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Aircraft Ventilation Systems Study

Volume I

David E. Lorengo
Allen Porter
Heath Tecna Aerospace Company

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16. Abstract

This report presents data required to assess the performance and effects of the environmental control system on smoke evacuation from the cabins of large commercial jet transports during an in-flight fire.

Volume I of the study contains data for the environmental control systems (ECS) of the Boeing 707, 727, 737, 747, 757, 767, McDonnell Douglas DC-8, DC-9, DC-10, Lockheed L-1011, and Airbus A-300, A-310. Included are descriptions of the ECS operation; airflow rates for various flight regimes; thermodynamic parameters; ducting schematics for distribution and ventilation systems; and ECS energy requirements.

Volume II presents historical data on in-flight aircraft cabin fires; jet transport certification and operating regulations relating to cabin and cockpit smoke evacuation; emergency procedures for smoke evacuation; and aircraft in-flight fire scenarios with analyses of options available to the crew.

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Preface

This study was conducted by Heath Tecna Aerospace Company for the Federal Aviation Administration Technical Center under Contract No. DTFA 03-84-C-0084 during the period November 1, 1984 - October 31, 1985. David Lorengo, Principal Investigator and Allen Porter, Program Manager, co-authored the report. Mr. Peter Versage was the Contracting Officer's Technical Representative for the FAA Technical Center.

The report comprises two volumes. Volume I presents the results of the survey of jet transport aircraft Environmental Control Systems (ECS). Volume II provides an assessment of procedures available for evacuating smoke and fumes from the interior of an aircraft during flight.

In Volume I, the survey is divided into sections for each of the twelve aircraft types studied. Each section includes detailed descriptions of the ECS components, the operation of the system, and typical performance data. The study does not attempt to cover each configuration of a given aircraft unless there is a significant difference in the ECS. Where this occurs, the aircraft is reported as a separate model.

Volume II provides historical data on in-flight fires and identification of high fire risk areas. Certification requirements and recommended procedures for evacuating smoke from the aircraft are presented. Various in-flight fire scenarios are developed and analyzed with respect to the crews' options and actions in each hypothetical situation.

Environmental Control Systems performance data, schematic diagrams, and illustrations appearing in this report are based on information developed by the airframe manufacturers, manufacturers of the ECS equipment, and by airline operators. In some cases, diagrams, tables, and illustrations have been redrawn for clarity or to eliminate details extraneous to the study. The authors specifically acknowledge the cooperation and assistance of the AiResearch Manufacturing Company, a Division of the Garret Corporation, Hamilton Standard Division of United Technologies, Lockheed-California Company, Cammacorp., and numerous air carriers for providing detailed ECS performance data. Valuable insight into fire propagation phenomena and historical data on aircraft fires were provided by James Brenneman, who was a consultant for the study. Numerous technical reports, published data, and aircraft accident reports were used in the preparation of this report, and are identified as references or listed in the bibliography.

TABLE OF CONTENTS

DESCRIPTION | PAGE

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

DEFINITIONS AND ABBREVIATIONS

ECS: Environmental Control System

A/C: Air conditioning

Pack: The portion of the ECS that provides a supply of pressure and temperature conditioned air.

ΔP: Differential Pressure

ΔT: Temperature Difference

Air Cycle: Thermodynamic cycle in which engine bleed-air is compressed, cooled and expanded to provide a source of cold air.

Vapor Cycle: Thermodynamic cycle in which compression and expansion of a working fluid provides the source of cooling.

Bleed-Air: High temperature and pressure air taken from the compressor stages of the engines used for operating other aircraft systems.

ACM: Air Cycle Machine - Portion of the pack that compresses and expands bleed-air.

Outflow Valve: An adjustable opening in the fuselage skin used to control internal pressure.

Flow Control Valve: Regulates the flow of bleed-air from the pneumatic system into the pack.

Jet Pump: A device in which high pressure air is exhausted in the throat of a venturi to provide a source of low pressure upstream of the venturi.

Ram Air: Air impinging upon the surfaces of the airplane as a result of its velocity.

Back Draft: The rapid burning of flammable gases, vapors and particulate matter which are produced in a combustion process where insufficient oxygen is present. Also called Flash Fire.

Flame Over: The rapid spread of fire over one or more surfaces.

Flash Fire: See Back Draft and Flame Over.

DEFINITIONS AND ABBREVIATIONS

Flash Over:	The point in a fire where all combustible materials in the area are heated to or above their ignition temperature and ignite almost simultaneously.
N.A.:	Data not available for this study.
CVR:	Cockpit Voice Recorder.
DFDR:	Digital Flight Data Recorder.
C/F/R:	Crash/Fire/Rescue
KW:	Kilowatt
KVAR:	Kilo Volt - Amp Reactance
FL:	Flight Level
ϕ:	Phase
msl:	Mean Sea Level
psi:	Pounds per Square Inch

EXECUTIVE SUMMARY

The equipment onboard jet transport aircraft which provides ventilation and pressurization is collectively called the Environmental Control System (ECS). The ECS is composed of the air conditioning packs, temperature and pressurization controls, instrumentation for monitoring the status and performance of the various components, and distribution ducting for maintaining a uniform airflow throughout the interior of the airplane. In addition to providing a suitable environment for the aircraft's occupants during high altitude flight, the ECS performs other functions such as avionics equipment cooling and cargo bay heating.

This study surveys the Environmental Control Systems of the principal aircraft of the commercial fleet, to determine if the ECS can provide an effective means to evacuate smoke from the cabin in event of an in-flight fire. Included are detailed system descriptions and performance data; historical data relating to the incidence of in-flight cabin fires; descriptions of potential fire-risk areas; certification and operating regulations relating to smoke evacuation; and procedures which have been developed for emergency smoke evacuation. Several in-flight fire/smoke scenarios are presented which illustrate possible emergency situations and the actions which might be taken by the crew under those conditions.

Conclusions reached in the study are:

The incidence of in-flight fire or smoke in the cabins of jet aircraft is low relative to overall flight operations. It is significant, however, that for the past five years, an average of more than one cabin fire or smoke incident has been reported every two days, and of those reported, at least one each week has been serious enough for the crew to make an emergency descent or unscheduled landing. The potential for disaster from an in-flight cabin fire has been tragically demonstrated by the few accidents which have occurred during this period.

Today's jet aircraft have large quantities of concealed space containing electrical equipment, which are possible sources of ignition. The fact that ignition can occur and fire develop undetected in these areas is a potentially hazardous situation.

There are no Federal Aviation Regulations which quantitatively deal with cabin or cockpit smoke evacuation.

Although the ECS is the only system on jet aircraft which provides ventilation of the cabin, it is not designed to remove large quantities of smoke or toxic fumes, and is effective only in evacuating residual smoke after a fire has been extinguished.

The passengers' emergency oxygen system provides little protection from smoke in the cabin because it is designed only to produce supplemental oxygen to enrich cabin air during depressurized descent.

Certain emergency procedures developed by the aircraft manufacturers and airline operators to augment the ECS, and provide increased ventilation to the cabin for smoke removal have not been approved by the FAA.

Mass passenger movement during an in-flight cabin fire can affect aircraft stability due to changes in the aircraft center of gravity.

Changes to regulations relating to classification of wide body aircraft cargo bays have been recommended but not enacted.

INTRODUCTION TO VOLUME 1

Commercial jet transports currently operating around the world have compiled an outstanding record of safe operation, making air travel the safest form of transportation available to the public. However, serious aircraft accidents continue to occur and it is the responsibility of the industry and the appropriate Federal regulatory agencies to continue to strive to improve this record.

Of particular concern are those incidents involving an in-flight fire where the occupants are not subjected to traumatic impact injury, but succumb to the effects of smoke and toxic gases produced by the fire. Although an in-flight fire is a relatively rare occurrence, when a fire occurs that is beyond the ability of the crew to extinguish, it has usually resulted in a high loss of life.

Until recently, most research and technology efforts were aimed at reducing or eliminating post-crash fires. Little attention has been focused on maintaining a survivable cabin environment in event of an in-flight fire.

The 1983 in-flight fire aboard Air Canada Flight 797 near the Greater Cincinnati Airport, and the resulting loss of life in an otherwise survivable accident, pointed out the need for a better understanding of in-flight fire situations, and for methods to ventilate the cabin until an emergency landing and evacuation can be accomplished.

Thorough knowledge of the capabilities of onboard systems to cope with an emergency are of utmost importance to minimize the dangers to passengers and crew from in-flight fires. In particular, the ability of the Environmental Control System (ECS) to maintain a survivable atmosphere by venting heat, smoke, and toxic gases must be established. This report presents data required to assess the adequacy of the ECS to ventilate the cabin during an in-flight fire emergency, and options available to the crew to maintain a survivable atmosphere. It also provides a basis for recommendations of changes in procedures that will maximize survivability in an in-flight fire emergency.

