2A-30-10: General

1. **Description:**

Ice protection systems on the G550 aircraft employ either warm engine bleed air or heat generated by electrical resistance to prevent the formation of ice on critical structures and installations. During rain, flight crew forward visibility is enhanced during takeoff by a forced air blower that clears rain from the cockpit windshield until higher airspeeds prevent the accumulation of water.

CAUTION

IF OPERATING IN ACTUAL OR ANTICIPATED ICING CONDITIONS, REVIEW SECTION 07-01-00: ALL WEATHER OPERATIONS AND PROCEDURES. SPECIFIC ATTENTION SHOULD BE PAID TO THE LARGE INCREASE IN RUNWAY LENGTH REQUIREMENTS FOR TAKEOFFS AND LANDINGS ON CONTAMINATED RUNWAYS.

The aircraft is equipped with an ice detector system that is capable of notifying the flight crew of the presence of ice and, at the option of the crew, automatically activating anti-ice bleed air flow to the wing leading edges and engine air inlet cowls. On-demand anti-ice air bleed increases aircraft fuel efficiency by restraining engine bleed and the resultant fuel flow increase until ice formation is actually present on the aircraft.

Electrical heat for components can be activated at any time regardless of the presence or absence of ice since no performance degradation is associated with electrical heating. The only requirement is the presence of sufficient airflow to prevent overheating.

The ice and rain protection system is divided into the following subsystems:

- 2A-30-20: Ice Detection System
- 2A-30-30: Cowl Anti-Ice System
- 2A-30-40: Wing Anti-Ice System
- 2A-30-50: Cockpit Windshield Ice and Rain Protection System
- 2A-30-60: Cabin Window Heat System

2. **Limitations:**

A. **Flight Manual Limitations:**

(1) **General:**

Icing conditions exist when the SAT on the ground and for takeoff, or SAT inflight is +8°C or below, and visible moisture in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet and ice crystals).

Icing conditions also exist when the SAT on the ground and for takeoff is +8°C or below when operating on ramps, taxiways or runways where surface snow, ice, standing water, or slush may be ingested by the engines or freeze on engines, nacelles or engine sensor probes.

(2) **Use of Flaps:**

Use of flaps in icing conditions is restricted to takeoff, approach and landing only.

Holding in icing conditions is limited to 0° flaps only.

2A-30-20: Ice Detection System

1. **General Description:**

Since the exterior surfaces of the aircraft are difficult to view from the cockpit window while in flight, the crew is forced to rely upon observation of the limited features within the field of view to detect the presence of ice on the aircraft. To aid the crew in the timely recognition of icing on the aircraft exterior, the G550 has two ice detectors, one on each side of the aircraft, installed below the cockpit windows. The ice detectors are linked to the Monitor and Warning System (MWS) through the Modular Avionics Units (MAUs) - (left detector to MAU #1, right detector to MAU #2) - and provide the crew with a Crew Alerting System (CAS) message when ice is forming on the aircraft.

At the option of the crew, the WING and COWL selector switches on the ANTI-ICE panel on the cockpit overhead can be positioned to AUTO. If AUTO is selected, ice detector signals can be used to automatically activate wing and engine cowl anti-ice bleed air flow, provided the aircraft is within the prescribed altitude envelope for automatic operation. Because extracting bleed air from the engine decreases engine thrust, automatic anti-icing is not available below fifteen hundred (1,500) feet where full engine capability is reserved for takeoff and landing. However, if automatic anti-icing had been selected at a higher altitude, it remains operational in descent below 1,500 feet, since engine thrust requirements are minimized in descents, and engine cowls and wing surfaces must be kept clear of ice in preparation for landing.

NOTE:

Should a rejected landing become necessary, additional engine thrust will be gained by closing the wing and engine anti-ice bleeds, if weather permits.

Automatic anti-icing is also not available above thirty-five thousand (35,000) feet, since air temperatures and moisture content are extremely low and icing conditions unlikely. Engine bleed air can then be fully employed in meeting the demands of pressurization and cabin heating.

NOTE:

Engine cowl and wing anti-ice may be manually selected ON at any altitude when ice protection is required.

A schematic of the ice detector system is contained in Figure 1.

2. **Description of Subsystems, Units and Components:**

   A. **Ice Detector Probes and Automatic Operation:**

The ice detectors probes incorporate a vibrating sensor element extended into the airstream flowing around the fuselage. The element length is sufficient to avoid the frictional heating effects immediately surrounding the aircraft structure. The sensor vibrates in clear air at an extremely high frequency range (approximately 40,000 Hz); however, if ice accumulates on the sensor, the frequency of the vibrating element will show a decrease proportional to the amount of accumulation. The detection threshold is a frequency loss of 133 Hz, equivalent to a 0.020 ice accumulation. The frequency change is translated by the probes into electrical signals, and provided to the MWS for initiation of CAS messages indicating the presence of ice, and to the automatic function position of the control relays for engine cowl and aircraft wing anti-ice. Each ice detector (left and right) is wired to the control relays of both engines and both wings in order that a single detector can provide the signals necessary for automatic anti-icing. The flight crew must select the cockpit overhead anti-ice switches to the AUTO position to allow ice detector control of the cowl and wing anti-ice bleed valves. Wing and cowl anti-ice may be selected independently, however the switches should be positioned symmetrically (both wing switches to the same selection, both cowl switches to the same selection).

When the ice detectors no longer sense the presence of ice, the wing and cowl anti-ice bleed valves are signalled to close after a time delay. The time delay is incorporated into the control software of the ice detectors in order to ensure that all ice accumulations on the wings and engine cowls have been dissipated. Automatic anti-ice protection is terminated in the following sequence:

- After one (1) minute, the amber “Ice Detected, L (and/or) R” message is removed from the CAS window
- After three (3) minutes, the engine cowl anti-ice valves close
- After five (5) minutes, the wing anti-ice valves close

B. Ice Detector System Test:

A test pushbutton, labelled ICE DET is located on the SYSTEM TEST panel on the cockpit overhead. See Figure 2. Depressing the button will initiate an operational test of the ice detector control circuits of the ice protection system. The full system test requires placing the ANTI-ICE control switches in the AUTO position. The test function will override the weight-on-wheels (WOW) relay that normally prohibits ground operation of the automatic controls of the ice protection system. Depressing the pushbutton initiates the following actions:

- The TEST legend within the switch will illuminate blue
- The amber CAS caution message “Ice Detector Fail, L-R” is displayed
- The amber CAS caution message “Ice Detected, L-R” is displayed
- The wing and engine cowl anti-ice valves open, porting warm air to the wing leading edge and the front of the engine cowling
- The blue CAS advisory message “Cowl Anti-ice On, L-R” is displayed
- The blue CAS advisory message “Wing Anti-ice ON, L-R” is displayed
- The system test terminates after three seconds

Although the system test may be monitored on the ECS Pressure 2/3 window display, the information displayed would not be useful in determining system status due to the brevity of the system test cycle.

3. Controls and Indications:

A. Circuit Breakers (CBs):

The following CBs protect the ice detection system:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L ICE DET	LEER	F-3	ESS AC Bus ϕB
L ICE DET CONT	LEER	E-3	L ESS DC Bus
R ICE DET	REER	F-14	ESS AC Bus ϕC
R ICE DET CONT	REER	E-14	R ESS DC Bus

