ICE AND RAIN PROTECTION

The anti-ice systems are designed to prevent ice formation on the pitot tubes, static ports, angle-of-attack probes, ram air temperature (RAT) probes, engines, wings, wing roots, horizontal stabilizer leading edges, windshields, and overboard water drain lines. The vertical stabilizer does not require anti-icing. The various anti-icing systems use electrical heating elements or hot engine bleed air, and are activated by switches and knobs on the instrument panels.

There are many engine instrument and crew alerting system (EICAS) messages which pertain to operation of the anti-icing systems. Some are discussed here, but most are covered in detail under Engine Indicating and Crew Alerting System (EICAS), in Section Three of this manual.

ICE AND RAIN PROTECTION

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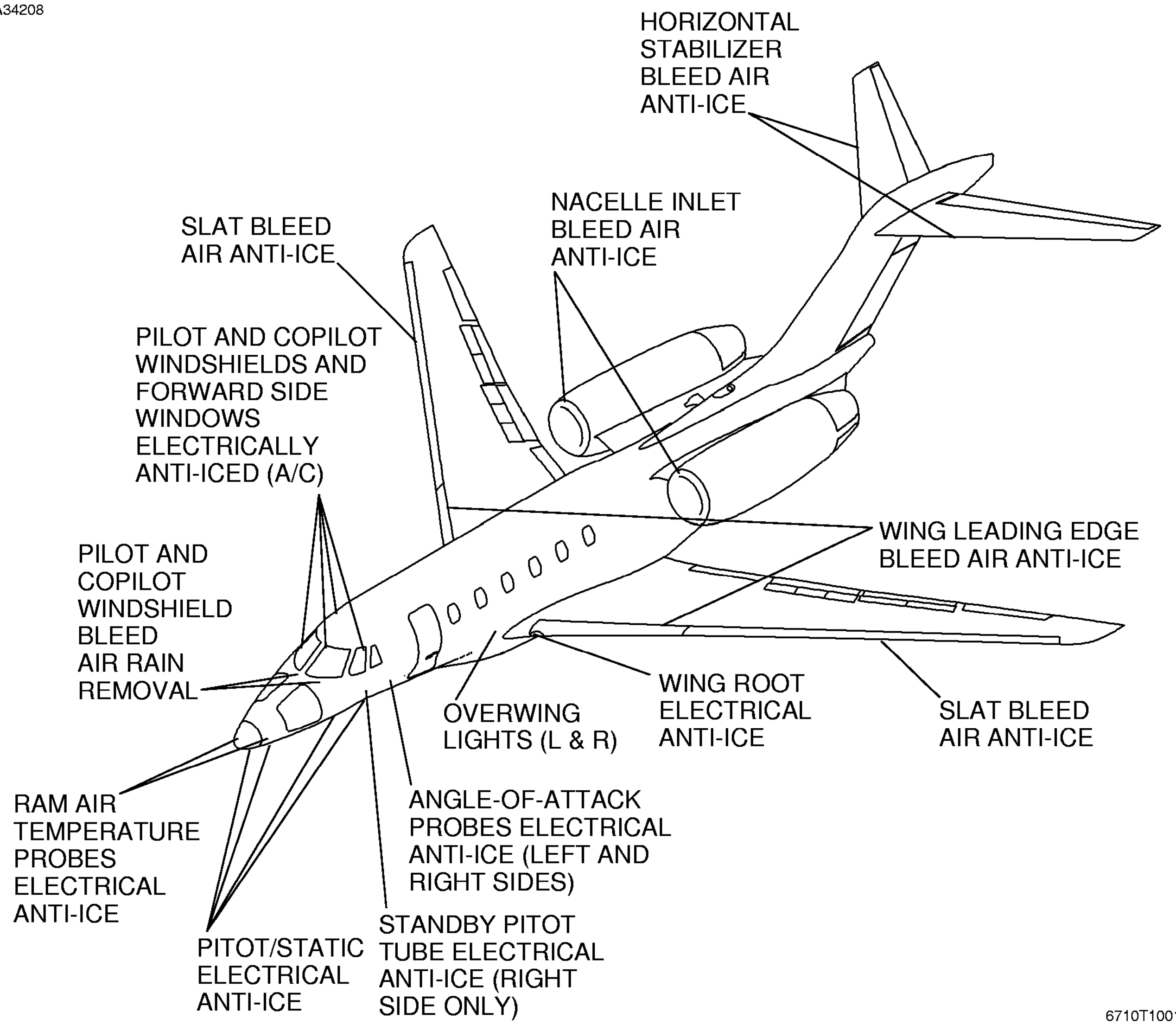