The following sections present, on a type-by-type and model-by-model basis, aspects of the ECS necessary to assess its capability to ventilate the cabin during an in-flight fire. Aircraft surveyed include the Boeing 707, 727, 737, 747, 757, 767, McDonnell Douglas DC-8, DC-9, MD-80, DC-10, Airbus A300, A310, and Lockheed L-1011. The data presented represent a typical configuration for the particular model being reviewed relative to lavatory and galley location, and passenger capacity. When a portion of the data applies only to a certain variant within a model series, it is presented separately and clearly identified as to which variant it applies. When the data are the same for all variants, these are identified only by the model designation. If variation in the ECS is driven by features other than model variant, the differences and their governing factors are identified. A paragraph at the beginning of each section describes important variations within the model series.

Each section covers a different airplane type, and presents thirteen items for each type surveyed. The sections are arranged with text followed by tabular data, illustrations and schematics.

The tabular data include compartment volumes, certification dates, approximate number produced, pressurization system capabilities, volume flow rates, system temperatures and pressures for varying flight regimes, and energy requirements of major ECS equipment and control systems. The values presented in the tables represent typical performance on a hot day. In this condition, the packs are operating at minimum efficiency and the flow rates are at the lower limits of system performance. Cabin temperature during all phases of flight is assumed to be 75°F maximum.

The illustrations are provided to show the pack schematic, conditioned air distribution ducting, individual air distribution ducting, equipment cooling systems, cargo heating systems, recirculation systems, ventilation systems, pressurization controls, and environmental controls.

The text provides further description of the operation of the systems, and other pertinent data necessary to assess the system's performance during an in-flight fire situation.

Details of the ECS vary by airplane type and model; in general, the air conditioning and distribution systems are similar, using either vapor or air cycle cooling systems. Vapor cycle systems were used on older types and were replaced by air cycle systems beginning with the 707-300 and the DC-9 programs. The air cycle system's main advantages are reduced weight and maintenance.

Vapor cycle systems are still in service on some 707 and DC-8 airplanes. The vapor systems can be divided into two subsystems, air supply and cooling. The air supply system consists of auxiliary compressors, driven by bleed-air, that supply hot compressed air to the heating and cooling systems.

The cooling of the supply air is accomplished by the freon vapor cycle system that operates much in the same manner as a home refrigerator. Freon gas is compressed, cooled, then evaporated in one side of a heat exchanger. The evaporating Freon extracts heat from the hot air blown through the other side of the heat exchanger to produce cold air. The remaining hot air is mixed with cold air according to cabin heating or cooling demand to produce temperature conditioned air.

The remaining airplanes included in this survey have air cycle systems. The source of air in this system is bleed-air from the engine compressor. The bleed-air is routed through a heat exchanger to be cooled by ram air before undergoing further compression. The compressed air is routed through another heat exchanger to be further cooled, then expanded in a turbine to provide cold air. This cold air is then mixed with hot air that has bypassed the air pack to produce air at the required temperature for cabin heating or cooling demands.

Conditioned air is introduced in the upper areas of the cabin, either from the ceiling or below the stowage compartments, passed down through the cabin, and then exhausted through floor-level outlets in the sidewalls. The cabin exhaust air then passes between the airplane skin and cargo compartment lining to provide heat for the cargo compartments. As the air passes over the cargo compartment lining, it moves aft where it is dumped overboard at a controlled rate through outflow valves located on the underside of the fuselage.

SECTION 1

BOEING 707

Model Variation

The 707 was produced in four models, designated as the -100, -200, -300 and -400. The 720 can also be considered to be of this line, being dimensionally similar, but structurally different. The -100, -300 and -720 were offered with a choice of two engines, a turbojet or a turbofan. The turbofan model was designated by a 'B' following the dash number. A summary of first flight, certification dates, and totals produced are shown in Table 1-1.

The -100 was introduced to fill long range over-water transport needs. It was followed shortly by a stretched re-engined version, the -300. The -400 then followed as a Rolls Royce-engined version of the -300, and the -200 as a re-engined -100. The -720 was developed as a long range option to the 707 series. The -720 incorporates advanced structures, reduced length and reduced passenger capacity to achieve long range capability. The -100, -300 and -720 models were then modified to use turbofan style engines. These models can be identified by the 'B' designation after the model dash number.

The 707 and 720 series were offered with two types of ECS, the vapor cycle system or the air cycle system. The vapor cycle systems were used on the -100, -200, -720 models, and the air cycle was used on some -300B and -300C models. The distribution ducting is the same for both systems with the exception of recirculation features for ground operation. The vapor and air cycle cooling systems will be presented separately, and differences in distribution ducting caused by the type of system will be clearly identified. Ventilation parameters for the 707 are shown in Table 1-2.

Environmental Control System

Vapor cycle and air cycle versions of the ECS are both two-pack systems which use engine bleed-air (turbofan airplanes only) or compressed air from auxiliary compressors as the air source. The packs are located below the wing center section in an unpressurized area of the fuselage. The ECS can be separated into two subsystems, air supply and cooling. A block diagram of the ECS is shown in Figure 1-1.

Hot compressed air is supplied to the pack by either auxiliary turbo compressors or engine compressor stages. The turbo compressors are mounted on the engine strut of engines 2, 3 and 4, and use 16th-stage engine bleed-air as a power source. The bleed-air expands in a turbine to drive a compressor that compresses atmospheric air. The air is heated by compression and is routed to the pneumatic system, then to the pack shut-off valve. Bleed-air from the engine intermediate compressor stages may also be used as a supplemental or alternate source of hot air on turbofan engined airplanes. The source of hot air can be selected from the flight engineer's upper panel. The air supply system is the same for all models and both types of packs. Flow rates for various combinations of turbo compressors and engine bleeds are shown in Table 1-3.

Vapor Cycle System

The vapor cycle pack consists of a freon compressor, evaporator, condenser and reservoir that function as a refrigerator to cool the hot air supplied to the pack. Freon gas is taken from the evaporator and compressed. The compressed gas is then cooled in the condenser to form liquid high-pressure freon. The freon is then routed to the receiver/drier. Liquid freon from the receiver is directed to the subcooler/superheater to cool the liquid further. From the subcooler/superheater, cool liquid freon is routed to the compressor motor for motor cooling, and to the freon evaporator. The evaporation process is endothermic, and extracts heat from the hot bleed-air that is circulated through the other side of the evaporator. The low temperature and pressure gaseous freon is then returned to the compressor to begin the cycle again. A control system regulates the flow of freon to the evaporator to maintain 48 °F evaporator discharge temperature at a nominal flow of 125 pounds of air per minute per pack. When cooling requirements are low (and therefore freon flow is low), a surge control system prevents compressor damage from a lack of freon flow by allowing freon from the compressor discharge to bypass the condenser and evaporator through the dual control valve and into the evaporator outlet line. The freon refrigeration system is shown in Figure 1-2.

Hot compressed air supplied to the pack is cooled in a heat exchanger by ram air then passed over the freon evaporator to be further cooled. The cold air is then ducted to the individual air (gasper) system and passenger and control cabin mixing valves. The mixing valves then add a controlled amount of hot air and route the warm air to the main distribution manifolds. Final adjustment of air temperature is accomplished by two electric resistance heaters, one each for the passenger cabin and flight deck. The vapor cycle pack schematic is shown in Figure 1-3.

The system incorporates two recirculation fans that can be operated only while the airplane is on the ground. Two fans draw air from the air conditioning distribution bay into the hot air duct. The recirculated air is then blown over the freon evaporator to further cool it. The air is then routed through the airplane as in normal flight. Only vapor cycle system airplanes have this recirculation system.

Air Cycle System

The air cycle packs consist of a primary and secondary heat exchanger, an air cycle machine and water separator. The air cycle pack schematic is shown in Figure 1-4. Air from the hot air supply system is divided and routed to the primary heat exchanger or the temperature control valve. Air routed to the primary heat exchanger is cooled by ram air. The air is then divided again, some going to the temperature control valve warm air inlet and the rest to the air cycle machine (ACM) compressor. Air is compressed in the ACM by air expanding in the ACM turbine side. Air exiting the compressor is cooled in the secondary heat exchanger by ram air, then expanded in the ACM turbine. The air exits the turbine at low temperature and enters the water separator to remove excess moisture. A 35 °F temperature control prevents freezing in the water separator by allowing hot air to mix with the pack discharge air as required. A portion of this air is routed to the individual air system, and the remaining air is delivered to the passenger cabin and flight deck temperature control valves. The temperature control valves mix cold, warm, and hot air according to cabin heating and cooling demands and deliver the air to the distribution systems.

The 707 also has provisions for allowing ram air into the air distribution system. A valve on the ram-air heat exchanger cooling duct on both sides of the airplane can be opened during unpressurized flight to allow ram air into the distribution system. This air is directed to the mixing valve and can be mixed to the desired temperature if the pneumatic system is functioning. The valve is controlled by a switch on the flight engineers upper panel.

