B737 NG CBT - ENGINES

COURSE OUTLINES

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COURSE START

1-The material contained in this training program is based on the information obtained from current state, local and company regulations and it is to be used for training purposes only. At the time of designing this program contained then current information. In the event of conflict between data provided herein and that in publications issued by the authority, the authority shall take precedence.

ENGINES

2-In this program, we will look at the airplane engines, its sub-systems and operations. Here is the chapter outline: * Introduction * Engine fuel system * Electronic engine control * Engine oil system * Engine indications and abnormal conditions * Engine ignition system * Engine starting system * Engine starting * Reverse thrust * Reverse thrust abnormal conditions

INTRODUCTION

3-The main function of engines is to supply thrust to the airplane. The engines also supply electrical power, hydraulic power and bleed air to related systems.

4-The Boeing 737 is powered by two CFM56–7 engines

5-The engine is an axial–flow turbofan with a dual–rotor. These two rotors are known as the N1 rotor and the N2 rotor.

6-The N2 rotor consists of a high–pressure compressor which is driven by a high–pressure turbine through a hollow shaft.

7-The N1 rotor consists of a fan and a low-pressure compressor which are driven by a low-pressure turbine through a shaft that goes inside the hollow N2 shaft.

8-The N1 and N2 rotors are mechanically independent and free to rotate at their own efficient speeds. However, the N1 rotor speed is lower than that of the N2 rotor.

9-An accessory gearbox on the left side of each engine is driven by the N2 rotor.

10-The accessory gearbox drives the integrated drive generator, oil pumps, hydraulic pump and fuel pumps.

11-Engine produces thrust by accelerating ambient air as it passes through the engine.

12-Some air goes through the compressor for combustion. The hot gases then exit through the exhaust to produce thrust.

13-The remaining part of air flows through the duct around and outside of the core engine. This cold or bypass air produces most of the thrust as it exits through the engine exhaust.

14-Each engine has separate flight deck controls.

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15-Engine controls consist of a forward thrust lever, a reverse thrust lever and a start lever for each engine.

16-The forward thrust levers let you manually set the thrust.

17-The forward thrust levers can also be positioned automatically by the autothrottle to set the thrust.

18-Reverse thrust levers control engine reverse thrust.

19-A locking mechanism prevents the operation of the forward thrust lever and the reverse thrust lever at the same time. Thus, you cannot select reverse thrust unless the related forward thrust lever is at IDLE.

20-There are two start levers, one for each engine. You use the engine start lever during an engine start and to shut down the engine.

21-An electronic engine control or EEC monitors and regulates each engine. Now let’s take a look at various engine systems briefly.

ENGINE FUEL SYSTEM

22-The function of the engine fuel system is to supply metered fuel to the engine for combustion

23-The boosted fuel from the fuel tank flows through the fuel spar shutoff valve to a low pressure engine fuel pump. The low pressure fuel pump increases fuel pressure to let the heat exchangers be more efficient.

24-The fuel from the low pressure pump then enters the IDG oil cooler. The warm IDG oil heats the engine fuel and by this process the IDG oil is cooled. Heating the fuel prevents the formation of ice from the water, which may clog the fuel filter and other downstream components.

25-After passing through an engine oil/fuel heat exchanger, the fuel then goes to the fuel filter in the pump assembly. The fuel filter protects delicate components further downstream the system from any contamination.

26-If the fuel filter becomes clogged due to contamination, the fuel automatically bypasses the filter. The fuel FILTER BYPASS light illuminates on the fuel control panel before the fuel bypass occurs.

27-The engine driven high pressure fuel pump is the next component behind the fuel filter. It increases fuel pressure to a higher level for proper fuel vaporization in the combustion chamber.

28-The fuel from high pressure fuel pump flows into the hydro mechanical unit or HMU. With the electronic engine control, the HMU supplies metered fuel to the fuel nozzles. The excess fuel that is not needed for combustion returns to low pressure fuel pump.

29-The high pressure shutoff valve stops the metered fuel flow when it closes.

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30-Both the spar fuel shutoff valve and engine fuel shutoff valve close when either the start lever is in the CUTOFF position or the engine fire switch is out.

31-The SPAR VALVE CLOSED and ENGINE VALVE CLOSED light on the overhead panel shows the respective valve position. Refer to the fuel system section for more information.

32-The fuel leaving the high pressure shutoff valve goes to a fuel flow transmitter.

33-The fuel flow transmitter measures fuel flow and transmits this information to display unit for fuel flow and fuel used indication and to the flight management system.

34-From fuel flow transmitter, the fuel is then routed to the fuel manifold which distributes the fuel to individual fuel nozzles

ELECTRONIC ENGINE CONTROL (EEC)

35-Each engine has a digital electronic engine control or EEC which has full authority over engine control functions. Each EEC has two independent computers which are called channels A and B.

36-Each channel can control the engine. One channel is in active control while the other channel is in standby. If the active channel fails, the standby channel automatically takes over the engine control.

37-Each time the engine is started, the ECC alternates between active channel and standby channel. This change of control occurs if N2 was more than 76 percent during the previous engine run and both channels are valid.

38-The EEC receives a lot of data from many airplane systems and sensors to perform its functions.

39-The EEC performs the following major functions: engine thrust management, structural limit protection, engine idle operation, reverse thrust control and flight deck indication.