B. Crew Alerting System (CAS) Messages:

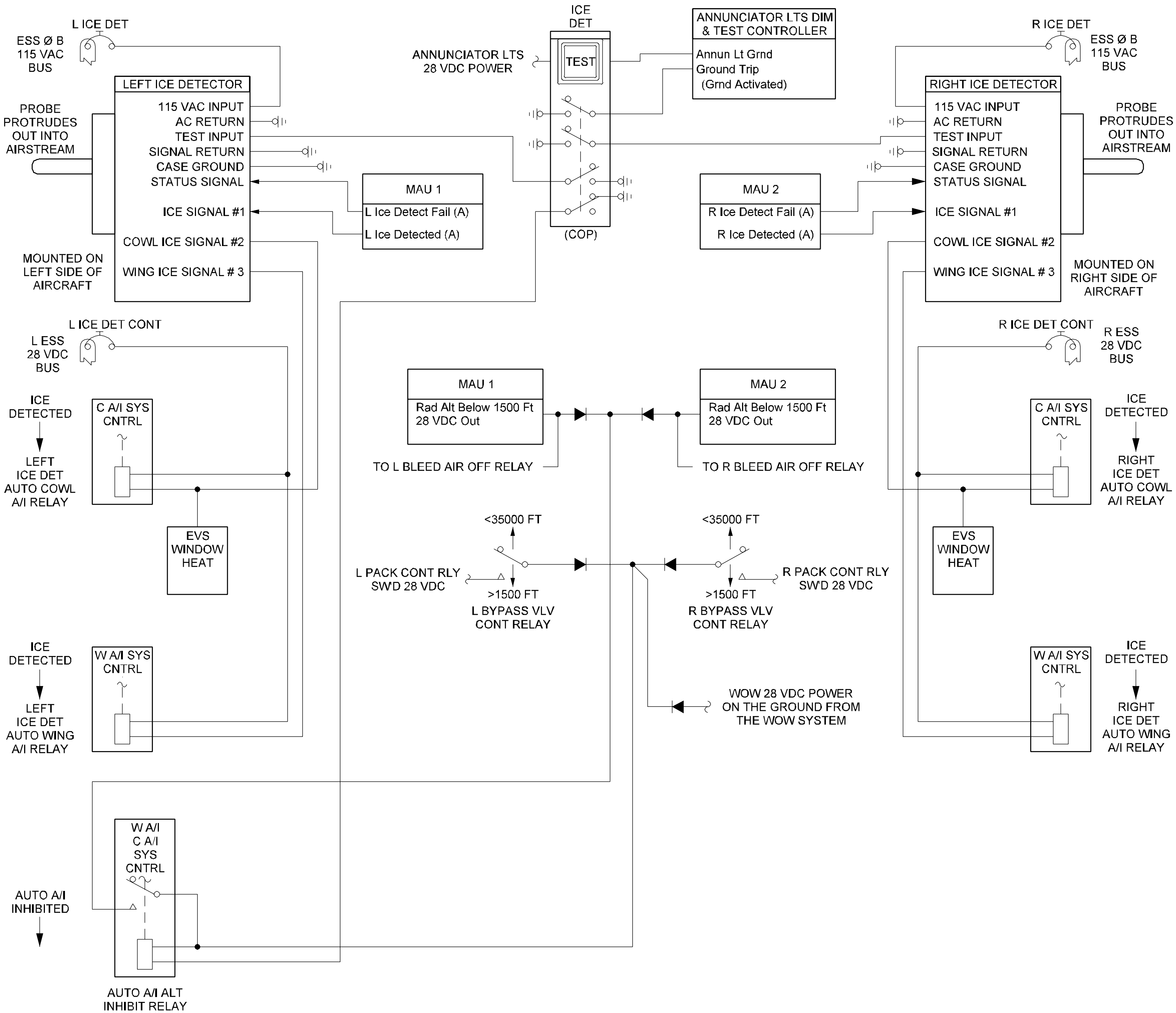
The following CAS messages are associated with the ice detection system:

Area Monitored:	CAS Message:	Message Color:
Ice Detector Probe	Ice Detected, L-R	Amber
Ice Detector Probe	Ice Detect Fail, L-R	Amber

4. Limitations:

A. Flight Manual Limitations:

Automatic anti-ice is inhibited above 35,000 ft. If anti-ice protection above 35,000 ft is required, it must be manually selected.



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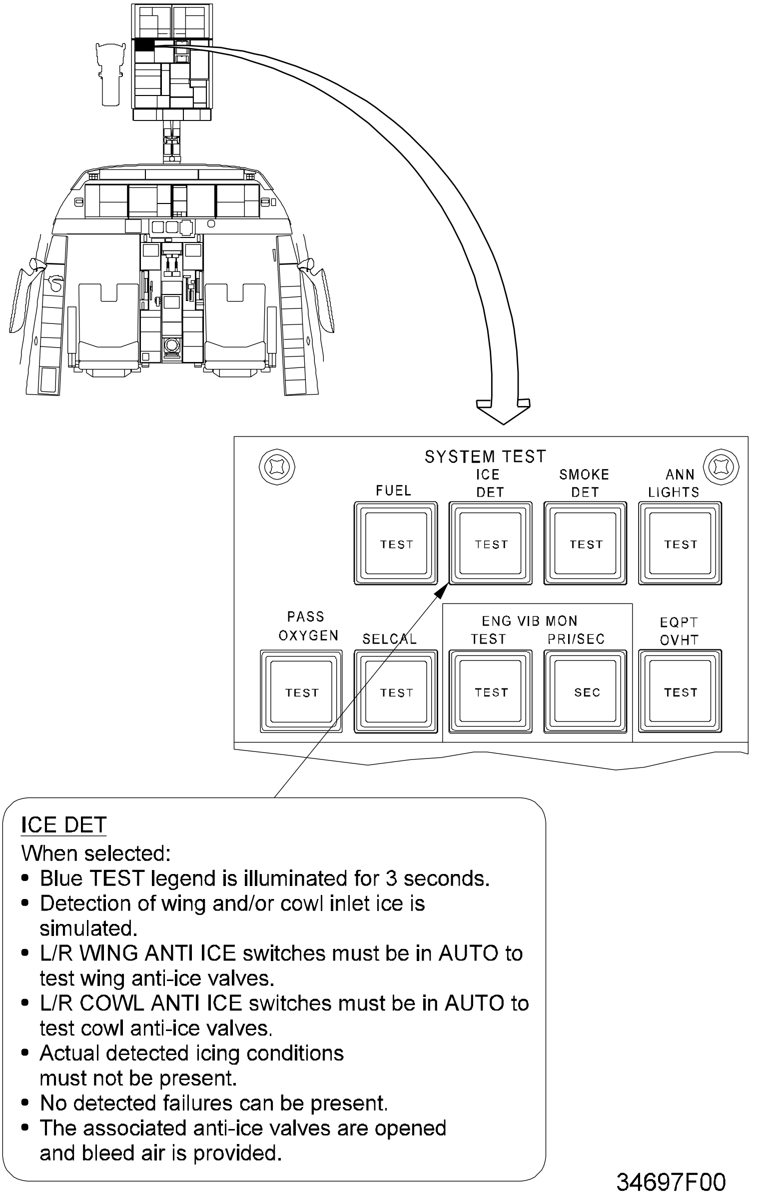
Ice Detector System
Figure 1



Ice Detector Test Switch
Figure 2

2A-30-30: Cowl Anti-Ice System

1. **General Description:**

Each engine has a dedicated, independent Thermal Anti-Ice (TAI) system. Warm engine bleed air is used to heat the air intake cowls on the engine nacelles during icing conditions to preserve an unobstructed airflow to the engines by preventing the formation of ice on the area surrounding the engine inlet. If ice were allowed to form on the inlet cowling, normal engine physical and sonic vibration would eventually detach the ice, allowing it to be ingested into the engine, causing damage to inlet vanes and rotors.

CAUTION

ICE ACCUMULATION ON ENGINE COWLS CANNOT BE DETECTED FROM THE COCKPIT. AIR ENTERING THE ENGINE INTAKE IS SUBJECT TO RAPID ACCELERATION DUE TO THE SUCTION CREATED BY THE ENGINE FAN BLADES AND THE CURVATURE OF THE AIR INLET. THE INCREASE IN SPEED CAUSES WATER VAPOR IN THE AIR TO CONDENSE AND FREEZE ON THE ENGINE COWLING AT TEMPERATURES NOT ORDINARILY ASSOCIATED WITH ICING. REVIEW SECTIONS COVERING LIMITATIONS, ALL WEATHER OPERATIONS AND PERFORMANCE ADJUSTMENTS WHEN OPERATING IN TEMPERATURES AT OR BELOW 8°C / 46.4°F.

NOTE:

If cowl anti-ice is selected ON for takeoff, anti-ice usage must be entered on the TAKEOFF INIT page 5/5 for the V speeds to box and the autothrottles to engage.

Within each engine nacelle, air is taken from the High Pressure (HP) compressor at the fifth stage and routed forward through ducting and a control valve to a circular tube located inside the air inlet cowling. The circular tube is perforated with small openings to distribute the warm pressurized air within the entire circumference of the engine cowl. The air exhausts through a grill opening on the underside of the engine cowl.

The engine TAI control valve position is determined by the position of the COWL ANTI-ICE selector switch on the cockpit overhead, shown in Figure 3. If the flight crew selects the left or right COWL switch to OFF, twenty-eight volt direct current (28v DC) power from the Main DC bus (left bus for left engine, right bus for right engine) is routed to a solenoid within the valve to maintain the valve in the shut position. The same control path shuts off engine bleed air to the cowl if the flight crew has selected the AUTO position for the COWL ANTI-ICE switch, but the ice detectors do not sense that icing conditions are present. (See the previous section 2A-30-20 for a complete explanation of the automatic control functions of the ice detectors). However, if the ice detectors sense the formation of ice on the aircraft with the COWL selector switch in AUTO, or if the crew manually sets the selector to ON, main DC power is removed from the solenoid in the TAI control valve, and the pressure of the engine bleed air will force the valve open, directing warm air to heat the engine cowl. The control circuit is designed open the engine TAI valve in the event of electrical power loss to preserve the integrity of the engine intake airflow.

Two contacts within the valve provide position sensing data to the Modular Avionics Units (MAUs). The left engine valve position is reported to MAU #1, the right engine valve to MAU #2. The position contacts confirm that the valve is either open or closed, and the respective MAU compares actual valve position to the commanded position by monitoring the selector switch position on the ANTI-ICE panel on the cockpit overhead, and the position commands from the corresponding ice detector if the selector switch is in the AUTO position. The MAUs communicate valve position to the Monitor and Warning System that in turn formats Crew Alerting System (CAS) messages for display apprising the crew of cowl anti-ice performance.

NOTE:

There is a fifteen (15) second delay incorporated into the valve position reporting circuit to allow adequate response time to the position commands from the selectors on the ANTI-ICE overhead panel or ice detector commands.