Flow through the system is shown in Table 1-3 for various cruise altitudes and hot air sources. The maximum supply temperature is limited by the duct overheat switch, and the minimum supply temperature by the water separator anti-ice control on the air cycle packs. On vapor cycle packs, the lower limit is evaporator discharge temperature (approximately 48 °F). Main distribution manifold pressure is limited to twenty inches of water (.72 psi) above cabin pressure by a pressure relief valve.

Distribution

Conditioned air leaving the mixing valves is routed to the main distribution manifold or flight deck supply manifold. The amount of air delivered to the flight deck distribution system is controlled by the flight deck flow controller, with the rest of the air directed to the passenger cabin. The vapor cycle main distribution manifold is shown in Figure 1-5, and the air cycle manifolds are shown in Figure 1-6.

Air entering the passenger cabin distribution system is routed through the airplane by plenums running fore and aft below the floor on both sides of the passenger cabin. The distribution manifolds are divided into three separate sections, the forward, mid, and aft cabin, all receiving air from the main distribution manifold. This allows zone temperature to be controlled separately by the zone temperature control system.

The main distribution system is shown in Figure 1-7. Air from the main plenums is routed up behind the sidewall and enters the passenger compartment through the light fixture located at the top of the sidewall. The riser ducts are located approximately every twenty inches along the fuselage. A typical riser duct is shown in Figure 1-8. A cross-section of the passenger cabin showing ducting locations is shown in Figure 1-9. Passenger cabin airflow patterns are shown in Figure 1-10.

The flight deck distribution system is supplied from the main distribution manifold by a duct running forward under the forward cabin right hand floor. Air enters the cabin through six or seven outlets (see Figure 1-11). Two outlets are located in front of the pilots and co-pilot's seats, two behind the pilot and co-pilot's seats and two in the overhead at the back of the compartment. On some airplanes, the outlets in the overhead are replaced by one outlet, and two additional outlets at the pilot and co-pilot's shoulder windows are added. On these airplanes, the front and shoulder outlets have an electric heater in the duct. A manual shut-off valve for stopping air flow to the flight deck is also provided (see Figure 1-10). An access door in the right aft floor provides access to the shut-off valve.

Individual (Gasper) Air

In addition to compartment conditioned air, the passenger also has available a separate air outlet that may be used to further cool personal space. This air is somewhat cooler than air supplied to the air conditioning system. Flow rates through the system are included in Table 1-3.

The gasper air system is supplied from the pack cold air lines by risers located behind the sidewall on both sides of the cabin just forward of the wing. The risers direct air to plenums, located behind the sidewall light, that run fore and aft. The plenums supply outlets located under the stowage rack (see Figure 1-12). The outlets are ball and socket type, adjustable for flow rate and direction.

Gasper air is also available to the flight crew. The flight deck has a separate supply and distribution system. The main supply duct runs forward under the left-hand floor, and is supplied from the left-hand passenger system riser. The flight deck distribution system has four outlets in the flight deck, and also supplies air to an outlet in each of the two forward lavatories. The flight deck has two outlets located at the outboard corners of the instrument panel, and two in the upper portion of the sidewall behind the pilot and co-pilot's seats. On some airplanes, the two forward outlets are located above the windshield in the center.

The gasper air system has a pressure-control valve to prevent excessive system pressures. A fan is provided to increase system pressure when supply pressure is low, and/or demand is high. A surge-bypass duct prevents fan buffeting if the fan is operating while system pressure is high, or demand is low (outlets closed).

Equipment Cooling

The equipment cooling system uses flight-deck conditioned air to cool instruments and electronic equipment. Cabin air is drawn through the equipment panels and into a system of manifolds and ducts before being exhausted overboard or recirculated. The 707 employs two similar systems, differing only in whether or not the air is recirculated after cooling. The equipment cooling systems are shown in Figure 1-13 and 1-14.

During ground operation or low altitude flight, the flow through the system is driven by a blower located in the equipment cooling blower discharge duct. The blower draws cabin air through the equipment racks and flight deck panels, and discharges it through the automatic flow-control valve. As the cabin to ambient pressure differential rises to about 0.9 to 2.0 psi, the blower stops, and flow is governed by the pressure differential and the flow-control valve. At about 1.8 to 2.8 psi differential, the flow-control valve gradually closes, and flow is driven overboard by cabin pressure through a flow limiting nozzle. On airplanes with recirculation ducts, the air is exhausted below the forward cargo compartment and mixes with cabin exhaust air before being exhausted through the forward outflow valve.

Both types of systems have a manual override of the flow-control valve for use during an emergency. The override should not be used when the airplane is pressurized.

Cargo Heating

The cargo compartments are heated in part by exhausting passenger cabin air between the fuselage and cargo compartment lining. Air passes down over the lining and is exhausted overboard through the outflow valves.

On some airplanes the forward cargo compartment also has an electric auxiliary heater. The forward cargo compartment heating provisions are shown in Figure 1-15. The heater is an electric plate fin resistance heater. Air from the main distribution manifold flows through the heater and enters the exhaust duct, then into the compartment. Flow through the system is manually adjustable by positioning the exhaust duct damper. The electric heater is controlled by a switch on the flight engineer's panel. The temperature of the heating element is limited to 240 ± 40 °F by three thermal switches.

Ventilation

Air is vented from the pressurized compartments by two systems, pressurization outflow valves and the equipment cooling system. The equipment cooling system is essentially a fixed flow system in that the crew has no control over the amount of air vented, for details see Equipment Cooling.

The pressurization outflow valves are located on the underside of the fuselage, and are of two types, pressure outflow valves and thrust recovery valves. The 707 uses two or three pressure outflow valves, one at the aft end of each cargo compartment and the third one (not installed on all airplanes) just forward of the aft cargo compartment forward bulkhead. The outflow valves are poppet type, and function together using pneumatic signals from the pressure controller to regulate the cabin pressure. Safety-pressure relief and vacuum relief are built into these valves. A typical valve and the valve locations are shown in Figure 1-16. One valve is adequate to handle all pressure control functions, if the other should fail.

The other type of outflow valve is the thrust recovery valve shown in Figure 1-17. The 707 uses three valves of this type, one located by each of the outflow valves. These valves were not used on the -720. The thrust recovery valves vent cabin air to ambient when the differential pressure rises above 0.5 psi. The valves are pneumatically operated, and electrically controlled by a switch on the flight engineer's panel. In addition, a limit switch closes the valves when the air conditioning system approaches full cold.

The rate of flow through the valves increases with the pressure differential to approximately 25 pounds per minute per valve at 8.6 psi differential.

Heating

Most heating requirements are satisfied by temperature adjustment of the air conditioning system. Some airplanes have auxiliary electric heaters installed in areas not adequately heated by the air conditioning system such as areas by escape hatches or areas over the wing.

Two styles of temperature control were available on the 707, two-zone control or four-zone control. On two-zone systems, the area is divided into the flight deck and passenger cabin zones. The temperature of the zones can be controlled manually by the flight engineer, or thermostatically. When using manual mode, the flight engineer controls the mixing valve by moving the control to cooler or warmer, and monitors cabin temperature on the gauge provided. Thermostatic control requires setting the desired temperature. The mixing valves adjust automatically in response to signals generated by the temperature sensing system. The temperature controls are shown in Figure 1-18.

The four-zone system functions much the same except that additional controls are provided to adjust the temperature in the passenger cabin. The zones and zone heat ducting is shown in Figure 1-19. The flight engineer can vary the zone temperatures by adjusting the forward and mid zone controls on the upper panel to either cooler or warmer to compensate for uneven passenger distribution. The temperature is varied by adding air from the pneumatic duct, to the forward and mid supply duct, to increase the temperature of these zones, or by adding hot air to the aft zone to cause the cabin temperature sensor to call for more cold air from the packs which will cool the forward and mid zones.

A variety of electric blanket type surface heaters are used through the airplane to provide heat where the air distribution ducting is absent or not adequate. Electric surface heaters are provided for the mid and aft cabin escape hatches (see Figure 1-20). The heaters are electric resistance type embedded in fiberglass that are mounted behind the sidewall on the surface of the door. Temperature of the heaters is thermostatically regulated between 75 and 100 °F. Operation is controlled from the flight engineer's panel. Electric heaters are also provided to heat the floor in the overwing area (see Figure 1-21). These heaters are low wattage and not thermostatically controlled. Operation is controlled by a switch on the flight engineer's panel.

On some airplanes electric heaters are installed in the flight deck distribution lines (see Figure 1-22) to provide additional heat to the crew. The foot heaters are rated at 500 watts, and the spray tube heaters are rated at 300 watts. Each heater may be operated on high or low, and operation is controlled by switches located at the pilot and co-pilot sidewalls adjacent to the ash trays.