40-The EEC uses N1 speed to control engine thrust. It has two modes of thrust management based on available inputs: normal and alternate. These modes can be selected either automatically by the EEC or manually by the flight crew.

Eec normal mode

41-In the normal mode, the EEC calculates the commanded N1 speed based on the position of the thrust levers, ambient total pressure, ambient static pressure, ambient total air temperature and bleed air demand.

42-The EEC then compares the commanded N1 to the actual N1 and adjusts fuel flow to achieve the commanded N1.

43-The maximum rated thrust is available when the thrust lever is at the forward stop. The full rated takeoff thrust for the installed engine is set at a thrust lever position less than the forward stop. The fixed or assumed temperature derated takeoff thrust ratings are available at thrust lever positions less than full rated takeoff.

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44-When the EEC is in the normal mode, the white ON light is in view on the respective EEC switch.

45-If the ambient total pressure data, which lets the EEC to calculate Mach number, is not valid the EEC goes into the alternate mode.

Eec alternate mode

46-The EEC can operate in one of two alternate modes: soft alternate and hard alternate mode.

47-When the ambient total air pressure data is not available, the EEC automatically goes to the soft alternate mode.

Eec soft alternate mode

48-In the soft alternate mode, the EEC uses the last flight conditions to determine the engine parameters and makes sure the engine thrust does not have large changes.

49-However, if the outside air conditions change while the EEC is in the soft alternate mode, the engine thrust can be less than normal or thrust exceedances may occur.

50-If the ambient total pressure becomes valid within 15 seconds, the EEC reverts back to the normal mode and you do not see an indication of the soft alternate mode.

51-If the EEC stays in the soft alternate mode more than 15 seconds, the amber ALTERNATE light illuminates on the respective EEC switch while ON is still in view, and the MASTER CAUTION lights and the ENGINE system annunciator come on.

52-When the soft alternate mode is engaged, if the thrust lever is moved to the IDLE position, the EEC goes to the hard alternate mode

Eec hard alternate mode

53-In hard alternate mode, the EEC uses assumed outside air temperature for the highest thrust requirement to ensure the airplane will have enough thrust in all conditions. Thus the maximum thrust rating exceedances are possible during hot day conditions.

54-When the hard alternate mode is entered by moving the thrust lever to idle while in the soft alternate mode, the ALTENATE switch remains illuminated and the ON indication remains visible.

Eec manual control

55-You can manually control the EECs through the EEC switches on the ENGINE panel.

56-Both EEC switches are guarded. The white ON lights are visible to indicate the ECCs are operating in the normal mode. The switches should be in the ON position for preflight and during normal operations.

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57-You can manually set the EEC to hard alternate mode through EEC switch for that engine. There is no manual selection of soft alternate mode.

58-You can manually select the hard alternate mode when the ECC is in either normal mode or soft alternate mode. Let's see how you can set EEC to hard alternate mode, say for engine number 1.

59-Before you select the hard alternate mode, set the thrust levers to the mid position.

60-If the autothrottle is engaged, disengage it.

61-These two steps prevent the engines from exceeding the maximum thrust limit and permit the thrust levers to stay manually positioned.

62-Lift the engine number 1 EEC switch guard and push the switch.

63-The ON light disappears and the ALTERNATE light stays illuminated. The EEC is now in the hard alternate mode

64-If one EEC is in the normal mode and the other EEC is in the alternate mode, you must put the other engine EEC in the hard alternate mode to prevent thrust lever stagger.

Eec structural limit protection

65-To keep engine operation safe and satisfactory, the EEC provides N1 and N2 redline overspeed protection in both normal and alternate modes.

66-When the N1 or N2 speed goes near the redline, the related EEC decreases the fuel flow to the engine.

67-However, you must observe the EGT limit, because the EEC does not provide EGT redline exceedance protection.

Eec idle operation

68-Engines take several seconds to accelerate from idle speed to full power speed due to inertia of the rotors. This is called engine acceleration time.

69-On the ground, there is a tolerance for the engine acceleration time and the lowest idle speed can be used.

70-However during approach engine acceleration time must be kept to the minimum if the airplane has to perform a go-around. Thus, the highest idle speed is needed to minimize the time needed for the engine to reach full power.

71-EEC uses three different idle modes for different requirements of engine acceleration time: ground idle, flight idle and approach idle.

72-The EEC selects ground idle to satisfy idle speed requirements for ground operations

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73-The EEC selects flight idle for most phases of flight.

74-The EEC selects approach idle in flight when flaps are in landing configuration, or the engine anti–ice is ON for either engine, or the flap or anti–ice signals are not available to the EEC while the airplane is below 19000 feet.

75-The EEC maintains approach idle for 5 seconds after touchdown; then it shifts to ground idle.

Engine control light

76-When an EEC detects an engine fault that requires a maintenance action, the respective ENGINE CONTROL light on the ENGINE panel illuminates.

77-The light operates only when the airplane is on the ground and the engine is running.

78-Whenever either ENGINE CONTROL light comes on, the MASTER CAUTION lights and the ENGINE system annunciator also illuminate.

79-The airplane cannot dispatch with this light on.

ENGINE OIL SYSTEM

80-The engine oil system provides lubrication and cooling for the engine bearings and the accessory gearbox.

