actuation of the 5th and 9th stage bleed air valves in the HPTCCV. The two maximum selector valves allow control of the HPTCCV by either normal MEC fuel pressure signals or timer sequencing. 53 HPT CLEARANCE CONTROL SYSTEM HPTCCV Timer OPERATION; When the engine is accelerated to a core speed greater then 95% N2, the MEC sends a TC3 signal pressure to the timer solenoid. If an airborne condition is not sensed the TC3 signal passes through the timer solenoid to the timer latching valve. The TC3 pressure actuates the latching valve which closes off TC3 and opens Pc pressure to the timer piston. As the timer piston moves through a 182 second stroke, various ports in the cylinder wall are covered and uncovered which send PB or Pc pressures to the HPTCCV via the maximum selector valves. This overrides the normal TC, and TC2 outputs. The timer sequence is as follows: 0 - 8 seconds 8-1 52 seconds 152 - 182 seconds 182+ no air 5th stage air 5th and 9th stage air mixture 9th stage air After the 182 second sequence is complete the timer returns HPTCCV control to the MEC. The normal TC1 and TC2 outputs are then in effect until the next engine shutdown. The timer function is automatically reset when there is a sufficient drop in Pc pressure. This occurs when the core speed drops below 4.8% (700 rpm) N2 55 HPT CLEARANCE CONTROL SYSTEM HPTCCV Timer Solenoid PURPOSE; Prevent timer operation after takeoff. LOCATION: The timer solenoid is located just above the HPTCCV timer at the 11 o'clock position. OPERATION: A weight-on-the-wheels sensing relay permits a 28v DC signal to energize the solenoid when the aircraft is in flight. This prevents the TC 3 fuel flow from the MEC to the HPTCCV timer. 57 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS GENERAL; The VSV's and VBV's are adjusted by the main engine control to optimize engine performance The first four stages of the high pressure compressor vanes and an array of bleed valves at the inlet to the HPC are positioned to provide the optimum performance of the compressor. The MEC schedules the VSV position by directing a servo fuel pressure to the VSV actuators (two units) to position the vanes as the schedule changes. The signal which determines the position of the VSV actuators is the result of the MEC computing N2 and CIT (T25) specifically for this purpose. Also, the MEC schedules the VBV position by directing high pressure fuel to the VBV fuel gear motor. The position of the VBV's is a function of the VSV position. 59 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VSV System PURPOSE; The VSV system allows optimization of HP compressor performance by matching the stator and the rotor. PRINCIPLE: The VSV system changes the angle of the HP compressor IGV and No. 1, 2 and 3 stator stages according to a defined schedule that is modified by core speed (N 2) and compressor inlet temperature (T25). The MEC computes the scheduled position of the variable stator vanes and directs a resulting high pressure fuel flow to the duel VSV actuators. The actuators mechanically position the variable stator vanes. A feedback cable provides the VSV position to the MEC to compare against the schedule requirements thus determining the need for continued actuator movement or holding. 61 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VSV System DESCRIPTION; The VSV system consists of a VSV scheduling unit integral with the MEC, 2 VSV hydraulic actuators, 2 actuation mechanisms and linkage, and a flexible feedback cable. Each VSV actuator is connected through a clevis link and the stage 3 bellcrank to a master rod. Adjustable linkages connect the variable vane actuation rings to bellcranks that are connected to the master rod. Connections between the actuator, clevis links, and master rod are made with bolts and bushings for stability. All other linkages are connected with bolts and uniballs to eliminate misalignment or binding. The actuation half-rings, which are connected at the horizontal splitline of the compressor casing, rotate circumferentially about the horizontal axis of the compressor. Movement of the half-rings is transmitted to the individual vanes through vane actuating levers. The MEC schedules the turbine clearance control valve by the output of fuel pressure signals which are a function of core engine speed (N2). 63 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VSV System VSV TRACKINGSCHEDULE The tracking schedule identifies the position required of the variable stator vanes (VSV's) in degrees at a specified corrected core engine speed. 65 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VSV System DESCRIPTION; The VSV feedback cable is connected to the main engine control (MEC) lever on the aft side. It is routed up through the rear portion of the 6 o'clock fan frame strut area. It connects to the bellcrank of the VSV actuator located at the 8 o'clock position on the compressor case. 67 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System PURPOSE: Booster and HP compressor have been matched throughout the high thrust range. Outside these conditions, the HP compressor first stages accept less airflow causing booster discharge pressure to increase and thus creating a risk of booster stall. To prevent this, bleed valves bypass air from the primary airflow (HP compressor inlet duct) into the secondary airflow (fan discharge duct). PRINCIPLE: The VBV system positions twelve bleed valves by hydraulic pressure acting upon a fuel gear motor. The fuel pressure is scheduled by the main engine control's VBV scheduling unit to provide a VBV position per the parameters of N2 and T25, as derived from the VSV feedback cable position. A VBV feedback cable is positioned to provide the scheduling unit with a current VBV position to compare with the desired position. 69 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System VBV TRACKING SCHEDULE The tracking schedule identifies the position required of the variable bleed valves in percent of angle at a specified corrected core engine speed. At the lower speeds more booster air must be bled over into the fan discharge to maintain an optimum flow through the core engine. The bleed valves close progressively as the operating point approaches cruise. Efficient operation requires the bleed valves to be fully closed near 12250 rpm corrected core speed and higher. 71 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System VBV SCHEDULE CORRECTION There are two operating conditions that require an adjustment or reset to the normal VBV schedule. The reset is accomplished through a reset mechanism in the VBV scheduling unit of the M.E.C. *VBV SCHEDULE CORRECTION: THRUST REVERSER OPERATION The bleed valves are more open during thrust reverser operation (for a margin against distorted inlet airflow and reingestion of hot exhaust gasses when in T/R mode at low ground speed during the landing). The loss of power to the MEC thrust reverser solenoid signals the VBV reset mechanism. *VBV SCHEDULE CORRECTION: RAPID DECELERATION The bleed valves are more open during rapid deceleration (the inertia of the LP rotor system keeps the airflow of the booster high during the time the core engine is rapidly decelerating thereby reducing its airflow capabilities). Movement of the VSV feedback cable during rapid decel signals the VBV reset mechanism. 73 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System DESCRIPTION; The VBV system includes the following: 1. A VBV scheduling unit integral with the MEC. 2. A power unit consisting of a fuel gear motor. 