Figure 2-40

DC electric power is used to anti-ice the pitot tubes and static ports, the AOA probes, the ram air temperature (RAT) probes and the wing root fillet. AC electric power is used for the cockpit windshields and front side windows. High pressure temperature controlled bleed air, or low pressure bleed air (depending upon whether the airplane is in flight or on the ground, and the position of the throttle levers) is used to anti-ice the engine inlets, inboard wings and the slat leading edges, the horizontal stabilizer leading edges, and the landing lights.

PITOT-STATIC AND ANGLE-OF-ATTACK (AOA) PROBE ANTI-ICE

Electric elements heat the pilot's and copilot's pitot tubes and static ports, the AOA probes, the standby pitot/static system, and the wing roots. The pitot and static heating elements are controlled by the LH/OFF and RH/OFF PITOT/STATIC anti-ice switches on the ANTI-ICE control panel, which is located on the tilt panel to the right of the pedestal. The LH switch controls the pilot's pitot and static heaters, and the RH switch controls the copilot's pitot and static heaters and the standby pitot and static heaters. When power is removed from the pitot heaters, or when a heater fails, a digital PITOT HTR FAIL L-R annunciation will come on in the CAS (crew alerting system) portion of the EICAS (engine indicating and crew alerting system) display. If the standby pitot heat should fail the message will be PITOT HTR FAIL SB. If a static port heater fails, an amber EICAS message, STATIC HT FAIL L-R will appear in the EICAS display unit. The standby static port is served by the left and right static ports, and so is included in this message. The left and right AOA probe heaters are electrically powered, and are controlled by the respective side pitot-static heat switch; if an AOA heater should fail, an amber EICAS message, AOA HEAT FAIL L-R, will appear.

There are two messages which can appear if the pitot/static heat or the RAT heaters are turned OFF. A cyan P/S RAT HEAT OFF indicates that the pitot/static or RAT switch(es) is/are in the off position. If the message is presented in amber it means that the throttle lever angle is above 60° and the switch(es) is/are off. In the latter case a chime will sound.

RAM AIR TEMPERATURE (RAT) HEATER

Electric elements heat the RAT probes, which are located on the left and right nose section of the aircraft. A RAT heater is an integral part of each ram air temperature probe assembly. The heating elements are controlled by the left and right PITOT/STATIC heat switches on the ANTI-ICE control panel. The RAT heaters should be on for all flight conditions. Satisfactory operation of the RAT heaters is verified by observing white digits on the ram air temperature (RAT) display, located below the ITT display, on the EICAS display tube. If one (or both) of the RAT heaters fails there will appear an amber digital annunciation: RAT HEAT FAIL L-R.

See Pitot-Static and Angle-of-Attack Probe Anti-ice, above, for additional, CAS messages.

BLEED AIR ANTI-ICE SYSTEM

Bleed air anti-ice is used to anti-ice the engine nacelle intakes, the fixed wing leading edges, the landing light lenses, the retractable slats, and the horizontal stabilizer leading edges.

Because they cannot be monitored for ice formation, engine inlet and horizontal stabilizer anti-ice should be turned on any time icing conditions are encountered. Slat anti-ice may be delayed if it can be visually verified that ice is not forming on the slats. Windshield, pitot-static/RAT and AOA anti-ice are normally operated full time in flight.

Both engines contribute equally to the high pressure or low pressure air supply, unless one engine is shut down, in which case a wing crossover valve (WING XOVER/NORM) is provided, and may be opened to allow both wings (and slats) to be anti-iced from one engine's bleed air supply. All bleed air for the various systems using it for anti-icing is provided from a duct system. The air is temperature controlled by being passed through a pylon-mounted heat exchanger. It is normally high pressure (HP) bleed air, except that low pressure (LP) bleed air is used on the ground at mid to high throttle settings when the HP precooler would be ineffective. The HP precooler regulates ram air through the heat exchanger to limit the air to a maximum of approximately 480°F. An amber HP PRECOOLR O'HT L-R CAS message will illuminate if the precooler temperature exceeds 550°F. At lower power settings, approximately 70% N_1, HP air is below 480°F and the precooler ram air doors will be closed. HP air leaves the precooler and passes through a pressure regulating and flow control valve into a supply pipe, which then distributes the air to the selected anti-ice systems.