Bleed air pressure within the duct leading to the engine cowl is monitored to ensure that an adequate supply of heated air is available for cowl anti-icing. Pressure is monitored rather than temperature because the TAI bleed air is drawn off prior to the bleed air system precooler, and therefore the temperature of the air supplied to the cowl is not controllable. A pressure transducer is located within the ducting, downstream of the control valve to measure the bleed air pressure actually delivered to the engine cowl. The transducer is powered by twenty-eight volt direct current (28vDC) from the main DC bus (left engine pressure by left main DC, right engine by right main DC). The pressure transducer communicates readings to the respective MAU for communication to the MWS in the same hierarchy as the valve position data (left to MAU #1, etc.). Although the pressure transducer is capable of monitoring a pressure range from zero to seventy-five (0 - 75) psi, the normal pressure within the duct with the cowl anti-ice operating is between zero to thirty-three (0 - 33) psi. (The operating pressure is also a function of engine rotational speed, but sufficient engine speed for anti-ice bleed air can be controlled by the flight crew with power lever position.) The MWS monitors the MAU furnished data and will issue an amber caution CAS message if either left or right duct pressure exceeds thirty-three (33) psi. A blue advisory CAS message will be displayed if the pressure within the left and right engine cowl anti-ice ducts differs more than seven psi plus or minus one psi (7±1 psi), prompting the flight crew to advance the power lever on the engine with the low reading. Cowl anti-ice pressures are displayed on the ECS Pressure 2/3 window display

2. Cowl Anti-Ice Displays:

A. ECS Pressure Synoptic 2/3 Window:

The anti-iced portion of the engine cowl is represented by a colored band at the front of the graphic depicting each engine. The band is shown in white when the engine is not running. If the engine is running and cowl anti-ice is selected on and the bleed air pressure to the cowl is between one point six and thirty-three psi ($1.6 \leq psi \leq 33.0$) the band is shown in green. If bleed air pressure is less than one point six or greater than thirty-three psi (1.6 ≥ psi ≥ 33.0) the band is shown in amber. If the pressure transducer data is invalid, the band is displayed in a dim white.

A digital display of the cowl anti-ice bleed pressure is positioned just forward of the engine graphic. The numerals are color coded to reflect system operating status in a manner corresponding to the colored band depiction of the cowl. The numbers are white when the engine is running and pressure is between one point six and thirty-three psi (1.6 ≤ psi ≤ 33.0). If the engine is not running and the cowl anti-ice is selected on, or the engine is running and bleed pressure is less than one point six or greater than thirty-three psi (1.6 ≥ psi ≥ 33.0) the numerals are shown in amber.

For a full depiction of the ECS Pressure synoptic 2/3 window, see Section 2B-07-00.

B. Primary Engine System 1/6 Window:

Whenever the cowl anti-ice is on, a visual cue is shown on the primary engine display. The letters “A/I” are displayed in green within the circular graphic of engine Turbine Gas Temperature (TGT). If the crew monitors the primary engine display while selecting cowl anti-ice on, system operation will be confirmed by a slight rise in TGT and a slight decrease in Engine Pressure Ratio (EPR).

3. Controls and Indications:

(See Figure 3.)

A. Circuit Breakers (CBs):

The following CBs protect the cowl anti-ice system:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L COWL ANTI-ICE	LEER	D-3	L ESS DC Bus
R COWL ANTI-ICE	REER	D-14	R ESS DC Bus
L COWL A/I PRESS	LEER	E-4	L MAIN DC Bus
R COWL A/I PRESS	REER	E-13	R MAIN DC Bus

B. Crew Alerting System (CAS) Messages:

The following CAS messages are associated with the cowl anti-ice system:

Area Monitored:	CAS Message:	Message Color:
Cowl Anti-ice Duct Pressure	Cowl Anti-ice Hi, L-R	Amber
Cowl Anti-ice Valve Position and Cowl Anti-ice Selector Switch	Cowl Valve Fail Closed, L-R	Amber
Cowl Anti-ice Valve Position and Cowl Anti-ice Selector Switch	Cowl Valve Fail Open, L-R	Amber
Cowl Anti-ice Valve Position and Cowl Anti-ice Selector Switch or Ice Detector Commands	Cowl Anti-ice On, L-R	Blue
Left and Right Engine Cowl Anti-ice Duct Pressure 7 psi Difference	Cowl Anti-ice Miscompare	Blue

4. Limitations:

(See Figure 4.)

A. Flight Manual Limitations:

Cowl Anti-Ice

- Use of cowl anti-icing is required for taxi and takeoff when the Static Air Temperature (SAT) is +8°C or below and visible moisture, precipitation or a wet runway is present. When taxiing or holding on the ground at low power in temperatures less than +1°C, engine operation at 40% LP for ten (10) seconds is recommended just prior to takeoff and at intervals of not more than sixty (60) minutes under these temperature and moisture conditions.
- Use of the cowl anti-ice system is required in flight as indicated in Figure 4:, when visible moisture or precipitation is present, or when signs of icing are observed. Ice accretion may be observed on wings or windshield edges.
- Engine vibration levels may increase when icing occurs. The fan should normally shed the ice and vibration will return to normal. To assist in shedding ice, if high vibration occurs and operational circumstances permit, one engine at a time may be quickly retarded to idle, held there for five (5) seconds and then accelerated to 90% LP. The power lever may then be returned to its original position.
- Automatic anti-icing is inhibited above 35,000 ft. If anti-icing protection is required, it must be manually selected.

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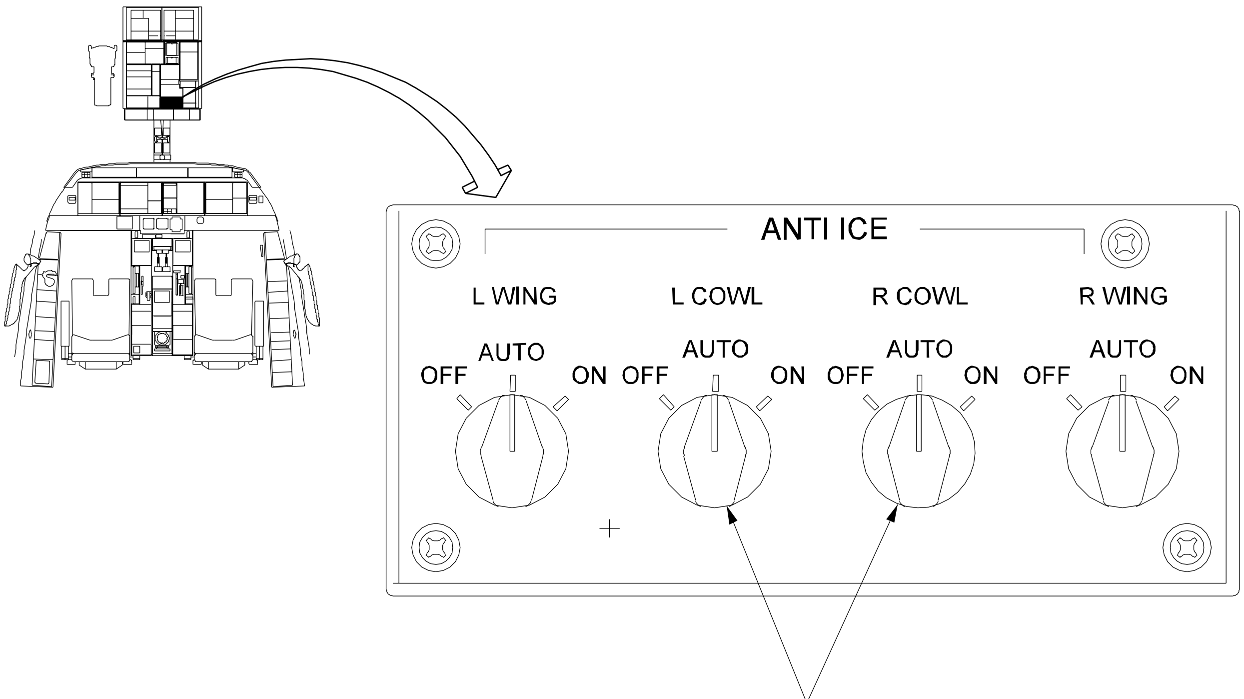

L COWL / R COWL ANTI ICE

OFF:

- Cowl anti-ice valves are closed; airflow is inhibited.

AUTO:

- Normal mode of operation.
- L Essential DC Bus powers L COWL; R Essential DC Bus powers R COWL.
- Airflow inhibited from ground to 1500 feet AGL (during climbout only) and above FL350. During descent, system remains functional until WOW shifts to GROUND mode.
- Bleed Air Controllers (BACs) continually process information, but take no action unless ice is detected.
- Aircraft altitude and ice detector input data is used to schedule airflow. If ice is detected and altitude allows, anti-ice valves are opened.
- Blue L-R Cowl Anti-ice On message displayed on Crew Alerting System (CAS) when airflow is operating.

ON:

- Used primarily when aircraft is on ground, but may be used anytime anti-icing is required.
- Bypasses ice detectors and automatic relays.