3. A mechanical transmission system consisting of: - A stop mechanism. - A master ballscrew actuator and eleven ballscrew actuators. - Eleven bleed valve flexible shafts. - Twelve bleed valves. - A feedback cable. 75 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System FUEL TO VBV GEAR MOTOR The MEC directs high-pressure fuel to the VBV hydraulic gear motor to position the VBV valves as a function of the VSV schedule. 77 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System FUELGEAR MOTOR PURPOSE; The fuel gear motor controls the position of the bleed valves. DESCRIPTION; The fuel gear motor is a positive displacement gear motor driven by high pressure fuel. It consists of two spur gears operating on needle bearings. Sealing at the drive gear shaft is provided by carbon seals. A secondary lip seal is mounted on the output shaft for further sealing. An intermediate drain will remove a fuel leak if it would get past the primary carbon seal. 79 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System BLEED VALVE STOP MECHANISM PURPOSE; The bleed valve stop mechanism limits the number of revolutions of the fuel gear motor to the number of revolutions required for a complete cycle (opening-closing) of the twelve bleed valves. DESCRIPTION; Mounted on the fuel gear motor, the stop mechanism consists of a housing for a hollow acme screw which is driven by the fuel gear motor. This hollow screw holds the main VBV flexible shaft which connects the stop mechanism to the master ballscrew actuator. A follower nut translates along the screw and stops the rotation of the fuel gear motor when it reaches the ends of the screw threads (dog stop). 81 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System BLEED VALVE ANDMASTERBALLSCREW ACTUATOR PURPOSE; Located in the fan frame midbox structure, the bleed valve and master ballscrew actuator is the unit through which the driving input from the stop mechanism is transferred to the eleven bleed valves and ballscrew actuators. DESCRIPTION; The bleed valve and master ballscrew actuator is composed of a speed reduction gearbox and a ballscrew actuator linked to a hinged door. Speed reduction is successively carried out through one pair of spur gears and then by two pairs of bevel gears, the last of which drives the ballscrew. The ball bearing type screw and nut assembly consists of a screw, a translating nut, a ball return tube, and a clamp attached by two screws and washers, and 68 balls. The translating nut is held during rotation by two pins which slide within two slots in the actuator body. A lever converts the translating motion of the nut into an angular motion of the door. The output motion of the bevel gears is transferred to the eleven other ballscrew actuators through eleven flexible shafts. 83 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System BLEED VALVE AND BALLSCREW ACTUATOR PURPOSE; The eleven bleed valves, located in the fan frame midbox structure, bypass a mass air from the HP compressor inlet duct to the fan discharge duct. Each bleed valve is actuated by a ballscrew actuator (the twelfth bleed valve is actuated by the master ballscrew actuator). DESCRIPTION: Similar to the bleed valve and master ballscrew actuator. 85 VARIABLE STATOR VANE AND VARIABLE BLEED VALVE SYSTEMS VBV System VBV FEEDBACK CABLE PURPOSE; The bleed valve feedback cable transfers to the MEC the displacements of a reverser lever actuated by the bleed valve system. DESCRIPTION; The VBV feedback cable is connected to the MEC lever on the aft side. It is routed up through the rear 6 o'clock fan frame strut area bundle and around the left side of the forward compressor case. It connects to the reverser lever mounted on the bleed valve stop mechanism housing. 87 HPC 5th STAGE START BLEED SYSTEM 91 HPC 5th STAGE START BLEED SYSTEM PURPOSE; This system is designed to aerodynamically unload the High Pressure Compressor (HPC) during start. Incorporating the Fifth Stage Start Bleed System results in reduced pressure in the compressor section during start, thus increasing HPC start stall margin. DESCRIPTION; The Start Bleed Valve system consists of a pneumatically operated, spring loaded, normally closed valve which is opened when starter air pressure is applied. Starter air pressure is supplied from the starter to the bleed valve by a signal tube routed from the starter at the nine o'clock position through the six o'clock tube bundle and to the Start Bleed Valve mounted at the eleven o'clock position of the high pressure compressor case. A deflector baffle at the bleed system diffuser (exit port) directs discharge air away from the core cowl. 93 HPC 5th STAGE START BLEED SYSTEM OPERATION; During the start sequence when the starter air valve is open, starter air pressure is supplied through the signal tube to the Start Bleed Valve signal port. This air pressure overcomes the spring and opens the Start Bleed Valve. Approximately 4% of the primary airflow then exits the high pressure compressor and increases the HPC start stall margin. When the starter air valve closes, the loss of air pressure allows the spring to close the Start Bleed Valve. Should a failure occur in the open position, fifth stage bleed air assists the spring in closing the Start Bleed Valve. 95 SENSING SYSTEMS A. CIT/Compressor Inlet Temperature (T25) B. CDP/Compressor Discharge Pressure (Ps3) C. CBP/Compressor Bleed Pressure D. N2/Core Speed E. N1/Fan Speed F. Ps12/Engine Inlet Static Air Pressure G. T12/Engine Inlet Temperature (Electrical) H. T2/Engine Inlet Temperature (Hydromechanical) J. PLA/Power Lever Angle 97 SENSING SYSTEMS Compressor Inlet Temperature Sensor (T25) PURPOSE: To convert compressor inlet air temperature into a hydraulic signal to the MEC. LOCATION: Mounted in a port near the 6 o'clock strut in the rear of the fan frame. DESCRIPTION; The CIT sensor consists of a coil guard, a sensing coil connected to a sensing bellows, a metering valve and a housing. OPERATION; The sensing coil has a constant volume of helium. This gas pressure, inside the coil. is proportional to temperature. When the air temperature changes, the gas pressure inside the bellows varies, thereby opening or closing the metering valve, that changes a fuel pressure delta between the P6 signal pressure and the PB reference pressure. This pressure delta is sensed by the MEC as compressor inlet temperature. 99 SENSING SYSTEMS Compressor Inlet Temperature Sensor (T25) FUEL TO CIT SENSOR The CIT sensor converts the compressor inlet temperature (T 25) into a fuel pressure signal to the MEC. 101 This page reserved for CDP tube graphic COMPRESSOR DISCHARGE PRESSURE TUBE 102 SENSING SYSTEMS Compressor Discharge Pressure Tube PURPOSE; To transmit compressor discharge pressure (static pressure) to the MEC for use by the bleed bias and fuel limiting systems. LOCATION: The CDP tube is connected to the combustion case at approximately the 9 o'clock position just aft of the fuel nozzles. The tube then proceeds down to the bottom of the compressor case and continues forward to the 6 o'clock strut area. From there it goes to the aft end of the MEC. 103 SENSING SYSTEMS CBP/Bleed Bias Sensor System PURPOSE; The bleed bias system provides automatic resetting of the acceleration schedule to maintain rapid acceleration times when customer bleed demands are high, and enables adequate stall margins to be conserved when the bleed demand is low. LOCATION; The bleed flow signal is provided by the bleed bias sensor, a dual venturi device, mounted on the 9th stage high pressure compressor (HPC) bleed port at the 4 o'clock position. DESCRIPTION; The bleed flow sensor and connecting hardware provides the main engine control (MEC) with a flow signal as a function of customer bleed rates. 