81-The oil system incorporates an oil tank which keeps sufficient oil for continuous supply to the oil distribution circuit.

82-An engine driven supply pump pressurizes the oil from the tank.

83-Oil from the pump goes to the supply oil filter which removes foreign particles from the oil.

84-The oil is then routed through oil temperature and oil pressure sensors to the engine for lubrication and cooling.

85-The oil temperature and oil pressure sensors transmit the oil temperature and pressure data to the engine display through the EEC.

86-The oil pressure sensor also lets the ECC activate the OIL PRESSURE alert light on the upper display unit when the oil pressure is less than the redline limit

87-The scavenge pump removes the oil that collects in the engine bearing compartments and gearbox sump.

88-The oil then goes to a scavenge oil filter which removes debris from the oil.

89-If the scavenge oil filter becomes clogged due to debris, oil automatically bypasses the filter. Before the oil bypass occurs, the OIL FILTER BYPASS light illuminates on the upper display unit.

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90-Before returning to the oil tank, the oil passes through the engine oil/fuel heat exchanger where the oil cools as it heats the fuel.

ENGINE INDICATIONS AND ABNORMAL CONDITIONS

91-Engine parameters are shown on two display units or DUs: the upper display unit and the lower display unit.

92-The upper display unit normally shows primary engine parameters.

93-If upper display unit fails, the engine indications automatically moves to the lower display unit in a compact engine display.

94-You can also use display select panel to manually select the primary engine indications to either the Captain's or First Officer's inboard display unit, or the lower display unit.

95-The lower display unit normally shows the secondary engine indications.

96-You can also use the display select panel and the ENGINE switch on the engine display control panel to manually select secondary engine indications, except for fuel flow, to either the Captain's or First Officer's inboard display unit. There is no automatic switching for a lower DU failure.

Primary engine indications

97-N1 and EGT are the primary engine indications shown on the upper display.

98-The N1 digital readout shows the engine low pressure rotor speed in % RPM. A pointer on a round dial also shows N1 speed. A shaded area follows this pointer. The digital readout, the box around the readout and the pointer are white when the N1 is in normal operating range.

99-The white N1 Command Sector arc on the outside of the dial, shows the momentary difference between actual N1 and the N1 value commanded by the thrust lever position.

100-For instance, when you move the thrust levers forward, the command sector appears shortly to indicate the difference between the commanded N1 and the actual N1. As the actual N1 reaches the commanded value, the sector disappears.

101-The N1 reference bug and N1 reference digital readout show the target N1.

102-The N1 reference bug and the N1 reference digital readout are controlled by the N1 SET selector on the center forward panel

103-The outer knob has four positions: BOTH, AUTO, 1 and 2.

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104-With the outer knob in the AUTO position, the FMC automatically sets both N1 reference bugs to the display active N1 limit for the autothrottle. The N1 reference readouts are blank or show dashes.

105-The BOTH, 1 and 2 positions let you manually set the target N1 by using the inner knob. Note that manual N1 setting has no effect on the autothrottle operation.

106-You use the BOTH position to set target N1 for both engines. When the outer knob is in the BOTH position, the N1 reference readouts on both displays are visible. If you turn and hold the inner knob, both of the N1 reference bugs move to the new position and the N1 reference readouts change respectively.

107-The outer knob positions 1 or 2 is used to set the target N1 for that respective engine. In this example, the outer knob is in the 1 position and the N1 reference readout is visible above only the number 1 N1 display. If you turn and hold the inner knob, the number 1 N1 reference bug moves to new position and the N1 reference readout changes respectively.

108-The N1 redline shows the maximum certified engine N1 speed.

109-When N1 exceeds the operating limit and goes above the N1 redline, the digital readout, the box around N1 digital readout, and the N1 pointer and the shaded area becomes red.

110-When the N1 drops below the redline, the indication goes back to the normal color. However, on the ground, after engine shutdown, the box around the digital display changes to red to indicate that an inflight N1 exceedance has occurred.

111-The exhaust gas temperature or EGT digital readout shows the exhaust gas temperature in degrees Celsius. A pointer on a round dial also shows EGT. The dial does not have a scale. A shaded area follows the pointer. The digital readout, the box around the readout and the pointer are white when the EGT is in normal operating range.

112-The EGT start limit redline indicates the maximum value for the EGT during ground engine starts until the N2 is approximately 59%. This redline does not show in flight.

113-The EGT redline shows the maximum takeoff EGT limit

114-The EGT amber band is the EGT caution range.

115-Continuous operation of an engine with EGT in this range could cause damage to the engine.

116-The EGT caution range shows as an arc between the maximum continuous limit and the EGT redline.

117-When the EGT exceeds the EGT maximum continuous limit, but is less than the EGT redline, the EGT digital readout, the box around the digital readout, and the pointer and the shaded area change to amber.

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118-During takeoff and go-around, the amber color change is inhibited for five minutes or until completion of takeoff, whichever comes first.

119-If one engine fails within the first five minutes of the color change inhibit, the inhibit will be extended to ten minutes for the operating engine.

120-When EGT goes above the EGT redline, the same indications change to red.

121-The fuel flow data is also displayed continuously on the upper display unit below the primary engine indications

122-The FUEL FLOW switch on the center forward panel lets you control the type of data that the digital readout show.