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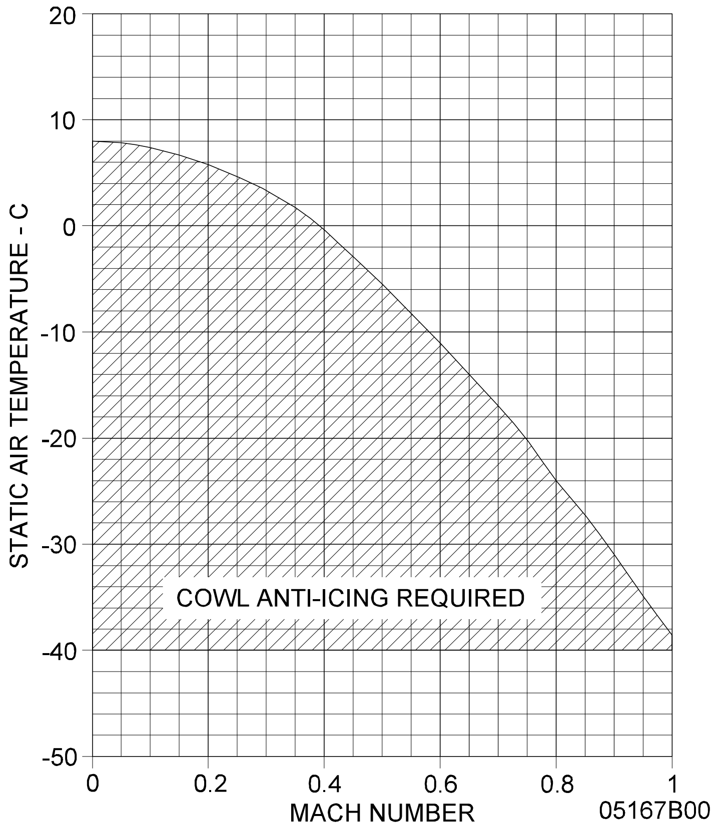
Cowl Anti-Ice Controls
Figure 3



Temperature Range For Cowl Anti-Icing
Figure 4

2A-30-40: Wing Anti-Ice System

1. **General Description:**

   The leading edge of the wing is warmed to approximately one hundred thirty degrees Fahrenheit (130°F / 54.4°C) with hot engine bleed air to prevent the accumulation of ice and consequent disruption of airflow over the wing that could lead to a rapid increase in the stall speed of the aircraft. Wing anti-ice is controlled with the L WING and R WING switches on the ANTI-ICE panel located on the copilot side of the cockpit overhead. The control switches select wing anti-ice OFF, AUTO or ON (seeFigure 5). In the AUTO position, the flow of engine bleed air to heat the wing is automatically controlled by signals from the ice detectors when ice is forming on the aircraft. The AUTO anti-ice function is restricted to altitudes above fifteen hundred feet and below thirty five thousand feet (1,500 - 35,000 ft) to preserve engine fuel efficiency. However, if the automatic wing anti-ice function is operating above fifteen hundred feet (1,500 ft), it will continue to operate until the aircraft touches down and compresses the weight-on-wheels switches. (For a complete discussion of the control function of the ice detectors in the automatic anti-ice mode, see Section 2A-30-20: Ice Detector System.) The flight crew is notified of wing anti-ice system operation in either manual or automatic mode by a blue Crew Alerting System (CAS) advisory message informing the crew that “Wing Anti-ice On, L-R”.

2. Description of Subsystems, Units and Components:

A. Wing Anti-ice Bleed Air Source and Distribution:

Hot pressurized air is drawn from the fifth (5^{th}) and/or eighth (8^{th}) stage of the compressor of each engine as a source of anti-ice bleed for the respective side wing (right engine for right wing, etc.). Fifth (5^{th}) stage air is augmented by eighth (8^{th}) stage air to provide a temperature of five hundred twenty degrees Fahrenheit (520°F / 271°C) at the pre-cooler inlet to the engine bleed air manifold. Fan stage air is used in the pre-cooler to moderate the bleed air manifold temperature to four hundred degrees Fahrenheit plus or minus ten degrees (400 ±10°F / 204 ±5.5°C).

The four hundred degree Fahrenheit (400°F) air is routed forward to each wing through the wing anti-ice control valve and ducting beneath the cabin floor. The wing anti-ice control valve is opened or closed by the Bleed Air Controller (BAC) in response to the both the position of the selector switches on the ANTI ICE panel on the cockpit overhead (OFF, AUTO or ON) and the temperature sensors within the wing leading edge. The control valve has a solenoid and a torque motor. The solenoid powers the valve in response to a selector switch ON command or an ice detector command if the selector switch is positioned to AUTO. The temperature sensors communicate with the BAC, that in turn operates the torque motor of the valve to open or close the anti-ice control valve to maintain the wing leading edge at a temperature of one hundred thirty plus or minus ten degrees Fahrenheit (130 ±10°F / 54.4 ±5.5°C).

A crossover duct is installed between the two supply ducts to allow a single engine to supply heated air to both wings if necessary. One way check valves upstream of the crossover duct prevent the flow of bleed air back to the inoperative engine or anti-ice control valve. When only one engine bleed air source is available for wing anti-ice, the BAC of the remaining engine increases the temperature within the bleed air manifold to five hundred degrees Fahrenheit plus or minus ten degrees (500 ±10°F / 260 ±5.5°C) by decreasing the flow of fan stage air through the pre-cooler. Increasing temperature of the anti-ice supply air compensates for the decrease in volume supplied to each wing and the additional area to be anti-iced by a single source.

B. Wing Air Distribution and Temperature Monitors:

The wing anti-ice supply ducts branch out to the leading edge of each wing. The leading edge is divided lengthwise into two sections: the air supply section and the air return section. In the supply section, hot bleed air is distributed along the leading edge by a perforated tube, termed a “piccolo tube”, that extends from the wing root to the wing tip. Hot bleed air flows out of the holes in the piccolo tube to warm the leading edge, and then enters the return section via openings in the dividing wall separating the two sections.

The bleed air supply lines are tapped off at the wing root to supply two small semicircular piccolo sections incorporated into the area surrounding the landing lights. The sections direct hot air forward onto the landing light lens covers to prevent ice from blocking the effectiveness of the landing lights.

The anti-ice air return sections are between the supply sections and the forward wing beams that form the front of the aircraft fuel tanks. The return extends the length of the wing, providing a means for the bleed air to exhaust from wing. The return ducts are configured to direct air through the main wheel wells to melt any ice that may have accumulated on the wheels and brakes during takeoff. The air is then exhausted overboard through louvers on the underside of the aircraft at the rear wing fillets.

Located within the bleed air return section of each wing leading edge are a temperature sensor and four temperature switches. The temperature sensor operates at all times when there is electrical power on the aircraft, whether the wing anti-ice is selected on or not. The temperature switches are powered whenever wing anti-ice is selected on and the anti-ice control valve opens to provide bleed air to the wing. The sensor and switches are positioned at the gap bands on the leading edge. (The gap bands are removable panels that cover the joints of the four sections of the leading edge - the sections facilitate replacing damaged metal on the leading edge without removing the entire front of the wing.) The temperature sensor is mounted in the return section behind gap band number two (2), at approximately one third (1/3) of the wing length outboard from the root. The sensor communicates over an ARINC-429 connection with the BAC to provide a temperature reading for operation of the wing anti-ice control valve. The BAC varies the open cross section of the control valve to maintain the wing leading edge at the desired temperature of one hundred thirty degrees Fahrenheit, plus or minus ten degrees (130 ±10°F / 54.4 ±5.5°C). Each BAC transmits wing temperature data to the respective Modular Avionics Unit (MAU) - left wing to MAU #1, right wing to MAU #2. The MAUs in turn forward temperature information to the Monitor and Warning System (MWS) for formatting and presentation on the ECS Pressure synoptic window display. See the system diagram in Figure 6.

Three temperature overheat switches and one underheat switch in each wing provide protection for the anti-ice system. The overheat switches close when the temperature in the wing bleed air return exceeds one hundred eighty degrees Fahrenheit (180°F / 82.2°C). Overheat switch closure is reported to the onside MAU (left wing to MAU #1, right to MAU #2) and forwarded to the MWS for display of an amber Crew Alerting System (CAS) message text reading “Wing Hot, L-R”. The overheat switches are located inboard at gap band number one (1), adjacent to the temperature sensor at gap band number two (2) and toward the outboard section of the leading edge at gap band number four (4).

The underheat switch is mounted next to the overheat switch at gap band number two (2), and closes if the temperature within the return drops below one hundred degrees Fahrenheit (100°F / 37.7°C). Unlike the overheat switches, an underheat condition is reported to both MAUs #1 and #2 for redundancy since each wing has only one underheat switch. The MAUs signal the underheat condition to the MWS that generates an amber caution CAS message “Wing Temperature Low, L-R”. The low temperature caution message is inhibited for two (2) minutes after the wing anti-ice is selected on (either manually or automatically) to allow hot air to reach the wing leading edge and warm the supply and return sections of the duct.