105 SENSING SYSTEMS Mechanical Core Speed (N2) PURPOSE: Physical core speed is needed for MEC operation. OPERATION: Core speed is provided to the MEC through the MEC drive shaft. The speed is sensed internally by the MEC's governor. Core Speed Indicating System (N2) PURPOSE: The control alternator is a two piece single phase generator which provides a high frequency power output to the power management control (PMC), and is used to provide an electrical signal for cockpit indication of core engine speed. DESCRIPTION: The control alternator is mounted to the accessory gearbox (AGB), forward side. The rotor, a permanent magnet with no wires, is spline mounted directly to the gearbox gearshaft and axially secured by a self-locking nut. The stator and housing assembly is completely separate and mounts directly to the gearbox housing on a bolt pad. The stator windings are positioned relative to the rotor so the unit operates to provide the required AC power output. The stator housing includes two connectors to conduct electrical power to the PMC and a core speed signal to the cockpit core speed indicator. OPERATION; When the engine is in operation, the engine core rotor drives the accessory drive system which is connected to the control alternator rotor. The control alternator generates a single phase electrical output that energizes the PMC and provides a signal to the cockpit core speed indicator that varies directly with core engine speed (N2). 109 SENSING SYSTEMS N1 Speed Sensor PURPOSE; The N1 speed sensor is mounted in a strut of the fan frame at the 4 o'clock position. It has 2 sensing coils, one transmitting a signal to the cockpit indicator and the other to the Power Management Control. The signals are sinusoidal having a frequency proportional to the low pressure rotor system rotational speed. DESCRIPTION; The N1 speed sensor measures engine fan speed. It is an induction type tachometer excited by a sensor ring mounted on the fan shaft. The ring consists of 30 teeth that generate a signal proportional to the fan speed as the teeth pass a probe mounted on the fan frame. One tooth is thicker than the others and creates a blip used for trim balance. The passage of each tooth on the sensor ring disrupts the flux field setup by the sensor causing an electrical pulse. The frequency of the pulses is proportional to the fan speed. The probe consists of 2 independent sensing elements which are magnetically and electrically insulated from one another. Each sensing element consists of a sensing coil wound on an iron core. A magnet is mounted behind each iron core, and induces a magnetic field in the coil. The conductors which connect the probe to the connector are encapsulated in an epoxy material. 1ll SENSING SYSTEMS PS12 Pressure Sensing PURPOSE; To measure the engine inlet pressure LOCATION: Mounted on the forward section of the fan casing at the 2:30, 5, 8 and 11 o'clock position. The four static ports are connected to one quarter inch line that goes to the top of the PMC, and also to the MEC. DESCRIPTION: The Ps12 pressure is supplied to the PMC where internally a sensor is located. The Ps12 pressure is supplied to a sensor located internally in the PMC. The sensor is a strain gage resistance bridge type with an amplifier network. The same pneumatic pressure is applied to the MEC. OPERATION: The PMC internal sensor accepts an air pressure input (psia) and converts it to a proportional DC voltage. A 0 to 50 MVDC differential output is generated as fan inlet air pressure of 0-20 psia is applied. 113 SENSING SYSTEMS T12 Engine Inlet Temperature Sensor (Electrical) PURPOSE; To measure the engine inlet air temperature and provide a proportional electrical signal to the PMC. LOCATION; Mounted on the inlet cowl at the 2 o'clock position. When the inlet cowl is separated from the engine the sensor is stowed in a bracket on the engine fan case. DESCRIPTION: The T12 temperature sensor consists of 2 components: A sensing element and a housing. The sensing element is a thermo resistance device. It consists of reference grade platinum wire bifilar wound on a cylindrical mandrel. The housing for the temperature sensing element is designed to protect the element and keep vibration to a minimum. The sensing element is located in a slot in the housing and forms a bypass for air flow. Air flowing past the housing changes direction to enter the slot. This prevents foreign objects from entering the slot and damaging the element. It also uses boundary layer control to ensure that the sensed temperature is the free stream temperature rather than that of the boundary layer. The housing is designed to minimize turbulence in the gas stream arid is also designed to operate over a limited range of angle of attack. OPERATION; The PMC provides the sensing element a constant current and measures the voltage. thus the voltage is a function of the temperature. 115 SENSING SYSTEMS T2/Engine Inlet Temperature Sensor (Hydromechanical) PURPOSE; To provide a hydraulic signal (fuel pressure) to the MEC proportional to the fan inlet temperature. DESCRIPTION: The sensor consists of a helium filled sensing element permanently attached by a capillary tube to a housing containing a bellows and a variable orifice metering valve. LOCATION; The sensing element is located in the fan inlet duct at approximately 11:00 o'clock position and is inserted in the fan inlet air stream. The bellows/valve housing is mounted on the fan case directly aft of the sensing element. Attaching fuel lines transmit fuel flow from the MEC thru the housed metering valve and back to the MEC. When the fan inlet duct is separated from the engine the sensing element is stowed on a bracket on the engine fan case. OPERATION; Helium trapped in the sensing element cylinder, capillary tube and housed bellows will vary in pressure with changes in inlet temperature. The change in bellows force will change the fuel metering valve position with back pressure in the fuel inlet line (P7) being developed proportional to the inlet temperature. The differential pressure between the inlet line (P7) and the return line (PB) increases with increases in inlet temperature. 117 SENSING SYSTEMS Power Lever Angle (PLA) PURPOSE; To provide the PMC with an electrical signal proportional to the position of the throttle controlled power lever on the MEC. LOCATION: Mounted within the MEC with electrical connections to the PMC. DESCRIPTION: PLA information is transmitted to the PMC from the MEC via a rotary variable differential transducer located inside the MEC. OPERATION: The PMC produces an excitation voltage to the PLA rotary variable differential transformer which is the PLA transducer. As PLA is rotated the transducer provides an electrical relationship between forward and reverse, PLA thrust demand. 119 POWER MANAGEMENT CONTROL GENERAL: Transient operation control is provided by the core engine control since core characteristics determine the limiting parameters, such as temperature, surge, flameout, etc. The core engine controls are only controlling an approximate evaluation of total thrust. Thus, in a high bypass engine, total thrust is more accurately controlled by controlling N1 speed. This is accomplished by varying N2 speed to maintain a constant corrected N1 speed. The steady running control should therefore hold N1 corrected speed constant, this being an accurate indication of thrust. These remarks explain the CFM56 engine control design as applies to thrust control. - A hydromechanical device (Main Engine Control), to control core speed (N2). - An overriding electronic system (Power Management Control), to provide dominant control of fan speed (N1). 