123-The switch is spring-loaded to the center RATE position. With the switch in RATE position, the digital readout shows rate of fuel flow to the engine.

124-When the switch is momentarily moved to the USED position, the quantity of fuel used since the last reset is indicated. After 10 seconds, the fuel used indication automatically goes back to the fuel rate indication.

125-The RESET position is used to set the fuel used display digital counter to zero.

126-When you momentarily move the switch to RESET, the readout first shows the fuel used, then decreases to zero and then displays to fuel flow rate.

Secondary engine indications

127-The secondary engine indications are the N2, fuel flow, oil pressure, oil temperature, oil quantity, and engine vibration.

128-The secondary engine indications are automatically displayed when the displays are initially powered, in flight when an engine start lever is moved to CUTOFF, in flight when an engine N2 speed is below idle and a secondary engine parameter is exceeded.

129-The N2 digital readout shows the engine high pressure rotor speed in % RPM. A pointer on a round dial also shows N2 speed. A shaded area follows this pointer. The digital readout, the box around the readout and the pointer are white when N2 is in normal operating range.

130-The N2 redline shows the maximum N2 operating speed

131-When N2 exceeds the operating limit, the digital readout, the box around the N2 digital readout, and the N2 pointer and the shaded area turn red.

132-When the N2 goes below redline, the indication goes back to the normal color. However, on the ground, after engine

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shutdown, the box around the digital display changes to red to indicate that an inflight N2 exceedance has occurred.

133-When the N2 speed decreases below a stabilized idle position of approximately 50% and the engine start lever is in the idle position, an amber ENGINE FAIL alert shows on the related EGT display.

134-If the N2 increases above stabilized idle or the start level is moved to the CUTOFF position or the engine fire switch is pulled, the ENGINE FAIL alert is removed.

135-If a crossbleed start is recommended for an inflight engine start, a magenta crossbleed indication appears above the N2 display.

136-An oil pressure digital readout and a pointer indicates each engine oil pressure in psi. The indications are white when oil pressure is in normal operating range.

137-The red index marker indicates oil pressure operating limit.

138-The oil indicator also has an amber index marker which shows the caution limit for oil pressure.

139-The position of amber marker is variable depending on the N2 speed. As the N2 increases from 65%, the marker moves upward.

140-When N2 is less than 65%, the amber marker index does not show.

141-The oil temperature in each engine is indicated by an oil temperature digital readout and a pointer in degrees Celsius. The indications are white when the oil temperature is in normal operating range.

142-The amber index marker indicates the caution range and the red marker shows operating limit for the oil temperature.

143-When the oil temperature enters the caution range, the indications change to amber.

144-If the oil temperature exceeds the operating limit, the display changes to red.

145-The oil quantity digital readout shows usable oil quantity in quarts. In some B737 models, usable oil quantity is displayed in percent full.

146-The low oil quantity is indicated by a LO message.

147-During engine start, takeoff and climb out, the indicated oil quantity may decrease significantly. This does not affect the engine operation and the correct oil quantity should be indicated during level flight

148-The vibration level for each engine is indicated by a vibration digital readout and a pointer.

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149-The airborne vibration monitoring system continuously calculates the N1 and the N2 vibration of for each engine. The highest vibration level is indicated on the display.

150-High vibration, which is above 4.0 units, is indicated by reverse video.

Abnormal conditions

151-Now let’s take a look at some abnormal conditions, associated indications and alerts provided by the engine indicating system. Four abnormal conditions will be discussed: low oil pressure, high oil temperature, oil filter bypass and high vibration.

Low oil pressure

152-If the oil pressure drops between the amber limit and the redline limit, the digital display, the box around the digital display and pointer change to amber. This is the caution range.

153-If the oil pressure is in the caution range with takeoff power set, do not takeoff. Oil pressure in the caution range is not normal at high thrust settings.

154-When the oil pressure goes to the redline limit or below, the indications become red.

155-As the oil pressure display and pointer turn red, the amber LOW OIL PRESSURE alert shows on the upper display. The alert flashes for 10 seconds then remains on steady.

156-The oil pressure is now too low for continued engine operation and the affected engine must be shut down.

157-Note that the LOW OIL PRESSURE flash mode is inhibited for takeoff and landings. When inhibited, the alert illuminates steady.

High oil temperature

158-When the oil temperature enters the caution range, the oil temperature indications change to amber.

159-When the oil temperature is in the caution range, disengage the autothrottle, if it is engaged and retard the affected engine thrust lever slowly until the oil temperature goes below the caution range or the thrust lever is at idle. With the oil temperature below the caution range, run the affected engine at reduced thrust setting to keep oil temperature within the operating range.

160-If the oil temperature remains in the caution range, you can operate the engine for 45 minutes in this condition.

161-If oil temperature is still in the caution range 45 minutes after the thrust reduction, you must shut down the affected engine.

162-If the oil temperature exceeds the operating limit, the display changes to red.

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163-When the oil temperature is at or above the redline limit, you must shutdown the affected engine

Oil filter bypass

164-The engine indication system also provides an OIL FILTER BYPASS alert for the flight crew.