In addition to the electric heat, hot air can be directed to the flight deck for use when the regular ventilating air is shut off. The valve is controlled by a switch on the flight engineer's panel (see Figure 1-22).

The 707 also has provisions for manual override of the passenger cabin temperature control valve. The manual override is located below an access door in the passenger cabin floor over the air conditioning distribution bay.

On airplanes equipped with vapor cycle packs, two electric heaters are mounted in the main distribution duct for the passenger cabin and flight deck. These heaters provide heating of recirculated air during ground operation, or supplemental heating during flight when the pneumatic system cannot provide enough hot air to satisfy heating demands. The main heater is located in the distribution bay, and is rated at 27 kilowatts. Surface temperature is controlled to 240 °F or less. The flight-deck heater is located in the flight deck supply duct and is rated at three kilowatts, (see Figures 1-5 and 1-6).

Pressurization Control

The 707 series uses a pneumatically operated system consisting of an automatic controller, manual controller, outflow valves, thrust recovery valves and appropriate gauges to monitor the cabin altitude, cabin altitude rate of change, and differential pressure. Pressurization system limits and capabilities are shown in Table 1-2.

During normal flight, the pressure control is usually on the auto controller. The auto controller requires the flight engineer to enter the desired cabin altitude, cabin altitude rate of change, and a barometric-correction factor for landing field elevation. During flight, the pressure controller modulates the outflow valves to maintain requested cabin conditions, or limits the differential pressure to 8.6 psi, if the cabin altitude is too low for flight altitude. If the auto controller fails, control is transferred to the manual system. The manual control can only be adjusted to increase, decrease or maintain cabin pressure. The crew must monitor the gauges to prevent over/under pressurization.

The pressurization system control panels are shown in Figure 1-22. The configuration of gauge and switch placement will vary from airline-to-airline and model-to-model, but all have basically the same controls and operate in the same way.

ECS Controls

ECS control panel is shown in Figure 1-18. The bleed-air controls are basically the same for vapor cycle and air cycle systems, and are installed on turbofan engine airplanes only. The switches are located on the upper portion of the air conditioning and pressurization panels. The bleed-air controls consist of on-off switches for the turbo compressors, bleed-air on-off switches, and wing isolation valve switches. Gauges are provided to monitor compressor rpm and duct pressure. The source of pneumatic air can be any combination of turbo compressors or engine bleed-air that is required to fulfill the airplane's needs.

The pack switches control the pack operation by opening or closing the pack shut-off valve. On the air systems, the pack switches are connected so that both packs must be operated together. On the vapor cycle packs, the switches are separate so the packs can be operated singly or together. Warning lights are included to alert the crew if the system should malfunction or overheat. A gauge is also provided to monitor main duct pressure and temperature of various ducts and compartments.

The flight engineer's upper panel also has controls for other system features such as gasper fan, outflow valve override, main cabin heater panels, thrust recovery valves, ram-air inlet duct, forward cargo heater, auxiliary heat valve and cooling air flow doors. The use of these controls has been explained under the appropriate section.

The electrical energy requirements of the various ECS equipment and control systems are shown in Tables 1-4 and 1-5.

TABLE 1-1. BOEING 707 PRODUCTION DATA

MODEL	FIRST FLIGHT (REF 1)	CERTIFICATION (REF 2)	NO. PRODUCED (REF 3)
-100	12-20-57	9-18-58	57
-200	6-11-59	11-5-59	5
-300	1-11-59	7-15-59	69
-400	5-19-59	2-12-60	37
-720	11-23-59	6-30-60	65
-100B	6-22-60	3-1-61	72
-300B	10-6-60	3-3-61	89
-300C	1-31-62	5-31-62	221
-720B	2-19-63	4-30-63	336
		TOTAL	951

TABLE 1-2. BOEING 707 VENTILATION PARAMETERS

VOLUMES (CU FT)	MODEL NO. -120,-220	-320,-420	-720
TOTAL PRESSURIZED	11,865	12,565	10,832
PASSENGER CABIN	6,820	7,220	6,320
FLIGHT DECK	338	338	338
FORWARD CARGO	1,320	1,479	1,241
AFT CARGO	1,315	1,315	1,037

PRESSURIZATION

MAX Δ P (PSI)

CONTROLLER LIMITED	8.6
SAFETY VALVE LIMITED	9.42 $\pm$ .15

CABIN ALTITUDE CHANGE RATES (FT/MIN)

CONTROLLER SELECTED	MAX	2,000
	MIN	50
MANUAL SELECTION	MAX	10,000
	MIN	0

MAX CABIN ALTITUDE (FT) 13,000*

*IF PNEUMATIC SYSTEM CAN SUPPLY NEEDED AIR WHEN OTHER COMPONENTS FAIL

TABLE 1-3. BOEING 707,720 VOLUME FLOW RATES (CFM) (REF 4)

AIR SOURCE ▶ / FLIGHT REGIME	2 ENGINE BLEED 1 TURBOCOMPRESSOR	4 ENGINE BLEED	3 ENGINE BLEED	2 TURBOCOMPRESSOR	2 ENGINE BLEED
25,000	N/A*	N/A	2,600	2,600	2,300
30,000	3,100	3,600	2,600	2,600	1,900
35,000	2,800	2,900	2,200	2,500	1,600
40,000	2,100	2,000	1,500	2,200	1,100

TABLE 1-4. BOEING 707,720 AC ELECTRICAL ENERGY REQUIREMENTS (REF 5,6)

EQUIPMENT	POWER REQD	LOAD KW	KVAR
A/C RECIRC FAN MOTOR, RH*	115V 400 HZ	11.45	8.89
A/C CONDENSER FAN, RH*	115V 400 HZ	9.20	7.38
A/C RECIRC FAN MOTOR, LH*	115V 400 HZ	11.45	8.89
A/C CONDENSER FAN, LH*	115V 400 HZ	9.20	7.38
FREON COMPRESSOR MOTOR, LH	115V 400 HZ	26.75	12.19
FREON COMPRESSOR MOTOR, RH	115V 400 HZ	26.75	12.19
FLIGHT DECK TEMP CONTROL VALVE	115V 400 HZ	.61	.8
PASS. CABIN TEMP CONROL VALVE	115V 400 HZ	.61	.8
FLIGHT DECK PROGRAMMER	115V 400 HZ	.01	
PASS. CABIN PROGRAMMER	115V 400 HZ	.01	
A/C EXPANSION VALVE, LH	115V 400 HZ	.466	.35
A/C EXPANSION VALVE, RH	115V 400 HZ	.466	.35
RECIRC VALVE	115V 400 HZ	.15	.12
EQUIPMENT COOLING BLOWER	115V 400 HZ	.96	.72
CONTROL CABIN HEATER	115V 400 HZ	3.0	
FLOOR HEATER BLANKETS	115V 400 HZ	3.0	
PACK SWITCH, LH	115V 400 HZ	.3	
PACK SWITCH, RH	115V 400 HZ	.35	
CONTROL CABIN RELAY	115V 400 HZ	.35	
PASS. CABIN RELAY	115V 400 HZ	.35	

*OPERATES ONLY WHEN AIRPLANE IS ON THE GROUND.

TABLE 1-5. BOEING 707,720 DC ELECTRICAL ENERGY REQUIREMENTS (REF 5,6)

EQUIPMENT	POWER REQD	LOAD
TURBOCOMPRESSOR CONTROL UNIT	28V DC	.21 A
FLIGHT DECK PROGRAMMER	28V DC	.50 A
PASS. CABIN PROGRAMMER	28V DC	.50 A
THRUST RECOVERY VALVES	28V DC	3.0 A