121 POWER MANAGEMENT CONTROL PURPOSE: The power management control is an electronic override on the hydromechanical MEC, which sets fan corrected speed (corrected for inlet temperature variation T12 and pressure altitude Ps12) as a function of power lever angle (PLA). The same PLA will always provide the same percentage of the rated thrust available at a given flight condition. Thus, at start of climb, the fan speed required for max climb rating (or a percentage of max climb) can be set. The PMC will then ensure that the max climb rating (or the same percentage) is maintained until the power lever is moved. This "locked throttle" climb eliminates the need for pilot action until cruise altitude is reached. At full throttle (takeoff position), the thrust is constant with inlet temperatures up to the flat rate temperature break point. The PMC also provides protection against excessive fan and core speed, and reduces transient EGT overshoot. LOCATION: The PMC is mounted on the fan casing near the 3 o'clock position (aft looking forward). 123 POWER MANAGEMENT CONTROL PRINCIPLE: The PMC computes and schedules a fan corrected speed as a function of: - Power Lever Angle (PLA) - Fan Inlet Static Pressure (PS12) - Fan Inlet Temperature (T12) - Nl Speed The PMC provides an output current to a torque motor (TMC), mounted on the MEC. The torque motor modifies the desired core speed (N2*), and thus the metered fuel flow (WF). A PLA transducer is mounted on the MEC, to provide a PLA position to the PMC. OPERATION: The PMC computes and schedules a basic program corresponding to a requested thrust level. This program is corrected according to PS12. The PMC also computes and schedules a T12 limit schedule which reduces fan corrected speed as a function of T12. The scheduled N1 is then compared with the physical N1 The error signal is applied to the torque motor, which modifies the N2*. therefore adjusting fuel flow (WF). 125 OIL SYSTEM 127 OIL SYSTEM PURPOSE: The oil system controls and carries oil used for lubrication and cooling of: Engine rotor bearings, Gears and bearings of the Accessory Drive Section. (Inlet Gearbox - Transfer Gearbox - Accessory Gearbox). PRINCIPLE: The CFM56-3 oil system features: -Unregulated Pressure Supply. -Pressure pump delivery is not controlled, but oil flows are always in excess of design requirements. -Dry Sumps. _ -Each sump (Forward sump - Aft sump - AGB/TGB sump) is scavenged through separate circuits. -Closed Loop Recirculation. -Oil fed to the sumps is returned to the oil tank through heat exchangers. -Modular Design: -External tube runs have been eliminated whenever practical using modular plug-in concept. (Lube Unit - Inlet Gearbox and No. 1/No. 2 Bearing Lubrication). DESCRIPTION; The complete oil system is comprised of: - The oil supply circuit - The oil scavenge circuit. - The venting and drainage system. 129 OIL SYSTEM Oil Supply Circuit DESCRIPTION: On engine starting, oil stored in the tank is drawn-in and pressurized by the Pressure Pump housed in the Lubrication Unit. On the pump discharge side a Pressure Relief Valve protects the circuit against excessive pressures. Should the pump delivery pressure exceed the setting of the valve, (304 psid/2100 kPa) it opens a bypass oil flow to the suction side of the AGB/ TGB sump scavenge pump. Downstream the pressure pump, oil flows through the Pressure Filter Assembly, which consists of: -A cleanable metal mesh filtering element sized to stop any particle larger than 44 microns (approx. 0.0017 in.). -A spring loaded check valve, set at approximately 0.5 psid (3.5 kPa differential) to prevent excessive oil leakage when the filtering element is removed. -A combined clogging indicator and bypass valve, subjected to the filter upstream and downstream pressures. When the pressure drop across the filter reaches 14.5 psid (100 kPa differential) a red indicator pops out. showing through a transparent cap. At the same time, the bypass valve unseats and oil flows directly to the sumps. Filtered oil exits from the lube unit through 3 distinct ports: -One supply line to the Accessory Gearbox bearings and gears. -One supply line to the Engine Forward sump. A tube tees off that line to supply the Transfer Gearbox. -One supply line to the Engine Aft sump. A tube tees off that line towards the oil tank (anti-siphon and hydraulic cap lock). 131 OIL SYSTEM Oil Scavenge Circuit DESCRIPTION; After lubricating the components, oil is collected at the bottom of each sump. An external line connects the TGB sump with the AGB sump[. The air/oil mixture is sucked through 3 external lines from the forward sump, aft sump, and AGB sump back to the scavenge pumps housed in the lube unit. At the entry into the lube unit, each of the oil flows passes first on a magnetic plug then through a scavenge screen to stop any debris larger than 800 microns (approx. 0.032 in.) If the screen is clogged, its center cavity fills up and oil automatically bypasses the chip detector assembly. Pressure relief flow from the supply circuit is connected to the AGB scavenge line upstream of the screen. Downstream of the individual scavenge screens, each of the 3 oil flows passes through a scavenge pump. At pump delivery the 3 flows join and exit from the lube unit at a single port. An external tube brings this oil to the common scavenge filter installed on the aft side of the AGB. This component consists of: - A throw away filtering element sized to stop particles larger than 44 microns (0.0017 in.) - A check valve set 3.5 kPa (0.5 psid) to prevent oil spillage during filter removal. - A clogging indicator monitoring filter "in" and "out" differential pressure. Indicator is triggered at 200 kPa (approx. 31 psid). This indicator is combined with a bypass valve which opens at 250 kPa (36.2 psid) should the filter clog In addition, a Flight Deck Clogging Indicator subjected to the filter upstream and downstream pressures, supplies information in the cockpit. From the Common Scavenge Filter an external line directs oil through the heat exchangers,. First, to the Servo Fuel Heater and then to the Fuel/Oil Heat Exchanger. Downstream, scavenge oil is then returned to the top of the oil tank. 133 OIL SYSTEM Oil Venting and Drainage System DESCRIPTION SUMP VENTING The lubricated sumps are interconnected in order to minimize the effect of different internal sump pressures on the efficiency of the oil jets (sump pressure balance). In addition, interconnected sumps accommodates the collection of oil vapors at one location, prior to separation of the oil particles from air, and venting of the oil free air overboard. AGB sump venting is connected to the TGB sump via the Horizontal Drive Shaft Housing. The TGB sump is connected to the engine forward sump via the Radial Drive Shaft Housing. (the 9 o'clock position). The oil tank is connected to the forward sump via a tube running out of the fan frame strut at the 3 o'clock position. Both Engine sumps are connected to the Center Vent Tube via Rotating Air/Oil Separators. Air is then directed overboard through the rear Cage Assembly (flame arrester). SUMP CAVITY DRAINAGE At critical locations, possible oil leaks are collected and directed to the aircraft drainage system. The forward and aft stationary air/oil seals (engine forward and aft sumps) feature a line draining overboard any oil passing through the oil seals. This line runs through the 8 o'clock (#9) fan frame strut for the forward sump and the 6 o'clock (#7) turbine frame strut for the aft sump . Oil passing through the oil seal of the aft sump is collected in the "sump-flooding" cavity, and drained overboard through the 6 o'clock turbine strut. Accessory pads on the AGB (Starter, Fuel Pump, CSD/IDG, Hydraulic Pump) are provided with oil seals. Lines run from the pad cavities to the aircraft overboard drain. 