C. Cockpit ECS / Pressure Synoptic 2/3 Window Display:

The operation of the wing anti-ice system may be monitored on the ECS / Pressure synoptic display (wing anti-ice functions and temperatures are not shown on the ECS / Pressure system 1/6 window display). A schematic representing the bleed air ducts from each engine to the corresponding wing is shown on the synoptic display, as well as the crossover duct. The temperature within the anti-ice returns, as reported by the temperature sensors at gap band number two (2) is shown in Fahrenheit above the supply ducts. Both the duct schematic and temperature readouts are color coded to indicate system performance.

The ducts are depicted in white if the wing anti-ice is off. When the system is on, the ducts are shown in green when the system is functioning correctly and temperatures within the wing leading edge are acceptable. If a fault is present in a supply duct or temperatures are above or below normal range, the duct is represented in amber.

The digital temperature readout is similarly color coded. If wing anti-ice is off, or return temperatures are equal to or greater than one hundred degrees Fahrenheit but less than one hundred eighty degrees Fahrenheit ($100°F \le temp < 180°F$ / $37.7°C \le temp < 82.2°C$) within two minutes of selecting wing anti-ice on, the digits are shown in white. If the temperature is outside of the desired range, the digits are colored amber.

3. Controls and Indications:

A. Circuit Breakers (CBs):

(1) The following CBs protect the wing anti-ice system:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L WING ANTI-ICE	LEER	D-4	L ESS DC Bus
L BLEED AIR CONT	LEER	E-10	L ESS DC Bus
R WING ANTI-ICE	REER	D-13	R ESS DC Bus
R BLEED AIR CONT	REER	E-9	R ESS DC Bus

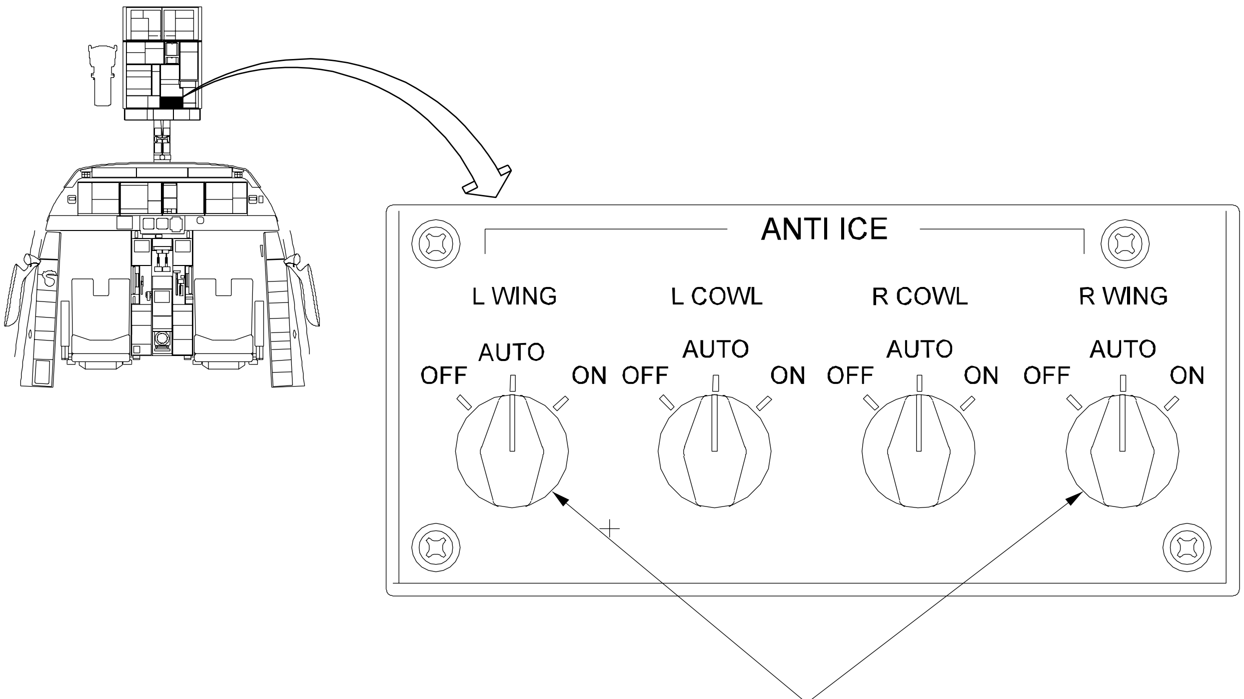
B. Crew Alerting System (CAS) Messages:

The following CAS messages are associated with the wing anti-ice system:

Area Monitored:	CAS Message:	Message Color:
Wing Anti-ice Control Valve, Bleed Air Controller	Wing Anti-ice Sys Fail, L-R	Amber
Wing Anti-ice Bleed Air Return Temperature	Wing Hot, L-R	Amber
Wing Anti-ice Bleed Air Return Temperature	Wing Temperature Low, L-R	Amber
Wing Anti-ice Selector Switches, Ice Detector Signals	Wing Anti-ice On, L-R	Blue

4. Limitations:

Wing Anti-Ice: Operation of wing anti-icing is required if icing conditions are imminent, or immediately upon detection of ice formation on wings, winglets, or windshield edges.



L WING / R WING ANTI ICE

OFF:

- Wing anti-ice valves are closed; airflow is inhibited.

AUTO:

- Normal mode of operation.
- L Essential DC Bus powers L WING; R Essential DC Bus powers R WING.
- Airflow inhibited from ground to 1500 feet AGL (during climbout only) and above FL350. During descent, system remains functional until WOW shifts to GROUND mode.
- Bleed Air Controllers (BACs) continually process information, but take no action unless ice is detected.
- Aircraft altitude and ice detector input data is used to schedule airflow. If ice is detected and altitude allows, anti-ice valves are opened.
- Blue L-R Wing Anti-ice On message displayed on Crew Alerting System (CAS) when airflow is operating.
- Wing temperature is controlled to 130 + 10 F when airflow is present.

ON:

- Used primarily when aircraft is on ground, but may be used anytime anti-icing is required.
- Bypasses ice detectors and automatic relays.
- Airflow is provided continuously and controlled to 130 ± 10° F whether ice is detected or not.

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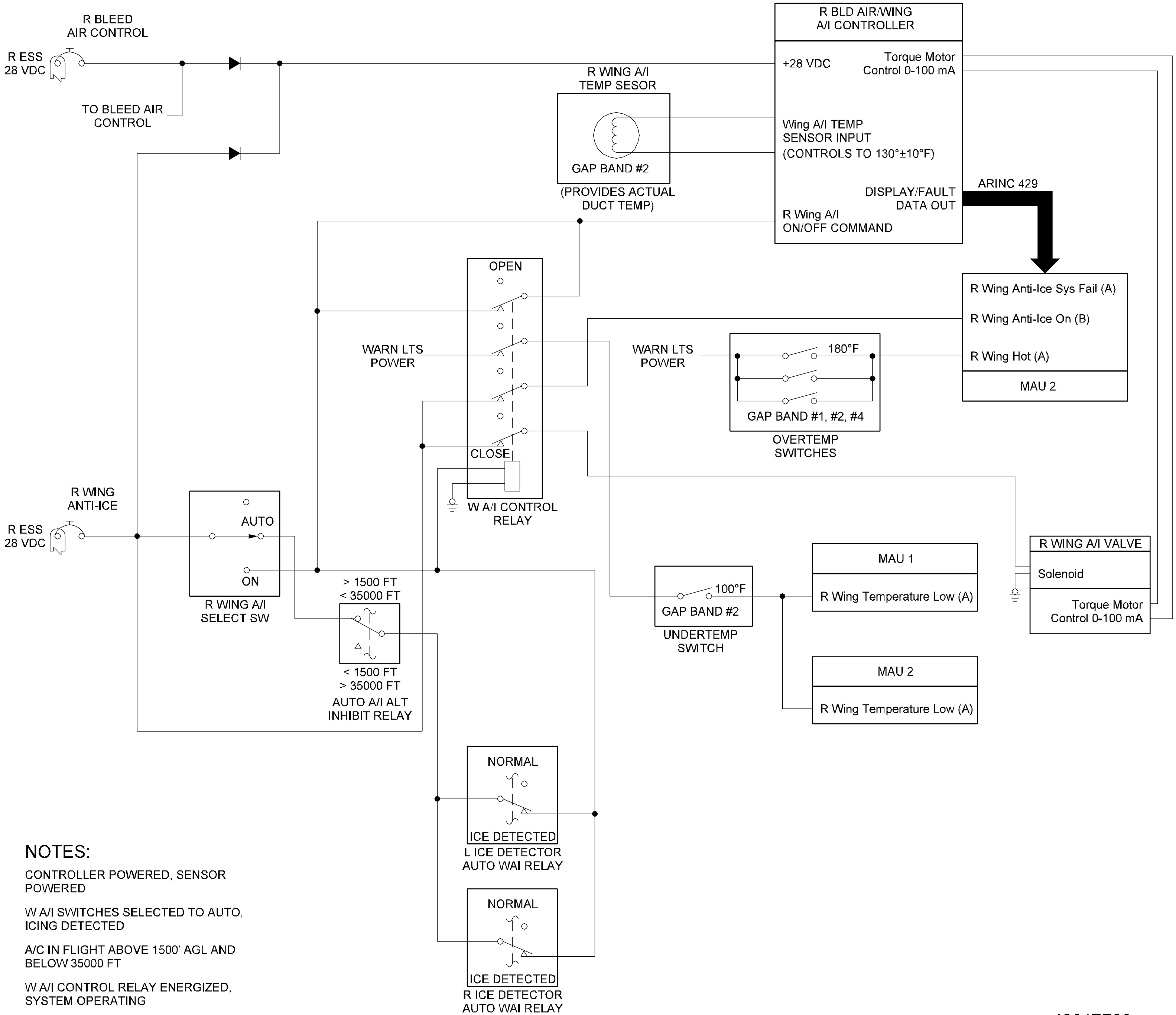
Wing Anti-Ice Controls
Figure 5