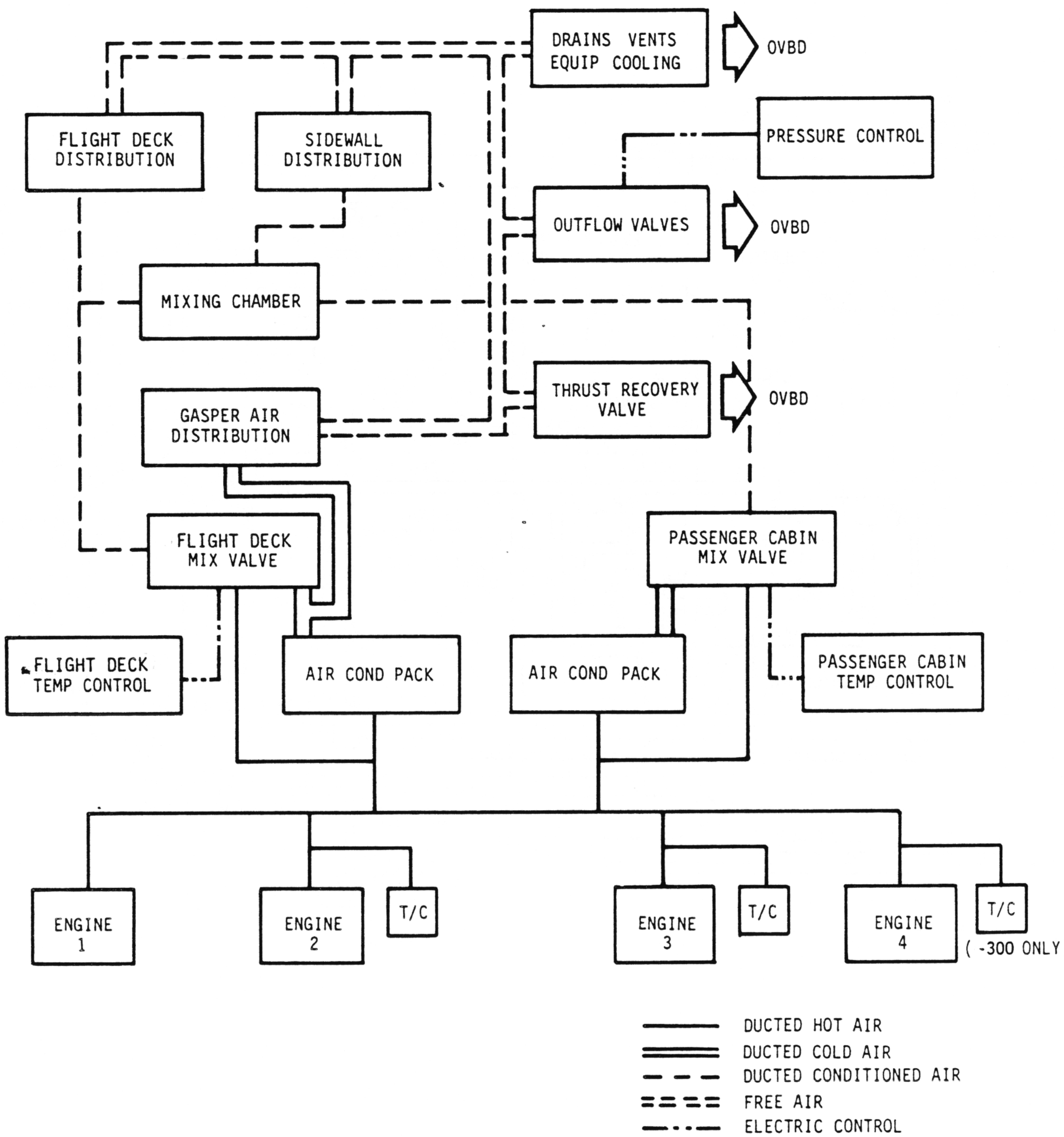


FIGURE 1-1. BOEING 707,720 AIR CONDITIONING AND PRESSURIZATION CONTROL BLOCK DIAGRAM

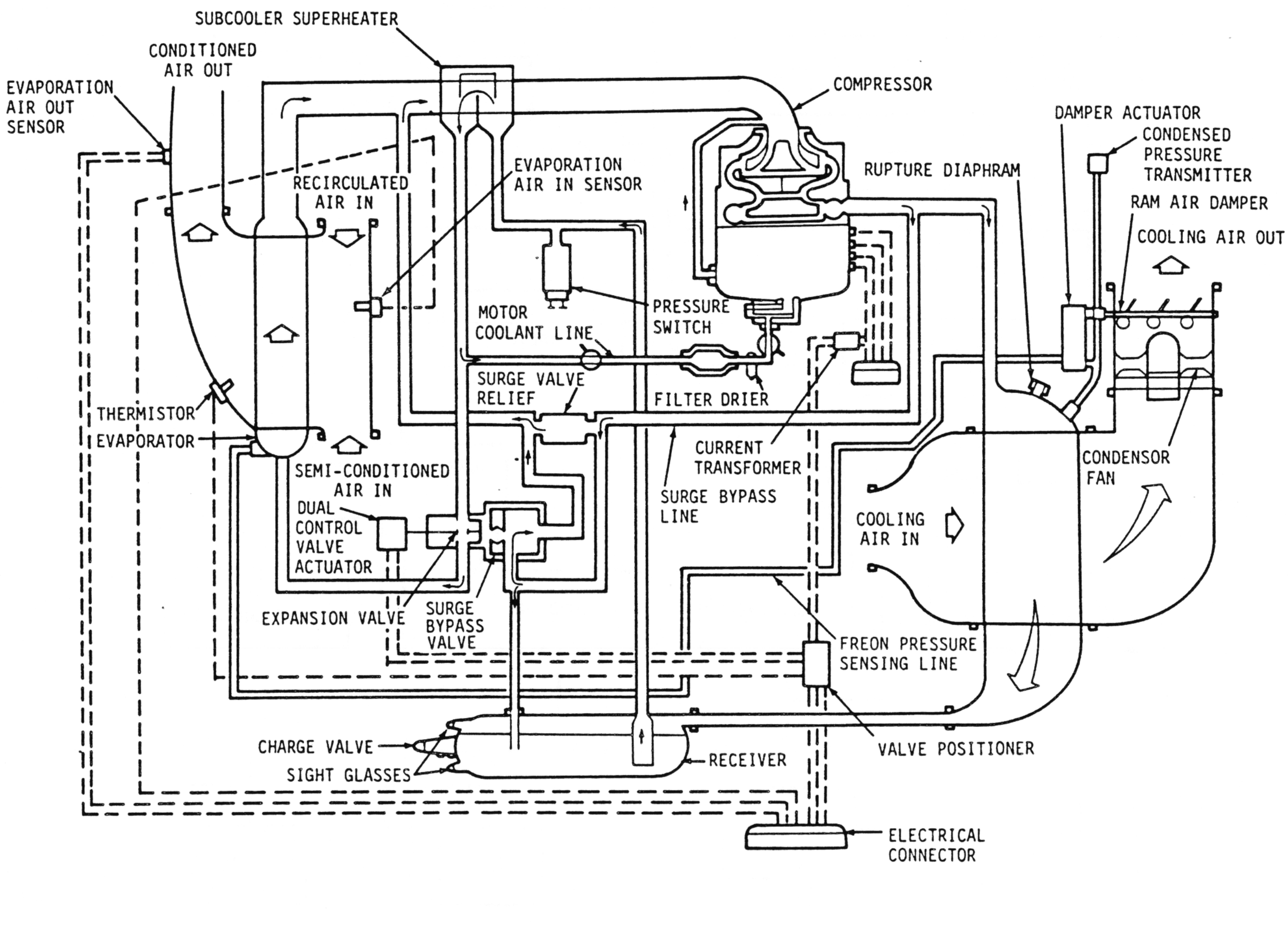


FIGURE 1-2. BOEING 707,720 FREON SYSTEM SCHEMATIC

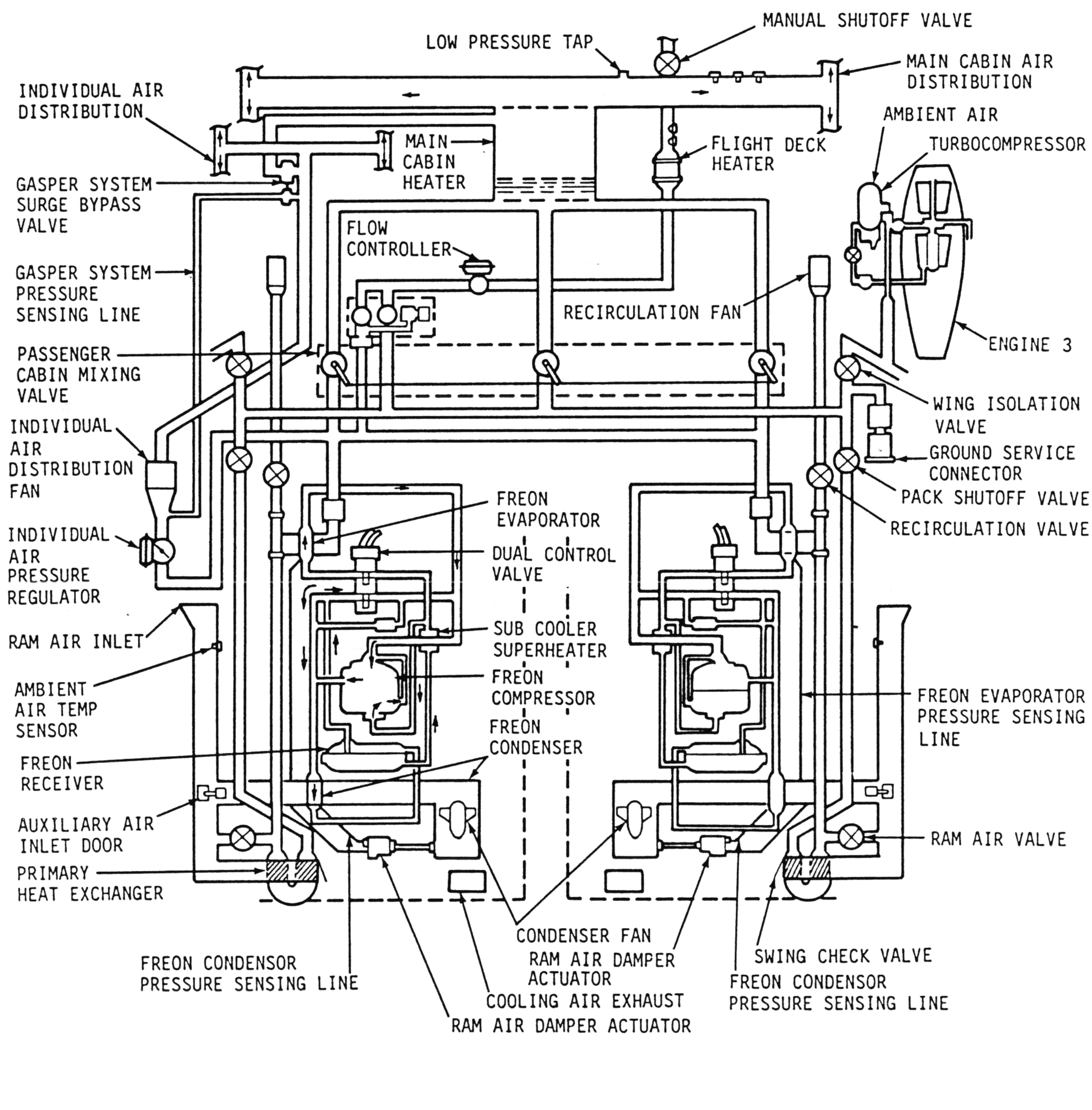


FIGURE 1-3. BOEING 707,720 VAPOR CYCLE PACK SCHEMATIC

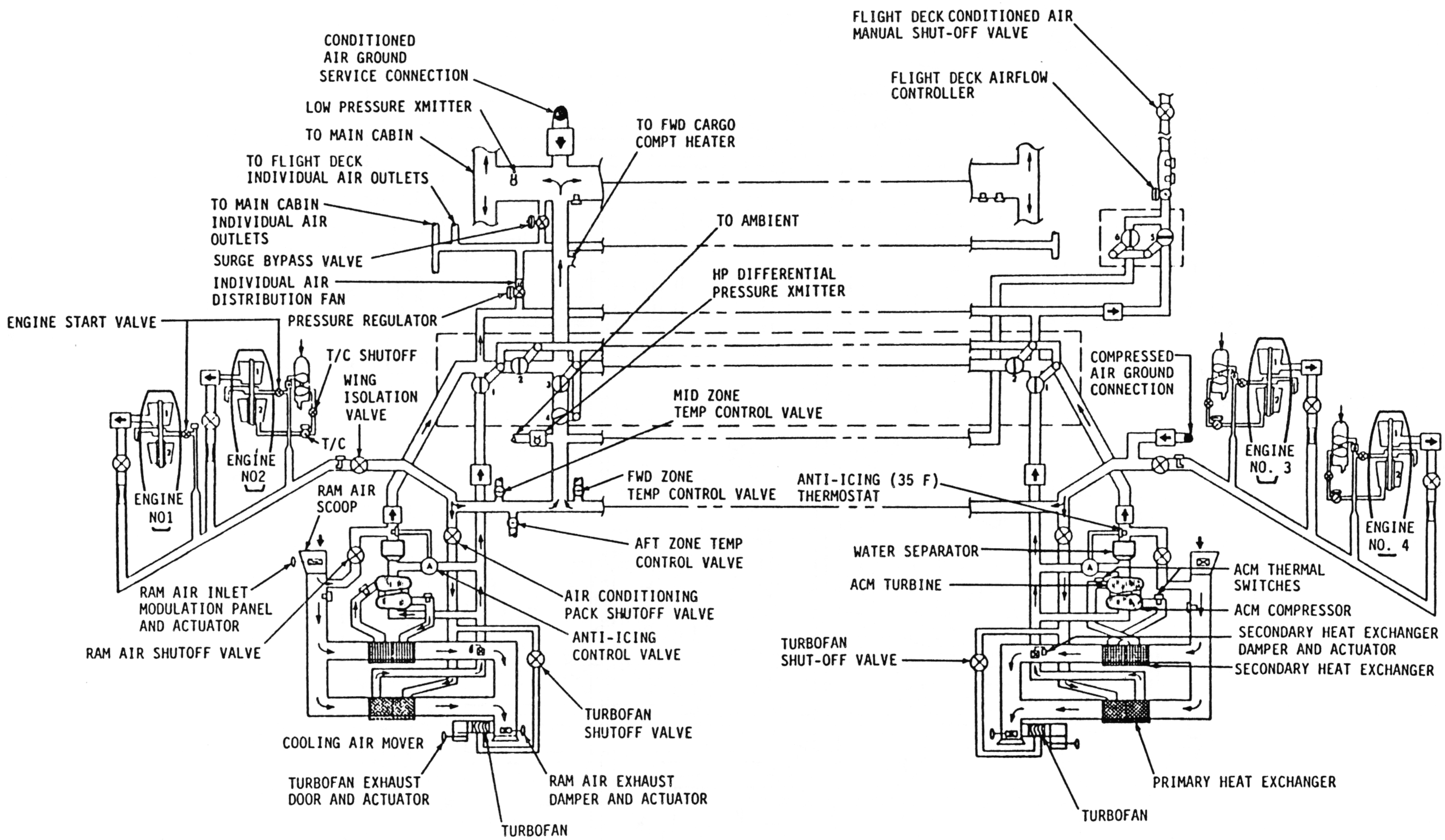


FIGURE 1-4. BOEING 707 AIRCYCLE PACK SCHEMATIC

BOEING 707

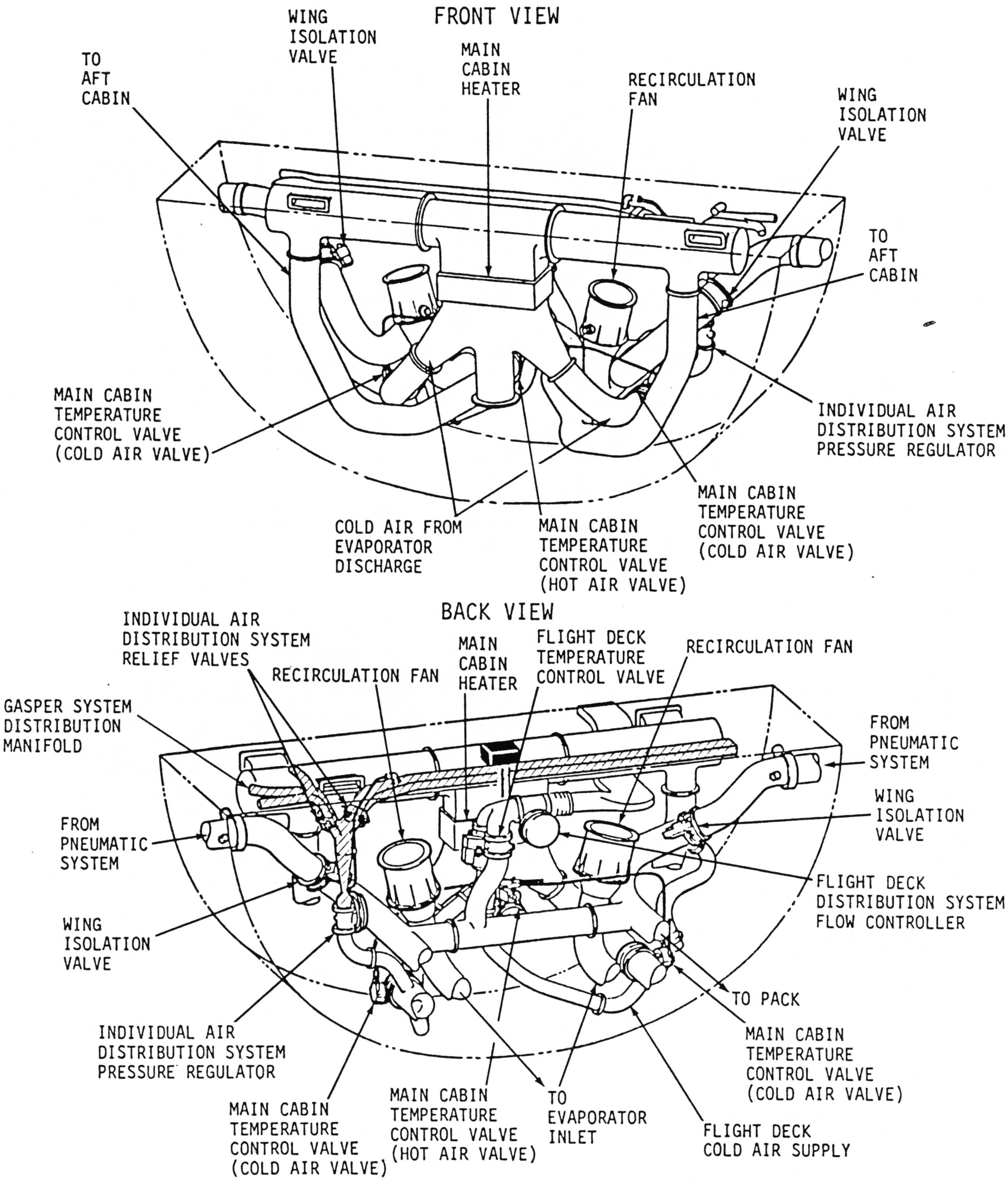
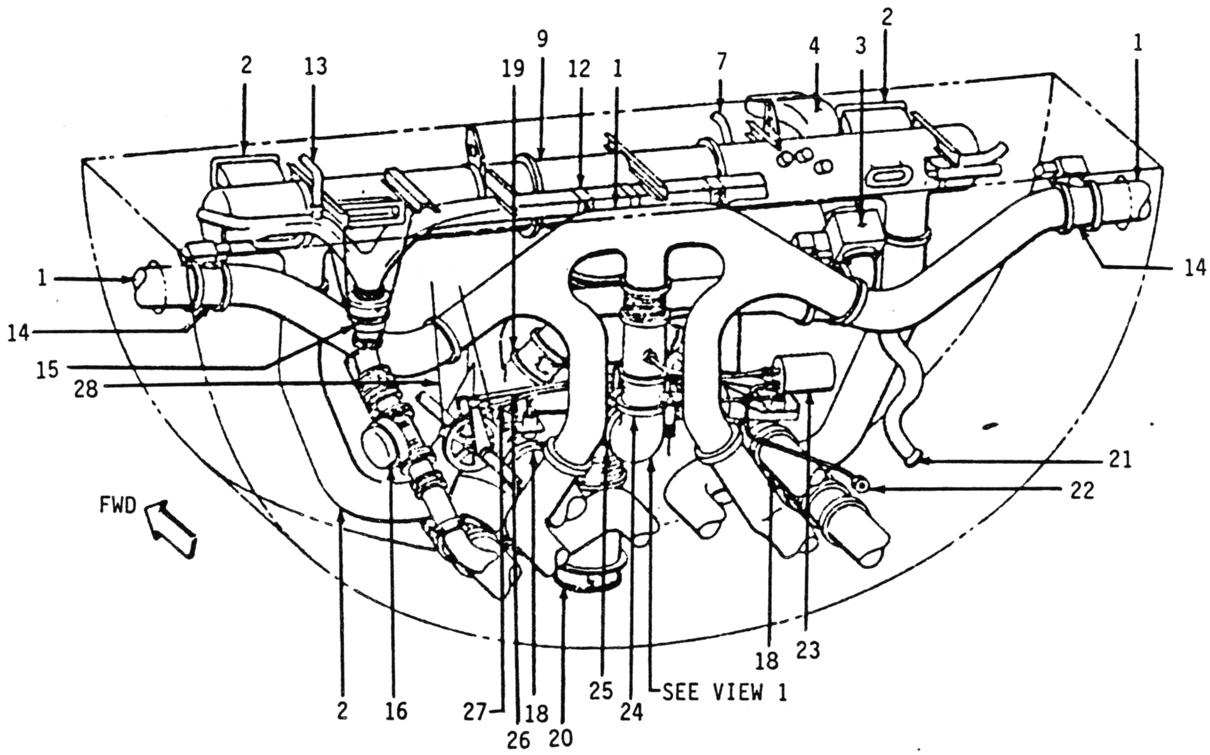