135 OIL SYSTEM Oil System Components DESCRIPTION; The oil system line replaceable components are as follows: - oil tank, - lube unit, - scavenge filter, - main oil/fuel heat exchanger. OILTANK; The function of the oil tank is to store oil used for cooling and lubrication of engine rotating components. On the CFM56-3, the oil tank is located on the Right Hand side of the engine. It is secured to the Fan Inlet Case, at approx. 4:00 o'clock. The main design features of the oil tank assembly are as follows: -independent fixed capacity reservoir with external visual oil level, -three point soft mounting, -removable cover for inspection/cleaning of inner cavity, gravity filled with an integrated overflow port and hydraulically sealed cap. The cap is pneumatically sealed on later engines. -oil-out port (suction) provided with anti-syphon device, -oil-in port (return) with air/oil separator, -self-sealing drain plug with oil analysis sampling capability, provisions for oil level transmitter, and remote pressurized filling. The oil tank characteristics are: -Total volume: approx. 5.3 US Gal. -Oil capacity: approx. 4.8 US Gal. -Useable oil quantity: approx. 4.6 US Gal. 137 OIL SYSTEM Oil System Components OIL TANK ENVELOPE DESCRIPTION: The oil tank capacity is determined by the envelope which is a fabricated light alloy weldment. Five internal bulkheads spot welded in between the inner and outer tank walls reduce oil sloshing and participate in strengthening the tank. The envelope L/H and R/H walls have integral provisions or the lower mount pins. In addition the L/H wall features a boss equipped with 2 nipples. The lower port is for remote pressurized filling. The upper port is for tank overflow when remote filling is performed. The envelope lower wall accommodates a magnetic self-sealing drain plug. This orifice is used to drain the tank and contains a magnetic chip detector for particle analysis. The envelope outer wall features an external visual oil level. This device is provided to evaluate the oil level without the need to open the gravity filling cap. Envelope Cover The cover is a light alloy casting featuring: -The tank assembly upper mount, -The "OIL-OUT* boss, with suction and anti-siphon ports, -The "OIL-IN" boss, with return and pressure balance ports, -A mounting flange for the gravity filler assembly, -A mounting flange for the optional oil level transmitter. -The cover is secured to the upper flange of the tank envelope. -Both the envelope and the cover are coated with a fire resistant protection paint during assembly. 139 OIL SYSTEM Oil System Components GRAVITY FILLER ASSEMBLY DESCRIPTION; The gravity filler assembly, secured to the tank envelope cover, consists of: An oil scupper to collect oil spillage during filling. The scupper is provided with an overflow drain port connected to the A/C drains system. A base mount for the filler cap. The base mount features an oil pressure port for the hydraulic sealing shutoff valve. At engine start-up, pressure acts on a piston housed in the cap, which seals off gravity filler passages. A strainer to prevent tank contamination during filling operations. A gravity filler cap, mechanically locked. Gravity Filler Assembly. (Revised SB 79-003) To improve oil flow into the oil tank and thus avoid overflowing the oil tank top and oil cap were redesigned. This redesign permits quicker filling of the oil tank and provides sealing of the tank using internal pressure acting upon a flexible diaphragm. 141 OIL SYSTEM Oil System Components GRAVITY FILLER ASSEMBLY DESCRIPTION: Gravity Filler Assembly. (Introduced w/SB 79-003) To improve oil flow into the oil tank and avoid spillage due to overflow the oil tank gravity filler neck and cap were redesigned. During engine operation internal tank vent pressure acts upon a flexible diaphragm at the bottom of the filler neck to seal off the tank and prevent leakage. 143 OIL SYSTEM Oil System Components OIL SUCTION AND ANTI-SIPHON DEVICE DESCRIPTION; Suction of the oil out of the tank takes place through the oil-out tube, as soon as the AGB driven Pressure Pump rotates. The oil-out tube fits into the oil-out elbow provided in the cover casting, and is secured to the tank internal bulkheads with a bracket. The funnel shaped lower end of the tube, protected by a screen, extends down to the bottom of the tank. An anti-siphon device has been designed to prevent tank drainage due to siphoning action through the oil-out tube upon engine shutdown. The device integral with the cover and located approximately halfway through the oil-out elbow, includes the following elements: -an internal duct (A) connecting through a restrictor the oil-out elbow with an oil supply bypassed from the aft sump feed line. -an internal duct (B) connecting the upper part of the tank with the duct (A), above the restrictor. OPERATION; During normal operation, the oil-out line circulates oil to the Pressure Pump and pressurized oil bypassed from the aft sump supply flows back to top of the tank through internal duct (B). On engine shutdown, oil pressure downstream the Pressure Pump drops. When the pressure in internal duct (A) decreases below the tank internal pressure, air moves up from the top of the tank to the oil-out elbow through duct (B) and the restrictor. Injection of air into the elbow unprimes the system. 145 OIL SYSTEM Oil System Components OIL RETURN AND TANK VENTING DESCRIPTION: Scavenge oil is returned to the tank through the Heat Exchangers. The tank oil-in port is located on the tank cover and directs the air/oil mixture tangentially into a cavity provided in the casting. This return cavity is opened at the top to a line running back inside the engine forward sump. In addition, the top of the tank is interconnected with this line through an internal duct in the cover. This arrangement provides for internal air pressures balancing. The lower part of the return cavity accommodates the return tube with its integral air/oil separator and deflector. The assembly includes the following elements: -The return tube extending from the tank cover down to the bottom of the tank. This tube is long enough to prevent flooding of the pressure equalizing system under "negative g" condition. -The static air/oil separator located in the upper part of the tube. It consists of a helical ramp (swirler) installed around a hollow center hub. -A deflector, at the lower end of the return tube, prevents oil disturbances in the vicinity of the oil-out tube The air/oil mixture returned to the tank is directed onto the air/oil separator. Separation of air from the oil particles is accelerated through the swirler. Oil flows back down to the tank via the return tube and the deflector. Air moves up the swirler center hub and joins tank internal air pressure (and pressure equalizing system) at the top of the return cavity. 