165-As you may recall, when the oil is about to bypass the oil scavenge filter due to filter contamination, the OIL FILTER BYPASS alert illuminates on the upper display unit. The alert flashes for 10 seconds then remains on steady.

166-When the OIL FILTER BYPASS alert illuminates, disengage the autothrottle, if it is engaged and retard the affected engine thrust lever slowly until the oil filter bypass alert extinguishes or the thrust lever is at idle. If the OIL FILTER BAYPASS light goes out, run the affected engine at reduced thrust to keep the alert extinguished.

167-If the OIL FILTER BYPASS alert does not extinguish after a thrust reduction you must shut down the affected engine.

168-Note that the OIL FILTER BYPASS flash mode is inhibited for takeoff and landings. When inhibited, the alert illuminates steadily.

High vibration

169-With no icing conditions, if the vibration level goes beyond 4.0 units, disengage the autothrottle, if it is engaged and retard the affected engine thrust lever until the vibration level is below 4.0 units or the thrust lever is at idle.

170-If the vibration level does not decrease when the thrust lever is retarded, check other engine indications on the affected engine. If other engine indications are normal, run the engine at reduced thrust.

Other indications and thrust mode display

171-The upper display unit also incorporates some other indications and thrust mode display.

172-Total air temperature is indicated in degrees Celsius at the upper strip.

173-Assumed temperature that is selected on the CDU TAKEOFF REFERANCE page for the reduced thrust takeoff N1 is also displayed in degrees Celsius at the upper strip.

174-With the N1 set selector in the AUTO position, the thrust mode display or annunciator shows the active N1 limit reference mode which is normally calculated by the FMC.

175-When the FMC N1 limit calculations, to the autothrottle, become invalid, the autothrottle computer calculates a degraded N1 limit for both engines. The autothrottle limit indication illuminates on the thrust mode display.

176-These are the thrust mode display annunciations: takeoff, reduced thrust takeoff, climb, reduced thrust climb, cruise, go-around, continuous and no FMC computed thrust limit.

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177-In some configurations, you see these thrust mode display annunciations.

Compact engine display

178-The primary and secondary engine indications are combined on the same display in a compact format.

179-There is no change in the N1 and EGT indications. All other indications are displayed with digital readouts only.

180-A rectangular box outline appears around the secondary engine parameters if limits are exceeded.

181-The outline has thick lines and blinks for 10 seconds. After 10 seconds, the lines are thinner and do not blink.

182-The color of the outline matches the color of the exceedance. White, amber or red. In this example, high vibration is indicated and the outline is white.

ENGINE IGNITION SYSTEM

183-The ignition system provides electrical sparks in the combustion chamber for combustion.

184-For safety reasons, each engine has two independent ignition systems with its own components and power supply.

185-The respective AC transfer bus supplies power to the left igniter. The AC standby bus supplies power to the right igniter.

186-The flight deck controls of the ignition system consist of the: start levers, the ignition selector switch and engine start switches on the ENGINE START panel. The engine start switch is discussed in the engine starting system section.

187-The ignition selector switch on the ENGINE START panel lets you select the left or right igniters on both engines.

188-The ignition left position selects the left igniter for use on two engines.

189-The ignition right position selects the right igniter for use on both engines.

190-When the switch is set to the BOTH position, both left and right igniters are selected for use on both engines.

191-The start levers allow you to control the ignition supply and fuel supply through the electric engine control.

192-Each start lever has two positions: CUTOFF and IDLE.

193-When the start lever is in the CUTOFF position, the ignition system is de-energized, and the engine fuel high pressure shutoff valve and the spar fuel shutoff valve are closed.

194-When the start lever is moved to the IDLE detent position, the ignition systems are energized. The spar fuel shutoff valve and the engine fuel high pressure shutoff valve open electrically via engine electronic control.

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ENGINE STARTING SYSTEM

195-The purpose of engine starting system is to provide initial torque and rotation speed high enough to start the combustion cycle.

196-The starting system on each engine incorporates a starter and a start valve.

197-The starter uses pneumatic power to turn the engine's N2 rotor through the engine accessory gearbox during a start or motor procedure.

198-Pneumatic power comes from the auxiliary power unit or a ground air cart or the opposite engine.

199-The start valve is electrically controlled and pneumatically operated. It controls pneumatic power to the starter.

200-Controls for the engine start are on the ENGINE START panel. Each ENGINE START switch has four positions.

201-When the engine start switch is in the OFF position, the igniters normally do not operate. However, if the EEC detects an imminent engine flameout condition, it turns on both igniters automatically.

202-When the start switch is moved to the ground position, the start valve opens and the pneumatic starter turns the engine.

203-The START VALVE OPEN light illuminates steady on the engine display to show the start valve is open and air is supplied to the starter.

204-For ground starts, the selected igniter arms to supply ignition when engine start lever is set to IDLE

205-For inflight starts, both igniters arm to supply ignition when the engine start lever is set to IDLE

206-At starter cutout, the switch automatically moves to the OFF position

207-With the switch in the continuous position, the selected igniters turn on and operate continuously.

208-With the switch in the flight position, both igniters turn on and operate continuously regardless of ignition selector switch position.

209-The START VALVE OPEN alerts on the engine display to indicate the position of the respective start valve.

210-As we have seen, the alert illuminates steady when the respective engine start valve is open and the start switch is in the ground position.