FIGURE 1-5. BOEING 707 VAPOR CYCLE SYSTEM DISTRIBUTION BAY

BOEING 707,720



LEGEND

1 PNEUMATIC DUCT
2 MAIN CABIN DISTRIBUTION DUCT
3 FLOW FLIGHT DECK CONDITIONED AIR
4 FLIGHT DECK DISTRIBUTION DUCT
5 FLIGHT DECK HOT AIR VALVE
6 FLIGHT DECK COLD AIR VALVE
7 MIXING CHAMBER (LOW PRESSURE) PICK-UP
8 CHECK VALVE
9 MIXING CHAMBER
10 INDIVIDUAL AIR DISTRIBUTION SYSTEM DUCT
11 FLEXIBLE COUPLING
12 INDIVIDUAL AIR PRESSURE RELIEF VALVE
13 FLIGHT DECK INDIVIDUAL AIR DUCT
14 WING ISOLATION VALVE
15 INDIVIDUAL AIR DISTRIBUTION (PSU) FAN
16 INDIVIDUAL AIR (PSU) PRESSURE REGULATOR
17 DELETED
18 ACM BYPASS VALVE
19 MAIN CABIN COLD AIR VALVE
20 CONDITIONED AIR GROUND SERVICE CONNECTION
21 PNEUMATIC SYSTEM GROUND SERVICE CONNECTION
22 AMBIENT PRESSURE PICK-UP (AIR SUPPLY DUCT PRESSURE TRANSMITTER)
23 AIR SUPPLY DUCT (HIGH PRESSURE) TRANSMITTER
24 TURBOCOMPRESSOR BACK PRESSURE VALVE
25 MAIN CABIN HOT AIR VALVE
26 MANUAL CONTROL ROD-MAIN CABIN TEMPERATURE CONTROL VALVE
27 VALVE CLUTCH ROD-MANUAL OVERRIDE
28 MANUAL OVERRIDE CONTROL CABLE
29 MANUAL OVERRIDE CLUTCH CABLE