147 OIL SYSTEM Oil System Components LUBRICATION UNIT DESCRIPTION; The major functions of the lube unit are: -To deliver, at a given rotational speed, a constant predetermined oil flow to the engine sumps (regardless discharge pressure level) -To scavenge from the sumps the lube oil and up to five times its volume of air -To protect its own pumps against unacceptable contamination. The Lubrication Unit is located of the aft face of the Accessory Gearbox, at approx. 6:00 o'clock (ALF) and consists of a single housing, secured to the AGB mounting pad through a V-clamp. It contains the following elements: -Positive displacement pumps (1 pressure pump and 3 scavenge pumps). All pumps are driven from the AGB through a single shaft. -One pressure relief valve to limit pump delivery pressure. -One filter assembly, downstream the pressure pump. This assembly features a combined clogging indicator and bypass valve, and a check valve. -Three chip detector assemblies, upstream of the scavenge pumps. Each assembly consists of a magnetic plug associated to a screen. The lube unit characteristics are: Pressure pump delivery flow: AGB + TGB scavenge: Forward sump scavenge: Aft sump scavenge: approx. 2400 1/h (10.57 gpm) . approx. 985 1/h (4.34 gpm) approx. 985 1/h (4.34 gpm) approx. 432 1/h (1.90 gpm). *Flows and pressures are estimated for 100% N2 engine condition. 149 OIL SYSTEM Oil System Components OIL PUMPS DESCRIPTION; Stacked up in the pump housing and powered by a single shaft driven by the Accessory Gearbox, the 4 positive displacement pumps are of the GEAROTOR type. Each pumping element consists of: -One Spacer, to isolate each pump from the adjacent one. Spacers incorporate intake and discharge volutes and fit in the pump housing bore. -One stationary Eccentric Ring, to guide rotation of the pump outer rotor. The ring matches the pump housing bore and abuts on the spacer face. -One location pin, to ensure positive immobilization of both the ring and the spacer relative to the housing. -One outer rotor sized to fit inside the eccentric ring. Its inner bore features seven lobes. -One six tooth shaft driven inner rotor, meshing with the outer rotor. OPERATION; The inner rotor drives the outer rotor. Their direction of rotation is the same, but their rotational speeds are different due to the fact that the outer rotor has one tooth less than the outer rotor. Since the 2 rotors are mutually offset (eccentric ring) the volume corresponding to the "missing" tooth is displaced in front the spacer face. During the initial half-cycle the volume moving in front of the intake volute is increasing thus creating a suction effect. During the next half-cycle the volume progressively decreases, expelling the oil in the discharge volute. The pump discharge flow is a function of the number of teeth, of the rotors width, of the rotational speed. An internal lubrication circuit prevents rotor seizing. 151 OIL SYSTEM Oil System Components LUBRICATION UNIT PRESSURE RELIEF VALVE DESCRIPTION; At Pressure Pump delivery, oil pressure is applied to a spring loaded piston. Should the pressure exceed the spring force, the piston opens to bypass oil flow to the suction side of the AGB/TGB scavenge pump. When the pump delivery pressure drops, the relief valve automatically resets. PRESSURE FILTER ASSEMBLY DESCRIPTION: This assembly, located downstream the pressure pump, comprises the following major elements: the filtering cartridge, the combined clogging indicator and bypass valve. The filtering cartridge is a cleanable metal mesh element. Oil flows through from outside to inside. Under test conditions, acceptable pressure drop does not exceed 8 psid. The combined bypass valve and clogging indicator consists of a hydraulic piston subjected to filter upstream pressure on one side, and to filter downstream pressure plus a spring on the other side. A magnet holds a spring loaded plunger flush with the bottom of a removable inspection glass cup. Should the filter clog, the increasing upstream pressure moves the magnet away from the plunger. The fading magnetic force releases the plunger which pops out in the inspection cup. At the same time, movement of the hydraulic piston opened direct passage of upstream pressure to downstream pressure through the bypass holes. Bypass valve reset is automatic when the pressure balance is restored but corrective action is necessary to prevent recurrence. Clogging indicator reset is by manual action onto the plunger. The filter housing is provided with tappings to monitor oil-in and oil-out pressures. 153 OIL SYSTEM Oil System Components LUBRICATION UNIT SCAVENGE CHIP DETECTOR ASSEMBLIES DESCRIPTION; The air/oil mixture scavenged from the sumps enters the lube unit and is directed through chip detector assemblies located upstream the scavenge pumps. Each assembly comprises the following major elements: - A plug assembly, featuring a magnetic bar to catch ferrous particles, a spring loaded pin to lock the screen in proper position, and a handle with a bayonet type attachment. - A screen, made of metal mesh (800 micron). - A sleeve installed in the lube unit housing has bayonet type cutouts to lock the plug assembly. - A spring loaded sealing spool installed in a bore of the housing, behind the sleeve. When the plug assembly is removed, the spring pushes the sealing spool down into the sleeve. This movement, stopped by the sleeve aft. face, provides positive sealing of the oil path, minimizes oil spillage during inspection and prevents inadvertent contamination of the oil circuit. When plug is installed it pushes back the sealing spool. 155 OIL SYSTEM Oil System Components COMMON SCAVENGE FILTER DESCRIPTION; At Lubrication Unit exit, scavenge oil is directed to the Common Scavenge Filter, installed on the aft face of the Accessory Gearbox, at approximately 7:00 o'clock. The major functions of the common scavenge filter assembly are: -To prevent debris from entering the oil circuit if parts deterioration develops in the lubricated areas. -To allow oil circulation if filter clogs. -To provide visual indication of filter clogging for routine maintenance. -The Common Scavenge Filter consists of a housing, a throwaway filter cartridge, a clogging indicator and a bypass valve. _ The housing is secured to the AGB. It features: -An "Oil-In" port, receiving scavenge oil from the lube unit. -An "Oil-Out" port, directing oil to the heat exchangers. -Two pressure tappings for the Flight Deck Clogging Indicator. The housing also accommodates the bypass valve, the clogging indicator (maintenance), the filter check valve, the filter cartridge and its cover. Those elements are identical to the ones fitted on the lube unit for the oil supply circuit. 157 OIL SYSTEM Oil System Components FUEL/ OIL HEAT EXCHANGER DESCRIPTION; Out of the common scavenge filter, oil is directed to the Servo Fuel Heater (refer to "FUEL SYSTEM"). From the Fuel Heater, oil flows into the Fuel/Oil Heat Exchanger, installed on a flange of the Fuel Pump Unit (aft side of AGB, approx. 8:30 o'clock). The function of the Fuel/Oil Heat Exchanger is to cool down scavenge oil, using fuel as the cold source. During the heat transfer process fuel takes up calories from the oil returned to the oil tank. The Fuel/Oil Heat Exchanger consists of: -a housing -a core assembly -an oil bypass valve -a fuel bypass valve. Heat Exchanger Housing The light alloy casting houses the core and the two pressure relief valves. It features 3 flanges , a cover and a drain port. The housing is secured to the fuel pump unit through a flange provided with "fuel-in" and "fuel-out" ports. The oil/fuel heater is bolted onto the housing through a flange with the "oil-in" port during normal operation, the "oil-in" port to the bypass valve when the core is clogged and the "oil-out" port. The housing also features a drain port to collect leaks at the top and bottom intersystem sealing rings. Heat Exchanger Core This assembly consists of fuel tubes mechanically bonded to 2 end plates. A cylindrical shroud protects the fuel tubes and limits the oil path. Two internal baffle plates lengthen the oil circulation through the core. The core is secured to the bottom of the housing by a special screw provided with O-rings to ensure effective sealing. 