211-When the start valve is open and the engine start switch is not in the ground position, the START VALVE OPEN alert comes on and flashes for 10 seconds, then shows steady.

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212-Note that the START VALVE OPEN flash mode is inhibited for takeoff and landings. When inhibited, the alert illuminates steadily.

Normal ground start

213-Now let's see normal engine start procedure on the ground.

214-Normal start sequence is engine number 2 then 1.

215-Set the air conditioning pack switches to OFF.

216-Set the ignition select switch to IGNITION LEFT or IGNITION RIGHT. It is recommended to change the selected igniter for each flight. In this example, right igniter has been selected.

217-The Captain announces the engine start sequence. The first officer puts the ENGINE START switch to the GROUND position.

218-With the ENGINE START switch in the GROUND position, the start valve opens and the START VALVE OPEN alert illuminates on the engine display

219-As the starter turns the N2 rotor, the N2 indication begins to rise.

220-Before you move the start lever to IDLE, verify there is a movement in the N1 indicator and N2 is at 25%, or if this is not possible, the N2 is at maximum motoring and a minimum of 20%. Note that maximum motoring occurs when the N2 acceleration is less than 1% in approximately 5 seconds.

221-Move the start lever to IDLE. Now, fuel and ignition is supplied to the engine and the fuel flow indication starts to rise.

222-Within 15 seconds after the start lever is moved to IDLE, you must observe an increase in the EGT indication.

223-Make sure the oil pressure also increases. As the engine accelerates, the LOW OIL PRESSURE alert goes off when oil pressure is above redline limit.

224-At 56% N2, the engine start switch automatically goes back to the OFF position. The start valve closes and the START VALVE OPEN alert extinguishes.

225-The First Officer makes sure that alert is extinguished and the engine start switch is in the OFF position.

226-If engine start switch does not go to the OFF automatically, the Captain puts the switch to OFF

227-The First Officer tells the Captain when the starter has cut out.

228-Now, monitor N1, N2, EGT, fuel flow and oil pressure for normal indications until they stabilize at idle.

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229-When the engine is stabilized at idle, you can start the other engine.

230-Note that the starter has a duty cycle. Thus, do not exceed 2 minutes during each start attempt and wait at least 10 seconds between start attempts

231-You should also observe the followings during a normal engine start: Do not move an engine start lever to idle early; it may cause a hot start. Keep a hand on the engine start lever until the engine is stable at idle. If the engine start lever is closed accidentally, do not reopen the lever in an attempt to restart the engine. If ENGINE START switch fails on GRD until the starter cutout, the RPM may cause a hot start; do not re-engage the ENGINE START switch until N2 is below 20%.

232-After the flight is complete and the airplane is at the gate, you shut down the engines.

233-Before engine shutdown, ensure the APU power or ground power is available.

234-In this example, we will use the APU power.

235-Move the APU GENERATOR bus switches to ON, to put the electrical busses on the APU.

236-If engine start switch does not go to the OFF automatically, the First Officer puts the switch to OFF.

237-Run the engines at or near idle thrust for a minimum of three minutes before shutdown to thermally stabilize the engines. Taxi thrust can be considered idle thrust. If idle reverse thrust or no reverse thrust is used during the landing rollout, the three minute period can start when thrust is reduced to idle for landing

Types of ground start

238-Depending on the source of air used, there are two types of ground start: ground air start and crossbleed. Let’s first review starting with the ground air source.

Ground air start

239-For a ground air start, the AC electrical power from the APU or ground power unit must be available.

240-For safety reasons, engine number 1 must be started first, because ground crew and equipment are in the area of engine number 2.

241-Now set the APU BLEED air switch is to off. This protects the APU from the high start air pressure.

242-Make sure the duct pressure from the ground air cart is at least 30 psi.

243-Now, you can use the normal start procedure to start engine number 1.

244-To minimize the hazard to ground crew, the external equipment should be disconnected, and you should start engine

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No. 2 using the crossbleed start procedure.

Crossbleed start

245-Before using the crossbleed procedure, make sure that the area behind the airplane is clear.

246-The crossbleed start uses bleed air from the opposite engine.

247-Make sure that engine BLEED air switches are set to ON, the APU BLEED air switch is OFF and the ISOLATION VALVE switch is in AUTO.

248-This ensures bleed air supply from engine number 1 to engine number 2 for engine start and protects the APU from the high start pressure.

249-Move the operating engine thrust lever forward until duct pressure indicates 30 psi.

250-Engine number 2 is ready to start. Use the normal start procedures to start engine number 2.

251-After starter cutout, adjust thrust on both engines, as required

Ground start protection

252-During ground starts, the EEC monitors engine parameters to provide protection against imminent hot starts, compressor stalls, EGT start limit exceedances, and wet starts.

Hot start

253-Hot start occurs when there is a rapid rise in EGT.

254-Hot start also occurs when the EGT approaches the start limit

255-When the EEC finds there is a possible hot start, the white box surrounding the EGT digital readout flashes. The EGT display also flashes when the compressor stall occurs.

256-The EGT digital display continues to flash until you move the engine start lever to the cutoff position or the engine reaches idle N2.

257-The current versions of the EEC software automatically stop the fuel flow to the engine and turn off the ignition for an incoming hot start or stall.