NOTES:

CONTROLLER POWERED, SENSOR POWERED

W A/I SWITCHES SELECTED TO AUTO, ICING DETECTED

A/C IN FLIGHT ABOVE 1500' AGL AND BELOW 35000 FT

W A/I CONTROL RELAY ENERGIZED, SYSTEM OPERATING

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Wing Anti-Ice Temperature Monitoring and Control System
Figure 6

2A-30-50: Windshield and Window Ice Protection and Rain Removal Systems

1. General Description:

The front windshields and side windows of the cockpit are heated to prevent the formation of ice and prevent fogging when operating at the low outside air temperatures associated with high altitudes or during conditions of high humidity. The front windshields are a composite sandwich made up of layers of chemically strengthened glass, urethane and polyvinyl butyral films. The side windows are composed of two layers of stretched acrylic separated by a vinyl film. A transparent but electrically conductive chemical oxide coating is applied to the inner face of the outer layers of both the windshield and side windows. When alternating current (AC) is applied to the conductive coating, the resistance of the coating causes an increase in heat. The amount of heat produced within the windshield and side window layers is controlled by maintaining the resistance within a specified range.

Two pushbutton switches on the WINDSHIELD HEAT panel on the copilot side of the cockpit overhead (shown in Figure 7) control the application of power to the cockpit windows. Each pushbutton controls a Windshield Heat Control Unit (WHCU) that directs AC power to both a windshield panel and a side window. The left pushbutton controls the WHCU for the pilot windshield and copilot side window heat, and the right pushbutton selects the WHCU for the copilot windshield and pilot side window heat. Four blue indicator lights, one for each heated window, are located above the switches and illuminate when power is applied to heat the respective windshield / window. See the system diagram in Figure 8.

The windows in the passenger compartment are also heated in a manner similar to the cockpit side windows to prevent fogging and to preserve passenger visibility at high altitudes.

Cockpit window heat is supplemented by a blower system that directs high velocity air onto the external surface of the windshields to remove rain. The rain removal system operates only when the aircraft is on the ground.

2. Description of Subsystems, Units and Components:

A. Cockpit Windshield and Window Ice Protection:

The flight crew initiates heating of the windshield and side windows by depressing the two pushbuttons on the WINDSHIELD HEAT panel on the cockpit overhead. Each pushbutton controls one WHCU that in turn provides power to one windshield and to the opposite side window. The pushbuttons are labelled with the windshield / window combination supplied by the WHCU: LF/RS for left front and right side and RF/LS for right front and left side. Four blue power on indicators are located above the pushbutton, one indicator for each windshield and side window. The indicators illuminate when power is applied to the respective windshield / window. When the pushbuttons are selected on, the WHCUs first perform a built-in-test (BIT) routine prior to applying AC power to the windshield / window panels. The WHCUs next select a resistance sensor for each panel. Each windshield / window has two resistance sensors for redundancy. The WHCUs select one of the two to monitor resistance as a measurement of heat. The WHCUs then close the relay to each panel directing AC power to the windshield / window.

The windshields are supplied with one hundred fifteen volts (115v) in two phases, ϕA and ϕB, allowing the windshields to draw up to two hundred eight volts (208v) to meet heating requirements. The side windows are powered with only a single phase (ϕC) and are limited to one hundred fifteen volts (115v). Power to the windshields is applied gradually over a four (4) minute interval to reduce thermal shock to the glass layers. The side windows are powered immediately, since the total amount of available voltage is less and the acrylic layers are more flexible.

After initial power has been applied, the WHCUs maintain voltage to the windshields / windows until a resistance of three hundred thirty-four (334) ohms is reached producing approximately one hundred fourteen degrees Fahrenheit (114°F / 45.5°C) within in the windshield / window layers. The WHCUs de-engergizes the power supply relays until resistance drops to three hundred twenty-six (326) ohms, or approximately one hundred four degrees Fahrenheit (104°F / 40.0°C). The WHCUs maintain windshield / window temperatures within this range whenever the system pushbuttons are selected on.

If a fault occurs within one of the windshields / windows or the controlling WHCU, the blue power on indicator associated with the malfunction will flash on and off for ninety (90) seconds and then extinguish. Fault monitoring for windshield / window heat is provided through connections to the Modular Avionics Units (MAUs) - MAU #1 for left front windshield / right side window and MAU #2 for right front windshield / left side window. The MAUs communicate system status to the Monitor and Warning System (MWS) that formulates Crew Alerting System (CAS) messages for display to the crew. If a fault is not correctable by the WHCU, the MWS will generate the appropriate blue advisory CAS message for the windshield / window heat failure. CAS messages for windshield / window heat failure are displayed for only five (5) minutes and are then automatically deleted on the CAS window.

Each WHCU has four indicator diodes for each corresponding windshield / window unit that illuminate to identify the system fault. The specific failure information is not readily available to the crew, since the WHCUs are installed in the equipment rack beneath the cabin floor near the main entranceway. The diode indications are useful for post-flight maintenance troubleshooting.

B. Windshield Rain Removal

Although the exterior of the windshields are coated with a sealant to promote water runoff, a blower system can be used to increase visibility through the cockpit windshields if rain accumulates on the outer surface. A large diameter duct located in the radome compartment houses a fan that draws ambient air from a plenum in the nose wheel well and forces it through two duct throats (one for each windshield) and out two hinged nozzles to impact on the bottom of each windshield. The high velocity airflow removes beaded water droplets to provide unobstructed visibility to the flight crew. The system operates only when the aircraft is on the ground (weight-on-wheels). If the system is left on during takeoff, the fan will shut off and the nozzles will rotate downward to fair with the nose of the aircraft as soon as the aircraft lifts off the runway. The fan is powered by one hundred fifteen volt alternating current (115v AC) and controlled by twenty-eight volt direct current (28v DC). The system is activated with a pushbutton switch labelled WSHLD BLWR located on the cockpit overhead adjacent to the windshield heat controls. See Figure 9.

C. Cabin Window Heat

The windows in the cabin are heated to preserve visibility by preventing the formation of condensation on the transparent surface. Each window structure includes an outer structural pane and a removable inner pane made up of two layers of stretched acrylic separated by a resistive transparent coating. The windows are heated by applying power to the coating though two small bus bar connections on the window edge. The resistance of the coating compound causes the inner pane to warm sufficiently to prevent fogging.

Each window is supplied with a single phase of low power alternating current (AC) from the main buses. The left side windows are powered by the left main bus and the right side windows from the right main bus. Current draw by the windows is limited by three (3) ampere circuit breakers to prevent the windows from overheating (the acrylic material will distort or bubble if temperatures within the coating layer exceed specifications). Windows number six (6) and seven (7) (windows are numbered forward to aft) on each side of the aircraft are emergency exit windows, and have special electrical connectors to supply window heat power. The emergency windows are removable to allow egress - the EXIT locking latch above the window is first pulled open to release the windows, then the windows may then be pulled inward into to cabin to free the opening for exit. The electrical connector for window heat is a contact type fitting incorporated into the locking latch. When the window is latched, the contact mates with the connection for the heating film on the exterior of the interior acrylic pane. When the latch is unlocked, the power to the window is interrupted. This same circuit is used to provide a window unlocked signal to the MAUs - windows six (6) and (7) on the left side are monitored by MAU #1, those on the right side by MAU #2. The MAU(s) report an unlocked condition to the MWS that will forward an amber “Cabin Window Unlocked” caution message for display on the CAS window. A diagram of the cabin window heat system is contained in Figure 10.

Cabin window heat is controlled with the pushbutton switch labelled CABIN WDO HT on the cockpit overhead panel to the left of the windshield heat controls (shown in Figure 9). The pushbutton switch is normally depressed to the on position since power will be applied to the cabin windows only after takeoff - a relay in the control circuit will not close until weight is off the aircraft wheels. If the pushbutton is not selected on, the OFF legend within the pushbutton will illuminate. There are provisions for applying power to the cabin windows while on the ground to perform maintenance on the system. A CABIN WDW HTRS GROUND BYPASS switch is installed in the Observer and Test Monitor Panel on the side of the Left Electronics

Equipment Rack (LEER). The switch is guarded and has two positions, OFF and ON.