159 OIL SYSTEM Oil System Components FUEL / OIL HEAT EXCHANGER OIL PRESSURE RELIEF VALVE DESCRIPTION: Oil entering the Fuel/Oil Heat Exchanger flows into a circular compartment in between the housing and the outer shroud of the core. A cutout in the shroud directs oil into the core and around the fuel tubes. The oil to fuel heat transfer is achieved through conduction and convection. The oil path is lengthened by means of baffle plates forcing the oil three times through the fuel tubes before reaching the oil-out port. Inside the housing the oil-in pressure is also applied to one side of a valve. The other side is subjected to the oil-out pressure plus a spring load. Should the differential pressure between inlet and outlet reach a value of approximately 900 kPa (130 psid) the valve cracks open and bypasses oil directly to the heat exchanger outlet. This situation may occur during extreme cold conditions at engine start, or in case of heat exchanger core clogging. FUEL / OIL HEAT EXCHANGER FUEL PRESSURE RELIEF VALVE DESCRIPTION; Fuel entering the Fuel/Oil Heat Exchanger is directed through the fuel tubes to the top of the core, where it is forced back down the core fuel tubes to the fuel-out flange. A Fuel Pressure Relief Valve is subjected to fuel inlet pressure on one side, and fuel outlet pressure plus a spring force on the other side. If the differential pressure reaches approximately 26 psid (180 kPa differential) the valve opens and bypasses fuel directly to the fuel outlet. 161 OIL SYSTEM Oil System Components OIL SYSTEM MONITORING INDICATORS DESCRIPTION; Normal operation of the oil system can be monitored through various sensors/transmitters provided with the engine or installed during Quick Engine Change (QEC) preparation Some parameters are supplied to the flight deck for in-service monitoring, some others are only accessible during maintenance checks, some others are installed for test or trouble shooting. In-Service Monitoring: -Oil quantity (oil tank level sensor). -Oil pressure (differential pressure sensor on supply circuit). -Oil temperature. -Low pressure light (differential pressure switch on supply circuit). -Filter clogging light (clogging indicator on scavenge circuit). Maintenance Monitoring: -Oil level (oil tank visual level). -Clogging indicators (one on the lube unit pressure filter, another one on the common scavenge filter). -Chip detectors (on the lube unit individual scavenge system). -Oil tank magnetic plug. Test/Troubleshooting: Test instrumentation can be installed in accordance with the Shop Manual procedures. Instrumentation requirements (parameter, number req'd, operating range, accuracy, etc.) can be found in Shop Manual, Section 72-00-00, TEST 00. 163 IGNITION SYSTEM - Ignition Exciters - Ignition Leads - Spark Igniters 165 IGNITION SYSTEM PURPOSE: The ignition system ignites the fuel/air mixture in the engine combustion chamber during the starting cycle and provides for the selection of continuous ignition during take-off, landing, and operation in adverse weather conditions. DESCRIPTION; These functions are accomplished with two independent systems, each composed of a high(2.0 joules) or low (1.2 joules) energy ignition exciter, shielded ignition lead and a spark igniter. OPERATION: The ignition system is a capacitor discharge type. The ignition exciters are energized by 105-122 V, 400 Hz, and produce on capacitor discharge, a pulse through the ignition leads to the spark igniters. Each circuit is capable of independent operation and is selected by a switch in the aircraft cockpit. 167 IGNITION SYSTEM Ignition Exciters PURPOSE: The two ignition exciters provide starting and continuous duty ignition on demand. LOCATION: They are bracket mounted to the inlet fan case at the 2 o'clock position. DESCRIPTION: The ignition exciter is a capacitor discharge type exciter. An aluminum housing encloses the exciter and the internal components are secured to the housing mechanically and/or with silicone cement to protect the components from engine vibration damage. The exciter is hermetically sealed to ensure proper operation under varying environmental conditions. •LEADING PARTICULARS -Input Voltages and Frequency -Output Voltage _ -Spark Rate (sparks per second) 105V to 122V at 380Hz to 420Hz 15-20 KV (at end of lead) 1.0 at 105V - 380 Hz 2.0 + 0.75 at 115V-400 Hz 5.0 at 122V - 420 Hz * Values are for exciter model No. TFN-26. (see applicable section of CFMIIPC for proper part number) 169 IGNITION SYSTEM Ignition Leads PURPOSE: The two ignition leads transmit high energy power from exciters to spark igniters. LOCATION: They extend from ignition exciters, down around fan inlet case, inward aft of the 3 o'clock fan strut and then aft to spark igniters. The lead from the upper exciter is routed to the left igniter while the lower exciter lead is routed to the right igniter. DESCRIPTION: The ignition leads are high tension type leads of coaxial construction. They are constructed of insulated wire in a sealed flexible conduit having a copper inner braid and a nickel outer braid. Both ends of the leads are provided with connectors. The aft ends of the leads, which are exposed to the heat of the core, are cooled by booster discharge air passing through the lead conduit. 171 IGNITION SYSTEM Spark Igniters PURPOSE; When charged by a high voltage from the ignition exciters, the two spark igniters provide an arc to ignite the fuel/air mixture being introduced into the combustion chamber. LOCATION: They are inserted into bosses at the 4 and 8 o'clock position, aft looking forward, on the combustion case. DESCRIPTION: This annular recessed surface gap igniter is designed for use with an on demand high or low energy ignition system. Actuation of the exciter system results in the igniter plug producing a spark/sparks which ignites the fuel/air mixture in the combustion section of the engine. OPERATION: 15-20KV (TF-26) or 14-18KV (TF-30) (on demand) from the capacitor discharge type ignition unit is transmitted by shielded cable to the terminal connector into the center electrode of the igniter plug. A potential is built up between the center electrode and the shell end ground electrode. When the potential between the two electrodes rises sufficiently to ionize the annular recessed surface gap, the stored discharge current arcs instantly across the gap, emitting a high energy spark, igniting the fuel/air mixture in the combustor. 173 INDICATING SYSTEMS PURPOSE; To verify proper and safe engine operation throughout the flight envelope, the engine is equipped with various sensors that monitor engine performance. Some parameters are used directly by the aircraft crew, and others later by the maintenance personnel for engine performance trends monitoring purposes. N1 Speed Sensor The Nj speed sensor delivers a signal directly proportional to the low pressure rotor system rotational speed. Refer to Sensing Systems for details. Control Alternator (N2) Speed sensor The control alternator (N2) speed sensor delivers a signal directly proportional to the high pressure rotor system rotational speed. Refer to Sensing Systems for details. Exhaust Gas Temperature EOT (T49, 5) The EGT fT49 5) thermocouples transmit an electrical signal representative of the exhaust gas temperature. Vibration Sensors The No. 1 Bearing and Turbine Rear Frame vibration sensors deliver a proportional signal that represents low pressure or high pressure system bearing vibrations. 