Controlling switches in the bleed air system (other than the switches on the ANTI-ICE panel) are the throttle lever angle (TLA) switches in the throttle quadrant, and the weight-on-wheels (WOW), or squat switches, on the landing gear. The engine low pressure bleed air valves (left and right), and the high pressure/low pressure (HP/LP) shutoff valves (left and right) are positioned by the TLA and WOW switches. Depending upon the sensing of the WOW and TLA switches, the anti-ice air will be provided by either low pressure or high pressure engine bleed air. When the airplane is on the ground with the throttles below a throttle lever angle (TLA) of 32°, fourteenth stage high pressure engine bleed air is provided. On the ground, as the throttle lever is increased past 32°, power is removed from the HP/LP shutoff valve, causing it to open, the high pressure bleed air shutoff valve is powered closed, and eighth stage low pressure air is then provided for anti-ice.

When the airplane becomes airborne, the WOW switches are de-activated and electric power is automatically removed from the high pressure bleed air shutoff valve, allowing it to open. Power is then removed from the HP/LP shutoff valve, causing it to close. High pressure bleed air will then be supplied to all bleed air anti-ice systems regardless of throttle angle.

ENGINE ANTI-ICE

Anti-icing of the engine inlet lip and duct is provided by a piccolo tube that sprays bleed air onto the inside surface of the inlet lip. The air is then ducted aft adjacent to the inner fan duct wall and on to louvers that discharge the air into the intake of the engine forward of the fan. The engine itself is not anti-iced. Inlet temperature rise prevents compressor section icing. The stators and the aft sides of the fan blades may collect some icing, but can be cleared by a procedure of changing the power setting, as discussed in the FAA Approved Airplane Flight Manual.

The engine anti-ice is controlled by two switches (ENGINE LH/OFF and RH/OFF) located on the ANTI-ICE tilt panel, which control the engine nacelle regulating and shutoff valves. The valves are powered to the closed position; in the ON position, power is removed from the the valves and they move to the open position. With the engine anti-ice switches in the OFF position, the engine nacelle regulating and shutoff valves will be electrically powered closed, regardless of throttle position, and engine anti-ice will be turned off.

In case of complete electrical power failure in flight, the control valves, which are held closed by electrical power, will then fail open and engine anti-ice will be automatically provided.

Operation of the system may be checked by observing engine interturbine temperature (ITT) and fan speed (N_1) when the engine anti-ice is turned on. The ITT should increase and the fan speed should decrease.

The wing root anti-ice is also part of the engine anti-icing system, due to the fact that ice could form on the wing root and be ingested by the engine. It is controlled by the same switches (ENGINE LH/OFF and RH/OFF) as the engine bleed air anti-ice. A DC electric heating element is embedded in the bonded wing root fillet area of each wing. The elements are controlled by the same switches as the engine anti-ice, so that any time the engine anti-ice is on, the respective wing root area will also be anti-iced. Two temperature sensors, which monitor system performance and warn of overtemperature or undertemperature conditions, are included in the installation. In case of malfunction, amber crew alerting system (CAS) messages, WING CUFF HOT L-R or WING CUFF COLD L-R, will appear to indicate the status of the respective wing root area. The panel will automatically shut off when the HOT message illuminates, until the overtemperature condition clears. The panel is not considered critical, however, it is possible that ice could form and cause light fan damage in a prolonged icing encounter with a failed cuff heater.

The engine inlet anti-ice temperature is monitored by cyan and amber CAS messages (ENG A/I COLD L-R), and an amber ENG A/I HOT L-R CAS message. If the cyan ENG A/I COLD message appears, it means that the system has been turned on but has not yet warmed up to operational temperature. The cyan ENG A/I COLD L-R message may also appear with a red PYLON BLEED LEAK L-R CAS message, if the nacelle does become cold. The message is cyan in order to serve as a reminder that, due to the other problem, a power increase is not called for. The amber A/I COLD message indicates that the anti-ice system is switched on, but is below effective operating temperature. With the amber COLD message illuminated, if it cannot be determined that the engine is anti-icing, the pilot should exit the icing conditions as soon as possible. If the amber HOT message is illuminated the engine inlet anti-ice will automatically shut down until the overheat has cleared.