NOTE:

When using the override switch to power cabin window heat, care should be taken to avoid overheating that will result in damage to the windows. The override switch should be used for very short periods to verify the integrity of the system.

3. Controls and Indications:

A. Circuit Breakers (CBs):

The following CBs protect the cockpit and cabin window systems:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L SIDE WSHLD	COP	A-1	R MAIN AC Bus ϕC
R FRONT WSHLD	COP	B-2	R MAIN AC Bus ϕA and ϕB
R SIDE WSHLD	POP	A-1	L MAIN AC Bus ϕC
L FRONT WSHLD	POP	B-2	L MAIN AC Bus ϕA and ϕC
WSHLD BLWR	LEER	F-5	L MAIN AC Bus
WSHLD BLWR CONT	LEER	E-6	L MAIN DC Bus
L WDO HT CONT	LEER	K-15	L MAIN DC Bus
L WDO HT 2&5	LEER	K-14	L MAIN AC Bus ϕA
L WDO HT 3&6	LEER	K-13	L MAIN AC Bus ϕB
L WDO HT 4&7	LEER	K-12	L MAIN AC Bus ϕC
R FWD WDO HT CONT	REER	F-28	R MAIN DC Bus
R WDO HT 2&5	REER	F-30	R MAIN AC Bus ϕA
R WDO HT 3&6	REER	F-31	R MAIN AC Bus ϕB
R WDO HT 4&7	REER	F-32	R MAIN AC Bus ϕC
R/L FWD WDO HT	REER	F-29	R MAIN AC Bus ϕC

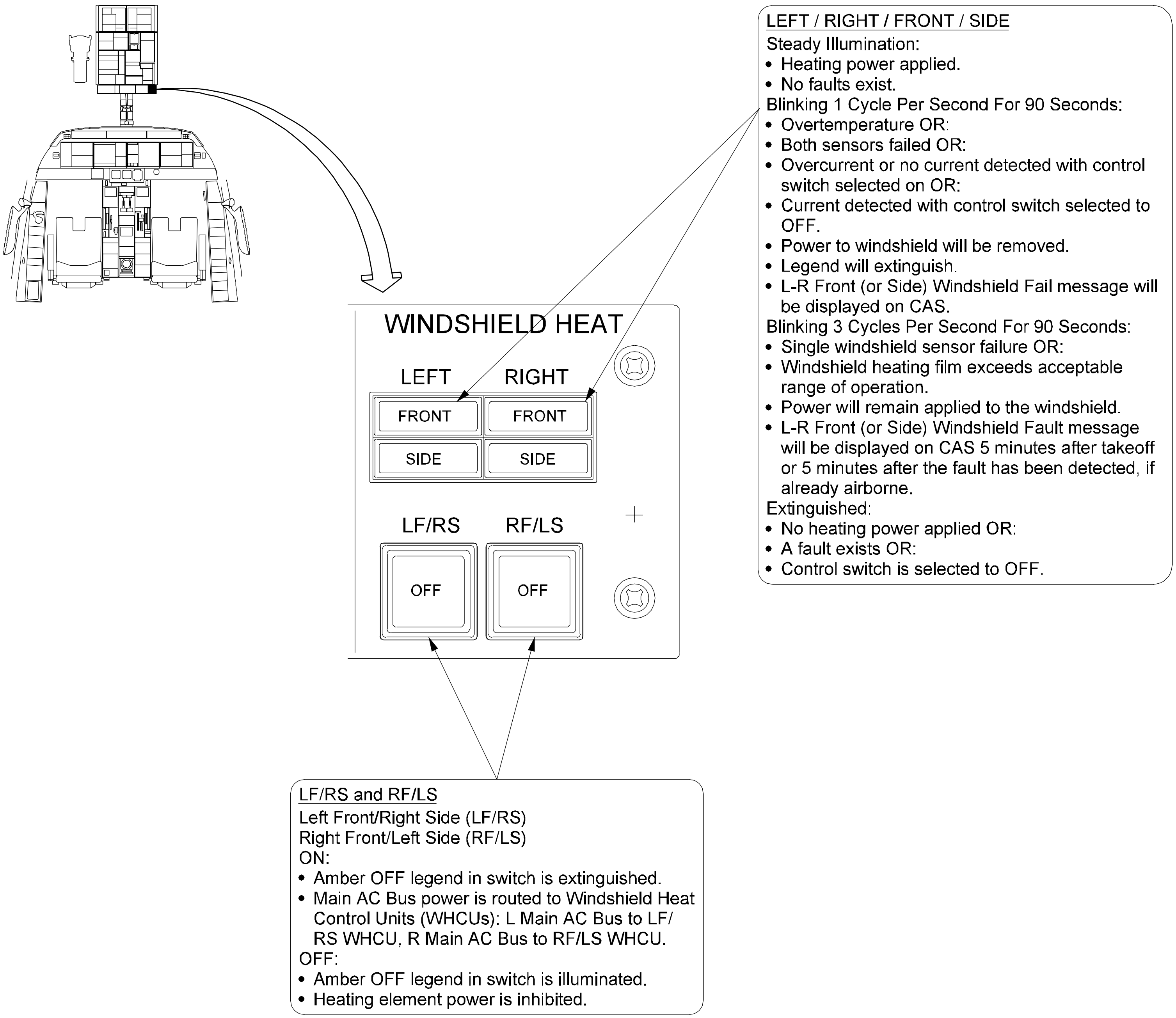
B. Crew Alerting System (CAS) Messages:

The following CAS messages are associated with the cockpit and cabin window heat and rain removal systems:

Area Monitored:	CAS Message:	Message Color:
Window Heat Control Unit, Both Resistance Sensors	Front Windshield Fail, L-R	Amber
Window Heat Control Unit, Single Resistance Sensor	Side Windshield Fail, L-R	Amber
Cabin Emergency Exit Window Latch (windows 6 and 7)	Cabin Window Unlocked	Amber
Window Heat Control Unit, Both Resistance Sensors	Front Windshield Fault, L-R	Blue
Window Heat Control Unit, Single Resistance Sensor	Side Windshield Fault, L-R	Blue

4. Limitations:

There are no limitations for cockpit and cabin window heat or rain removal as of this writing.