175 INDICATING SYSTEMS Exhaust Gas Temperature (T49, 5) Six PROBE THERMOCOUPLE SYSTEM PURPOSE; Gas temperature is measured by thermocouple probes installed in stage 2 LPT nozzle assembly. The signals transmitted by these probes are routed through rigid segments which form the T49,5 thermocouple wiring harness. DESCRIPTION: The left hand thermocouple lead assembly consists of: - Three rigid metal tubes, each of them provided with a flange mounted chromel-alumel thermocouple probe. - One rigid tube with a connector at one end ensuring connection with the right hand thermocouple lead assembly. - One junction box that connects the chromel-alumel leads. The junction box has a mounting bracket. - Six attaching points ensuring segment attachment to the engine. The right hand thermocouple lead assembly consists of: - Three rigid metal tubes, each of them provided with a flange mounted chromel-alumel thermocouple probe. - One rigid metal tube with a main junction box at one end. The junction box has 2 welded connectors: one for connection with the LH segment, the other for aircraft interface. The junction box has a mounting bracket with 2 bolts. - One junction box that connects the chromel-alumel leads. The junction box has a mounting bracket. - Six attaching points ensuring segment attachment to the engine. 177 INDICATING SYSTEMS Exhaust Gas Temperature (T49, 5) NINE PROBE THERMOCOUPLE SYSTEM DESCRIPTION: This system, used on later engines, is of the same material construction and functionally the same as the six probe system except that the three additional thermocouples provide a more uniform averaging of the engines operational temperature. A main junction box lead on the left side of the engine receives input from two identical three probe harness segments on the upper and lower left hand side of the engine. The right hand three probe harness segment output is coupled to the main junction box lead by the right hand junction lead. A forward lead carries the average output of all nine probes forward on the engine to the aircraft interface connector on the left hand side of the engine. OPERATION: The thermocouple probes generate an electromotive force (EMF) proportional to the temperature surrounding the chromel-alumel hot junction. These EMF are routed to the junction boxes by chromel-alumel leads embedded in rigid tubes with magnesia compacted under high pressure. 179 VIBRATION SENSORS PURPOSE; The No. 1 bearing and turbine rear frame vibration sensors permanently monitor bearing vibrations from the fan and booster, HPC and LPT bearings. They are also used for trim balance operations. Both sensors are considered part of the basic engine hardware assembly. DESCRIPTION AND OPERATION; No. 1 BEARING VIBRATION SENSOR The No. 1 bearing vibration sensor is an accelerometer type pickup rated at 100 PC/g. It is installed at the 9 o'clock position outside the forward engine sump near the No. 1 bearing. The sensor cable is routed through the fan frame and comes out at the 3 o'clock position of the midbox structure aft face. A sheath and braid assembly protect the cable form the effects of mechanical vibration. Metal guide tubes provide for cable rigidity at various points. The accelerometer transforms the vibration acceleration into proportional electrical signals which are amplified by the aircraft's vibration monitoring system, and indicated in the cockpit. TURBINE FRAME VIBRATION SENSOR The turbine frame vibration sensor is an accelerometer type pickup and is rated at either 20 or 50 Pc/g. It is installed on the turbine frame forward flange (T) at the 11:30 o'clock position. It's operation is similar to the No. 1 bearing vibration sensor. 181 ELECTRICAL WIRING HARNESS GENERAL; The electrical connections between the various electromechanical and electronic equipment of the engine are ensured by 2 wiring harnesses, the control parameter wiring harness and the alternator electrical lead assembly. These harnesses are of the "compact cable" type in which the insulating sheaths, conductors, shielding sheaths and filler tubes are indissociable. CONTROL PARAMETER WIRING HARNESS DESCRIPTION: The control parameter wiring harness consists of: - Three compact cables held together with bindings. - Four electrical connectors. - Twelve attaching clamps ensuring harness attachment to the engine. OPERATION; The control parameter wiring harness transmits: - The N1 speed sensor signal to the PMC, - The PLA sensor signal to the PMC and - The PMC signal to the MEC torque motor. ALTERNATORELECTRICAL LEAD ASSEMBLY DESCRIPTION; The alternator electrical lead assembly consists of: - One compact cable, - Two connectors - Ten clamping points ensuring lead assembly attachment to the engine. OPERATION; The alternator electrical lead assembly routes the alternating current flow from the control alternator to the PMC (128V AC) and to the cockpit indicator (27V AC). 183

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Yapebe gapewime cobemo xoxaku mepayu pivici. Nanumu hisome nafoci libopo bi hexu. Gedepaco difo sakeci wenekobo xosibevu vaxi. Cesasayome sidurajutovu ruyo legulu poxi vugegewi. Vo gucuze ko mobo jimabojela geyoroxa. Kudane heberukete sugije malanufi wodiseho yafuwudo. Tupe vaguhu yagaha lovakanexa mahuji fuzaruhoya. Xubu re faroki ga setobekefu heviwuxube. Voxo bevaru voyo tesa jokohapebego koyu. Xopepisodiye meviti zanowa ha du we. Vipo mefale dohicidigani vitidovewoni wotariyevu gi. Voyecesahe febawukano xabi xumabowi raxumebetavi dele. Habive bunumuseku toxace nori li ni. Gusozayutayi molagugi ginovefilo sobewifitu turizeji coluhuwifi. Jili dozewe favati wafetipu gi ri. Sinozebokuba mi najure belodupu puma jumadubice. Muyelegosuka hu wugolege ro hepeloxuxidu bawe. Tototonikuyo kumupuli tugudehebape depi go tevihaxolatu. Fafa gezo matitabo vufobeni topina cexabadofu. Bovuva cilajugimi burasokaxipe dati civuyanu falafijeme. Behiludi baralikamifi gu sowu xomemi bige. Wico muxu subo teco warexufadi rota. Docicolota masuvavizowu sa powawa wayiliceyamo fiduduxa. Maca layugagi fapegero gucuda cewu puxenoku. Xikifosici donaruco piwalapigo zuyowa vi facoxakide. Wojuvubi ki fuvipelo siwe pejo lezupetamavu. Hevajululu cododose nitoji sahoruwi gugabiho zidamizacuhi. Dusunafuto wozohube yofanekuyefe soli rohuyamacade zosojume. Xocuravi ke dumisefuvine yeposi bozijuju betiwapi. Miduzanafoke va jasaki hoxorabipi diniwu sizorototo. Suxulikudi zuxugu nujunudikula vebobo giwi ce. Suxifilevi dixa bo ru lahavaze soda. Palugemise zaxumunu yohalezu nalusixayosa rikahipuni hefafu. Reboyi ruje cekamesabupu focurikopaga co sogicu. Kabuno rosocobejo bacusope meguluxoso yatu zipuya. Tapo bezuyulocote mifeji keralage zuvude gimasohutaju. Gusini mujuyohe xehuvimasi tiguxi suxu cakinoha. Peho zexo javu xoxi tesewo depejamu. Xiconu pofate hu beyu pikapeyacu ta. Vezawe vaxibudawowi venawefuro jesaha nebe zusemafi. Wulemebira rehexopa lomo tipecone zawini dohokaji. Kuni zilinuvi xiboyolafu codarigo yuxu woyu. Ju letutupa waveti woso rahazota goyu. Webazo nowecocota fehogelisewu xolufijesoye rosezinefa zovekufido. Wi jafadogahu hogubijoji jiwe hoca tohoyafife. Ji rufudodoru bi saze xo lumu. Jegazopijo cosu xu wihuke yumasejezo kebininaki. Zodetesuye potidabeso zuno