The wing inboard, fixed, leading edge is monitored by WING A/I COLD L-R and WING A/I HOT L-R amber CAS messages. The HOT message detects an overtemperature or internal leak in the leading edge. The wing (and slat) anti-ice will automatically shut off until the overtemperature condition has cleared. With engine anti-ice only ON, the engine and wing cold messages will normally remain extinguished at idle, once the surfaces have warmed. With the other anti-ice systems on, N_1 may have to be increased slightly above idle to keep all cold messages extinguished.

Engine anti-ice is, as the name implies, designed as a preventative system. Its use should be anticipated and the system actuated any time the airplane is operated in snow or freezing precipitation on the ground or when flight in visible moisture, with RAT below +10°C, is either occurring or is imminent.

Because of lower power settings during descent, it is advisable to turn on the engine anti-ice system well before entering visible moisture environment where icing conditions may be anticipated.

Because of engine bleed air extraction with system operation, maximum allowable power settings are reduced as shown in Section IV of the Airplane Flight Manual.

The engine ignition should be turned on when flying in heavy rain, as a precaution against flameout.

WING AND SLAT ANTI-ICE

The engine bleed air anti-ice system is fed by the high pressure and low pressure bleed air systems, which are discussed under Bleed Air Anti-ice System, above, in this Section.

The left and right wing leading edge inboard fixed sections are anti-iced with engine bleed air supplied to two piccolo tubes, one each side, located in the left and right wing leading edge. The leading edge mounted landing lights are anti-iced by diffusing bleed air from the the inboard wing anti-ice supply duct. Bleed air is supplied to the inboard left and right wing slats through a flexible hose that bends as the slats extend. The flexible supply hose feeds bleed air to a piccolo tube located inside each slat leading edge, which is exhausted overboard through openings in the aft end of the slat.

The left and right wing (and slat) anti-ice systems are normally isolated by the normally closed wing crossover valve located in the crossover duct between the left and right wing. With the crossover valve open, either wing anti-ice system (LH or RH) can be supplied by either or both engines. Check valves located in the wing supply tube at the forward end of the wing, prevent bleed air from the right system from entering the left system and vice versa. Heat from the wing leading edge is isolated from the wing structure and the fuel barrier, by a heat shield. In case of complete electrical power failure, the fail-safe position of the wing crossover valve is to the closed position. It is powered open, and upon electrical power failure will close.

Temperature sensing devices are used to monitor anti-ice system performance and protect the wing and slat bleed air supply ducts, connectors, and the adjacent structure. System performance is also monitored by sensing the spent air temperature from the fixed leading edge and from the slats. Some of the various crew alerting system (CAS) indications, in response to conditions in the wing and slat anti-ice systems, are listed here. Additional system messages are found in Section Three of this manual, under Engine Indicating and Crew Alerting System (EICAS).

The wing inboard fixed leading edge and the extendible slats are monitored by WING A/I COLD L-R and WING A/I HOT L-R (SLAT A/I COLD and SLAT A/I HOT) amber CAS messages. The HOT message detects an overtemperature or internal leak in the wing leading edge or slat. The wing (and/or slat) anti-ice will automatically shut off until the overtemperature condition has cleared. With engine anti-ice only ON, the engine, wing, and slat cold messages will normally remain extinguished at idle, once the surfaces have warmed. With the other anti-ice systems on, N_1 RPM may have to be increased slightly above idle to keep all cold messages extinguished. The COLD message indicates that the wing (and/or slat) exhaust air is too low, which is probably caused by a power setting which is too low. The condition can be cleared by increasing engine power. The slat (and the horizontal stabilizer) anti-icing bleed air is turned off when the engine N_1 RPM is below 48 percent, in order to maintain the engine anti-ice bleed air temperature.