Egt start limit exceedance

258-In the event that the EGT exceeds the starting limit, the EGT digital readout, the box around the readout and the dial turn red.

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259-In case of the EGT start limit exceedance, the EEC automatically shuts off fuel flow to the engine and turns off the ignition.

260-When EGT drops below the start limit, the indication returns to white. However, after engine shutdown the EGT box turns red to indicate an EGT exceedance has occurred.

Wet start

261-A wet start occurs if the EGT does not increase after the start lever is moved to IDLE.

262-Fuel can collect in the combustion chamber and on the ground surrounding the airplane.

263-If a wet start is detected, the EEC automatically shuts off fuel flow to the engine and turns off the ignition 15 seconds after the start lever is moved to IDLE.

Inflight start

264-There are two methods of starting an engine inflight: windmill and crossbleed.

265-You must check the inflight start envelope to determine the correct method to use. Starts are not assured outside of the inflight start envelope.

Crossbleed start

266-CROSSBLEED START If an inflight crossbleed starting is required, the X–BLD START indication is shown above the N2 display.

267-In compact engine display, the XB indication appears next to the N2 indication.

268-For inflight crossbleed start, close the thrust lever of the affected engine and set the engine start lever to CUTOFF.

269-Move the air conditioning PACK switch to OFF. Make sure that DUCT PRESSURE is minimum of 30 psi.

270-Now, put the ENGINE START switch to GROUND position

271-When the N2 is at or above 11%, move the engine start lever to IDLE.

272-EGT increases within 30 seconds to indicate a normal start has occurred.

Windmill start

273-There is no X-BLD indication when the windmill start is required.

274-For a windmill start, move the ENGINE START switch to the FLIGHT position.

Inflight flameout protection

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275-The ground start protection features are not available during an inflight start.

276-However, an auto-relight feature is provided for flameout protection during flight.

277-The flameout is a condition where the flame in the combustion chamber is extinguished.

278-A flameout indicates itself with an uncommanded rapid decrease in N2 or with a decrease in N2 below idle speed.

279-When the EEC detects an engine flameout, both left and right igniters are activated for relight.

Abnormal ground start

280-ABNORMAL GROUND START Now let's take a look at some abnormal conditions related to ground start

281-You must abort the engine start when one or more of these conditions occur: the EGT does not increase by 15 seconds after the engine start lever is moved to IDLE

282-The N1 or N2 does not increase or increases very slowly after the EGT increases

283-The EGT quickly approaches or exceeds the start limit.

284-These three abort conditions occur after the engine start lever is moved to IDLE with the ENGINE START switch in GROUND.

285-To abort the start move the engine start lever to CUTOFF.

286-Motor the engine for 60 seconds to remove the collected fuel and cool the engine.

287-Finally, put the ENGINE START switch to OFF. This completes aborted engine start procedure.

288-The last condition for an aborted start is no oil pressure indication by the time that the engine stabilizes at idle.

289-In this case, move the engine start lever to CUTOFF to abort the start.

290-After the N2 decreases below 20%, move the ENGINE START switch to GROUND.

291-Motor the engine for 60 seconds.

292-Then put the ENGINE START switch to OFF. This completes aborted engine start procedure.

293-The other abnormal condition related to an engine start is when the START VALVE OPEN alert stays illuminated after the starter cutout.

294-In this case, the starter must be isolated from all bleed air sources to protect it from a possible damage.

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295-In this example, engine number 1 STARTER VALVE OPEN light remains illuminated. Make sure that the ENGINE START switch is in the OFF position.

296-With the ENGINE START switch in OFF, if the alert stays illuminated, move the ISOLATION VALVE switch to CLOSE, the PACK switch to OFF and the engine BLEED air switch to OFF.

297-If the APU is used to start engine number 1, place the APU BLEED switch to OFF.

298-Now, all related bleed air sources are isolated from the starter.

299-If the airplane is on the ground, move engine start lever to CUTOFF.

300-Disconnect the ground air source, if ground air is used for the engine start.

REVERSE THRUST

301-Reverse thrust provides a means of supporting the braking system to slow the airplane after landing or during a rejected take off (RTO) reducing landing distance and brake wear.

302-The thrust reverser system produces a deceleration force by diverting fan air exhaust in the opposite direction of the airplane movement.

303-Each engine is equipped with a thrust reverser system which consists of the translating sleeves, the cascade vanes and the blocker doors.

304-The translating sleeves are used to cover and uncover the cascade vanes, and move the blocker doors into fan discharge air

305-The cascades control the direction of the fan air exhaust during a thrust reverser (T/R) deploy operation. This helps create reverse thrust

306-The blocker doors change the direction of the fan air discharge flow during a T/R deploy operation.

307-When the thrust reverser is stowed, the translating sleeves are retracted and the cover the cascade vanes, the blocker doors are in line with fan air duct and there is no change in the direction of the fan air discharge

308-On selection of reverse thrust, the actuation system moves the translating sleeves rearwards which uncovers the cascade vanes. At the same time the blocker doors close off the fan discharge duct. The fan discharge airflow is diverted through the cascade vanes, which creates reverse thrust.

309-During normal operation, the engine number 1 thrust reverser is powered by hydraulic system A and engine number 2 thrust reverser is powered by hydraulic system B.