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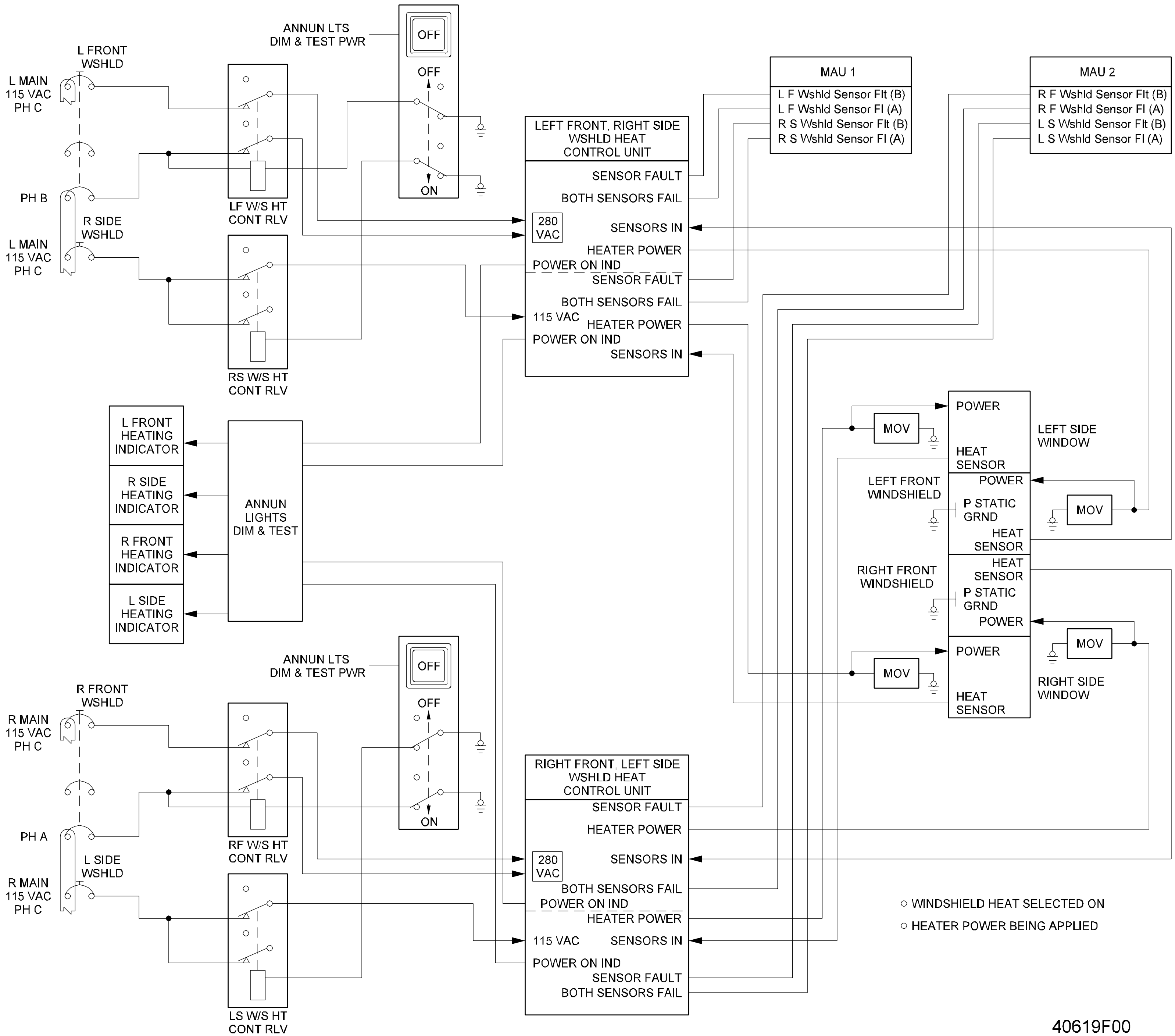
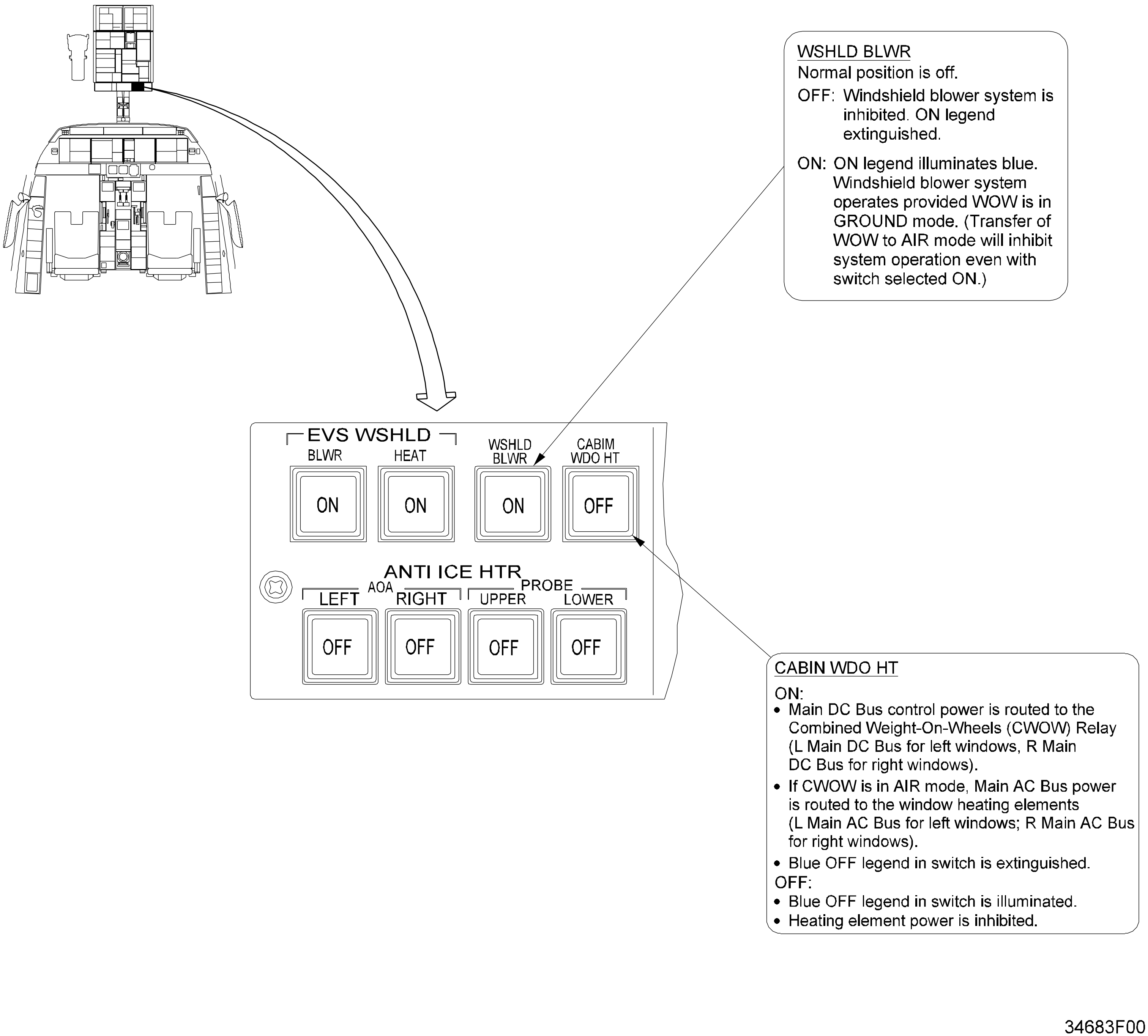
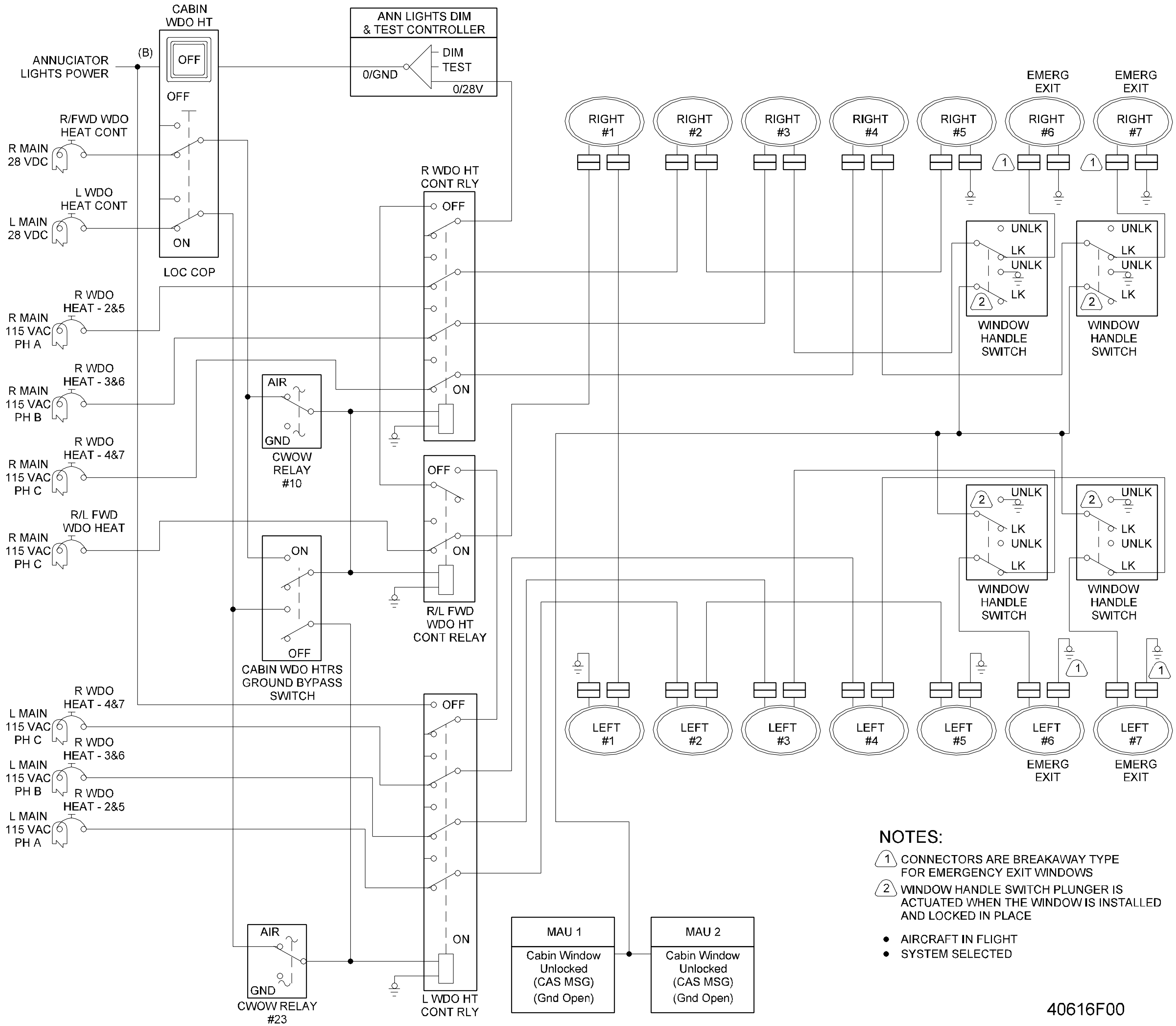
Windshield Heat Control Switches
Figure 7



Cockpit Window Heat
Figure 8



Windshield Blower and
Cabin Window Heat
Control Switches
Figure 9



NOTES:

1. CONNECTORS ARE BREAKAWAY TYPE FOR EMERGENCY EXIT WINDOWS
2. WINDOW HANDLE SWITCH PLUNGER IS ACTUATED WHEN THE WINDOW IS INSTALLED AND LOCKED IN PLACE

- AIRCRAFT IN FLIGHT
- SYSTEM SELECTED

40616F00

Cabin Window Heat
Figure 10