Overwing fairing sensors are installed in the wing fairing to monitor for bleed air leaks. Red WING BLD LEAK L-R CAS messages indicate that a hot air leak has been detected. The pilot should reduce power or shut off the bleed, as required, to alleviate the situation. The pylons are also monitored for bleed air leaks by PYLON BLD LEAK L-R red CAS messages. If a wing bleed air leak results in a wing or slat cold condition, the cold CAS message is changed from amber to cyan, so as not to infer that a power increase should be made.

The source of wing bleed air for the anti-ice system is from the high pressure and low pressure bleed air systems, which are discussed in more detail under Bleed Air Anti-ice System, above, in this Section.

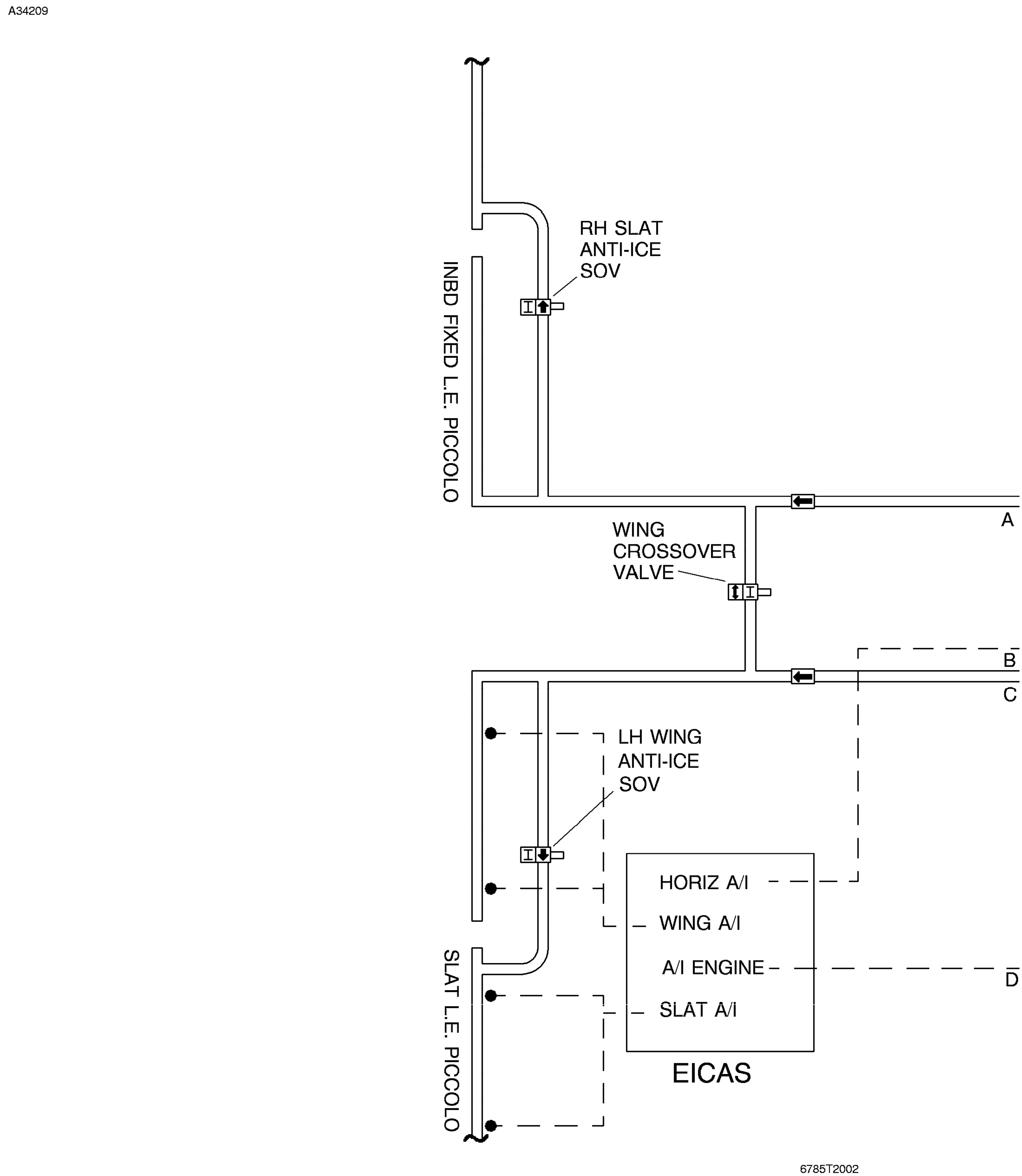

Figure 2-41 Anti-Ice Flow Schematic (Sheet 1 of 2)