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310-If either hydraulic system A or B fails, the standby hydraulic system operates the affected thrust reverser.

311-When the standby system is used, the affected thrust reverser extends and retracts at a slower rate. Thus, you can expect some thrust asymmetry.

312-An isolation valve and a control valve module controls hydraulic power to deploy or stow the thrust reverser.

313-The reverse thrust levers let you control engine reverse thrust. The movement of reverse thrust levers is mechanically prevented when forward thrust levers are not in the idle position.

314-Each reverse thrust lever has these positions: stowed, detent 1, detent 2 and maximum reverse thrust.

315-There are two indications in relation to the thrust reverser operation.

316-The REVERSER lights show just above the engine N1 indicators.

317-Each thrust reverser also has an amber REVERSER light on the engine panel.

REVERSE THRUST NORMAL OPERATION

318-During preflight and inflight operations, the reverse thrust levers are in the full down or stowed position.

319-With the reverse thrust levers in stowed position, the translating sleeves are retracted and locked. The blocker doors make part of the fan duct outer wall and there is no change in fan discharge airflow.

320-When the reverse thrust is selected, an electro-mechanical lock releases and unlocks the translating sleeves.

321-If the airplane is less than 10 feet of radio altitude or the air/ground sensor is in the ground mode, the isolation valve opens.

322-With the isolation valve open, the control valve sets to deploy position and directs the hydraulic pressure to move the translating sleeves to the deploy position.

323-When the translating sleeves are in transit, the amber REV light illuminates above the engine N1 indication.

324-The interlock mechanism restricts further movement of the reverse thrust lever until the translating sleeves are at the 60% of the travel to the deployed position.

325-As the thrust reverser reaches the deployed position, the REV indication changes to green. The interlock mechanism disengages and the reverse thrust lever can be raised to detent number 2.

326-When you raise the reverse thrust levers to detent number 2, the EEC adjusts adequate reverse thrust for normal operations.

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327-If maximum reverse thrust is required, you pull the reverse thrust levers beyond detent number 2. The EEC now sets maximum reverse thrust

328-When reverse thrust is no longer required, move the reverse thrust levers downward to detent number 1 or reverse idle. The EEC now sets a minimum reverse thrust.

329-To stow the reversers, you move the reverse thrust lever full down to the stowed position.

330-With the lever in the stowed position, the control valve sets to the stow position. Hydraulic pressure retracts the reverser sleeves.

331-As the translating sleeves are in transit, the green REV indication on the engine display changes to amber and REVERSER light on the aft overhead panel illuminates

332-After the sleeves are stowed, the isolation valve closes. The electro-mechanical lock activates, the REV indication on the engine display extinguishes and the REVERSER light goes out 10 seconds after the isolation valve closes.

333-If a thrust reverser control system component fails while being stowed, the REVERSER light stays on until the failure goes away.

334-Reverse thrust system also incorporates an auto–restow circuit which compares the actual translating sleeve position and the commanded reverser position.

335-If the auto–restow circuit detects an incomplete stowage or an uncommanded movement of the reverser sleeves toward the deployed position, it opens the isolation valve and sets the control valve to the stow position. This directs hydraulic pressure to stow the reverser sleeves.

336-Once the auto–restow circuit is engaged, the isolation valve stays open and the control valve is held in the stowed position until the thrust reverser is commanded to deploy or until maintenance crew takes a corrective action.

337-Activation of the reverse thrust on the ground without proper precautions is dangerous to ground personnel.

REVERSE THRUST ABNORMAL CONDITIONS

338-Let’s now glance at the abnormal reverse thrust conditions.

339-If the isolation valve or thrust reverser control valve is not in the commanded position, the REVERSER light on the engine panel comes on. In the example shown, although the reverse thrust levers are stowed, the isolation valve is open.

340-The REVERSER light also comes on, when auto-restow circuit is engaged.

341-The last condition when the REVERSER light comes on is the left and right translating sleeves on the same engine do

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not agree.

342-Whenever a REVERSER light comes on, the MASTER CAUTION and ENGINE system annunciation lights also illuminate after a time delay.

343-Illumination of the light during flight does not mean that thrust reverser is inoperative. You can anticipate normal reverse thrust operation after landing.

344-However, if the light illuminates during the flight, you should know that additional system failures may cause inflight deployment of the thrust reversers.

345-If the amber REV indication illuminates on the engine display during flight, a translating sleeve may be mechanically unlocked.

346-The unstowed reverser sleeves produce some yaw, roll and buffet and may restrict the movement of the forward thrust levers.

347-To ensure that the REV indication is illuminated due to unstowed the reverser sleeves, check the movement of the forward thrust lever on the affected engine. DO NOT actuate the reverse thrust lever.

348-If the forward thrust lever is restricted you must shut down the engine.

349-If the forward thrust lever is not restricted and buffet or yaw does not exist, the REV indication is incorrect. You can go on with normal operation.

350-If you pause when moving the reverse thrust levers past detent No. 1 toward the stowed position, the MASTER CAUTION and ENGINE system annunciator lights may illuminate.

351-If you pause for approximately 18 seconds, the electro-mechanical lock engages and prevents the thrust reverser sleeves from further movement. Cycling the thrust reversers may clear the fault and restore normal operation.

COURSE END

352-End of course. ?

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