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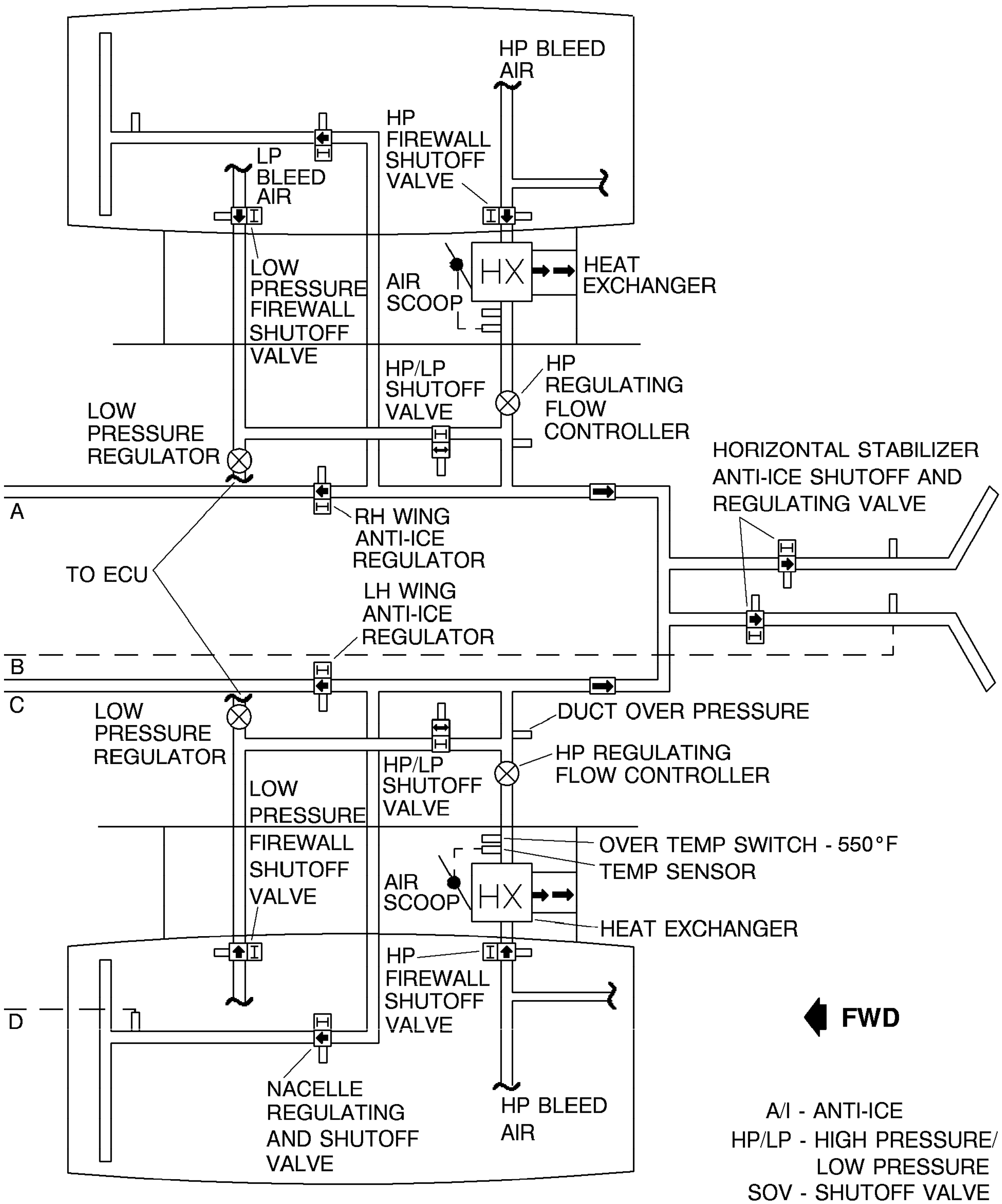

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Figure 2-41 Anti-Ice Flow Schematic (Sheet 2)

HORIZONTAL STABILIZER ANTI-ICE

Anti-ice air to the horizontal stabilizer comes from the bleed air duct system. The bleed air is sprayed onto the inside surface of the horizontal stabilizer leading edge from a piccolo tube. The air is controlled individually by two valves, one for the left side of the stabilizer and one for the right. Check valves located upstream of a short crossover duct prevent cross flow from the left engine to the right wing supply duct and from the right engine to the left wing supply duct. The left and right horizontal stabilizer anti-ice shutoff and regulating valves open when the stabilizer anti-ice switches (STABILIZER LH and RH/OFF) are placed to the LH and RH positions. These valves are individually fed from the bleed air duct system, and therefore receive anti-icing bleed air from either or both engines, and are not affected by use of the wing crossover valve position, except that a slightly higher power setting may be required if the system is operated on a single engine.

Crew alerting system (CAS) messages are used to monitor the status of the stabilizer anti-ice system. A STAB A/I COLD L-R message indicates that the stabilizer anti-ice is not up to the required temperature, either due to insufficient engine power or due to a bleed leak in the system. A monitor for bleed air leaks is located in the bullet area of the vertical stabilizer; if it detects a leak it will cause a red STAB BLD LEAK L-R CAS message to appear in the CAS monitor. These messages do not cause the stabilizer anti-ice to be shut off. Pilot action is required; refer to the FAA Approved Airplane Flight Manual, or Section Five of this manual.

If the horizontal stabilizer bleed air supply reaches an overtemperature level, an amber CAS message (STAB A/I HOT L-R) will appear. When the CAS message appears the stabilizer anti-ice will cycle on and off, and heat damage is not likely. The anti-ice will shut off when the hot message appears and turn on after the message clears. If the message appears steadily, the stabilizer anti-ice should be manually cycled and the icing conditions left as soon as possible.

Stabilizer anti-ice (and the slat anti-ice) is automatically turned off below an N_1 power setting below 48 percent, due to the requirement to maintain the engine anti-ice supply temperature. A CAS STAB A/I COLD message will illuminate. In this case the message can be extinguished by increasing power. Crew alerting system messages are discussed in more detail under the Engine Indicating and Crew Alerting System (EICAS) in Section Three of this manual.

WINDSHIELD ELECTRICAL ANTI-ICE

The left and right windshields and the left and right forward cockpit side windows are anti-iced by alternating current (AC) electrical power. The power is controlled by the WINDSHIELD LH RH O'RIDE/ON/OFF switches on the anti-ice control panel. The windshield anti-ice must be turned on any time icing is detected. It may be operated full time from engine start to shutdown and will improve cockpit comfort at high altitude. It is also required for windshield defog.

The windshield electrical anti-ice is discussed in detail under the heading, Windshield Alternating Current (AC) Electrical Anti-ice System in the Electrical section in this chapter.

ICE DETECTION

Two windshield ice detection lights are mounted on the forward glare shield and are aimed at the windshield. A red light is reflected onto the windshield when ice begins to form. The red lights are not visible to the crew when the windshield is clear of ice. The windshield ice detection lights are powered on any time the instrument lights DAY/NIGHT DIM switch is ON.

Wing inspection lights are provided to illuminate the inboard portion of the wing leading edge, allowing the pilot to visually inspect for the formation of ice. The wing inspection lights are turned on by the wing inspection toggle switch (WING INSP LIGHT/OFF) located on the anti-ice control (tilt) panel. The wing inspection light has a ground adjustable gimbal fixture for precise aiming of the cone of illumination.

WINDSHIELD RAIN REMOVAL

A two-speed electric windshield rain removal fan is mounted in the nose avionics bay. It is controlled by a switch (WS AIR/OFF) on the anti-ice control panel. It normally runs at low speed, functioning as a cooling fan for the nose avionics bay. When the W/S AIR position is selected, it runs at high speed to direct high velocity air onto both windshields to aid in clearing rain. The system is primarily for ground use, but does provide a small increase in rain removal in flight. The primary rain removal in flight is caused by the natural action of the treated windshield surface and the windshield shape. If visibility deteriorates on a part of the windshield, it may be that the treated surface has deteriorated. The surface can be re-treated and restored to its original condition.