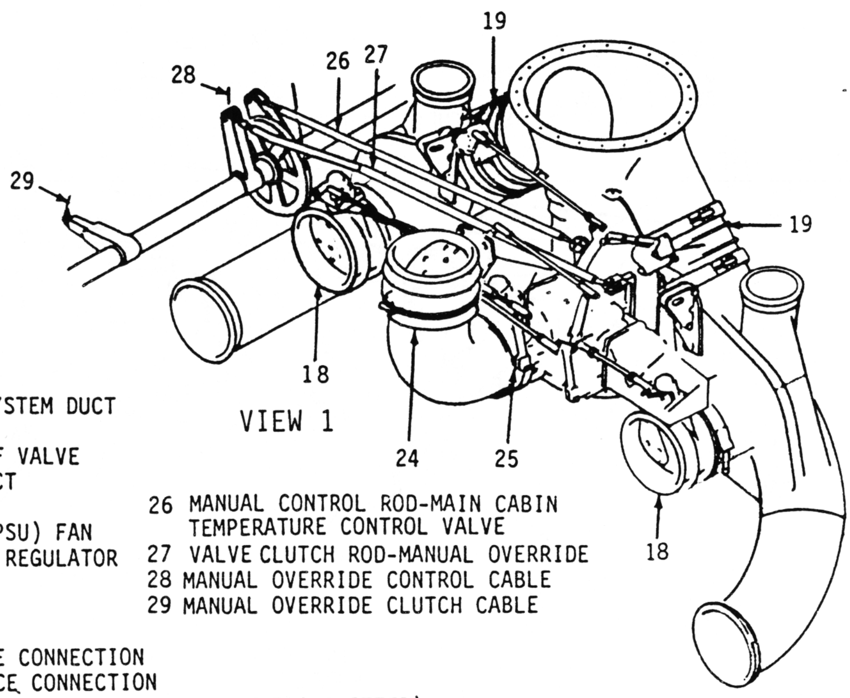


FIGURE 1-6. BOEING 707,720 CYCLE DISTRIBUTION MANIFOLD

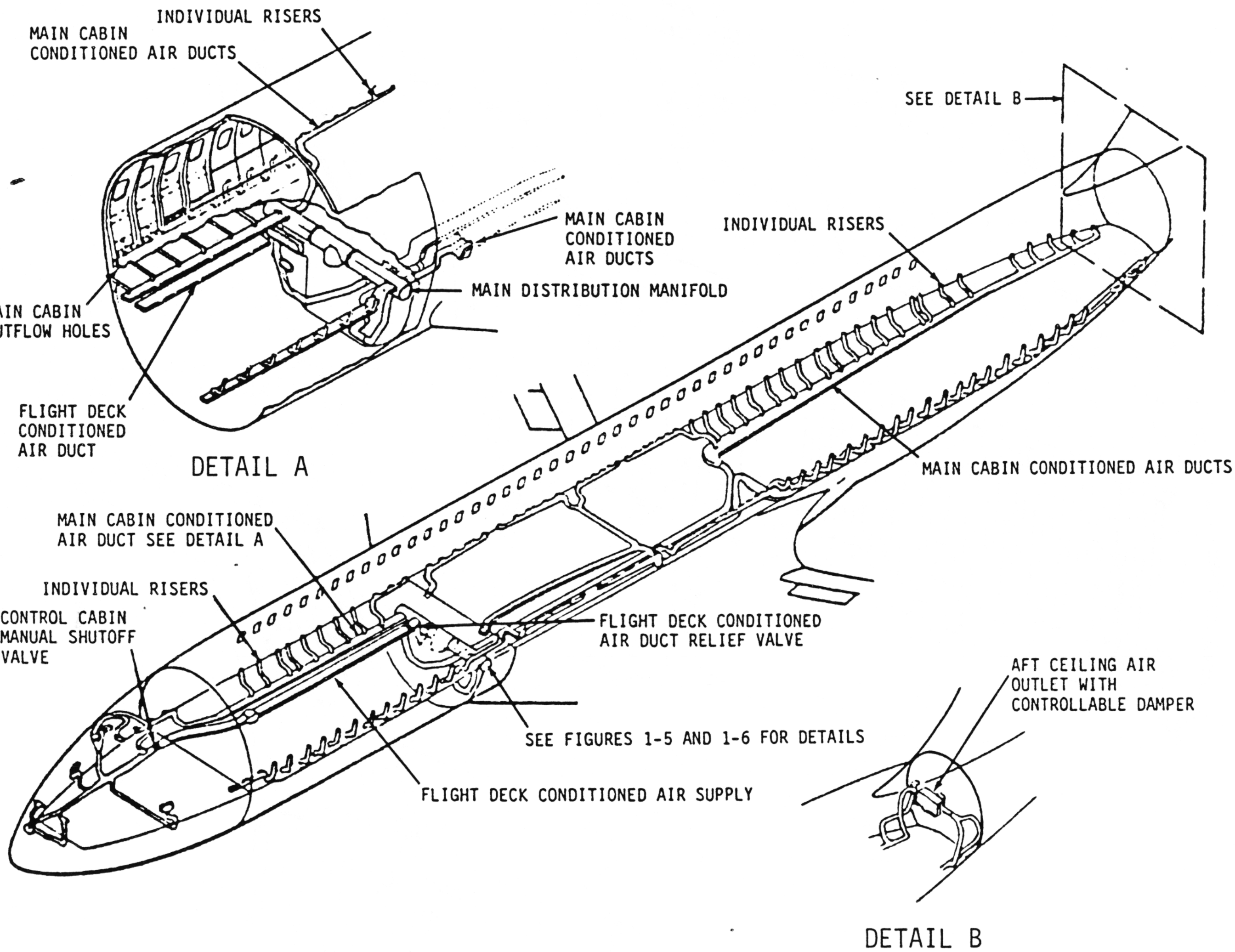


FIGURE 1-7. BOEING 707,720 PASSENGER
CABIN CONDITIONED AIR DISTRIBUTION

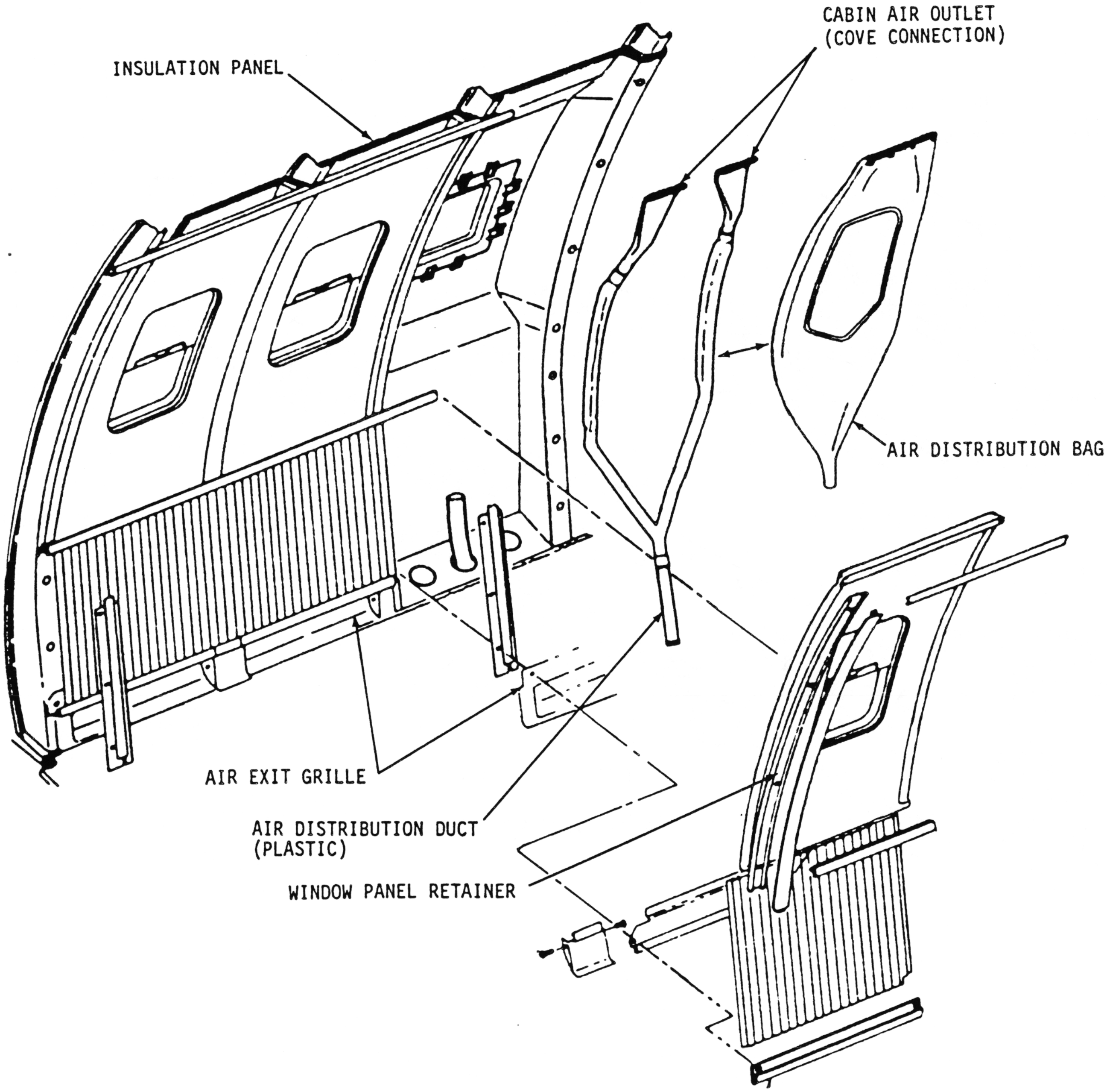


FIGURE 1-8. BOEING 707,720 SIDEWALL AIR DUCTS

BOEING 707,720

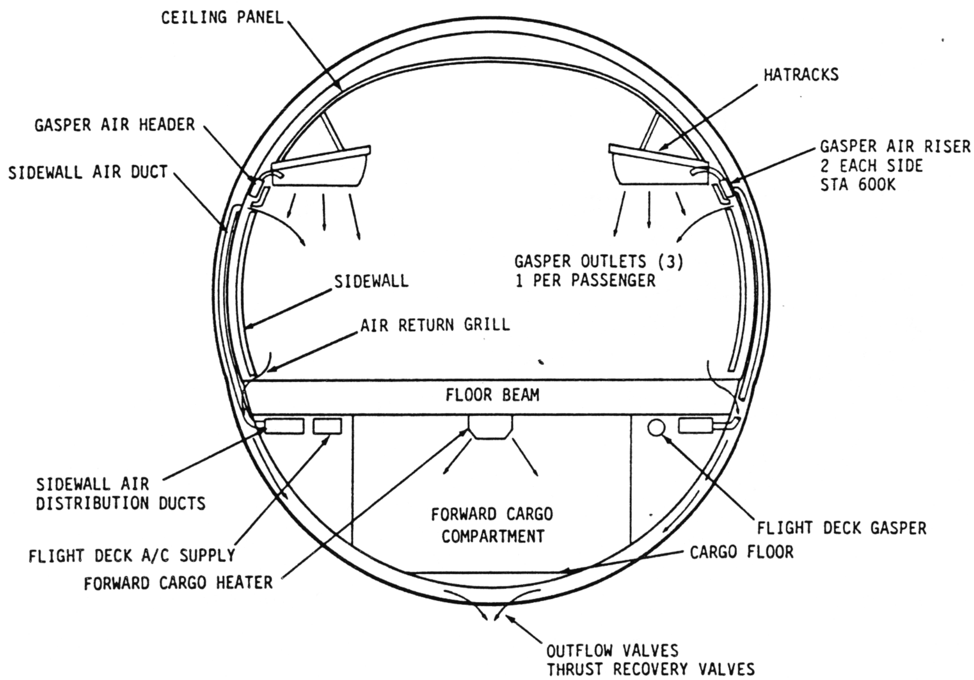


FIGURE 1-9. BOEING 707,720 PASSENGER CABIN CROSS SECTION

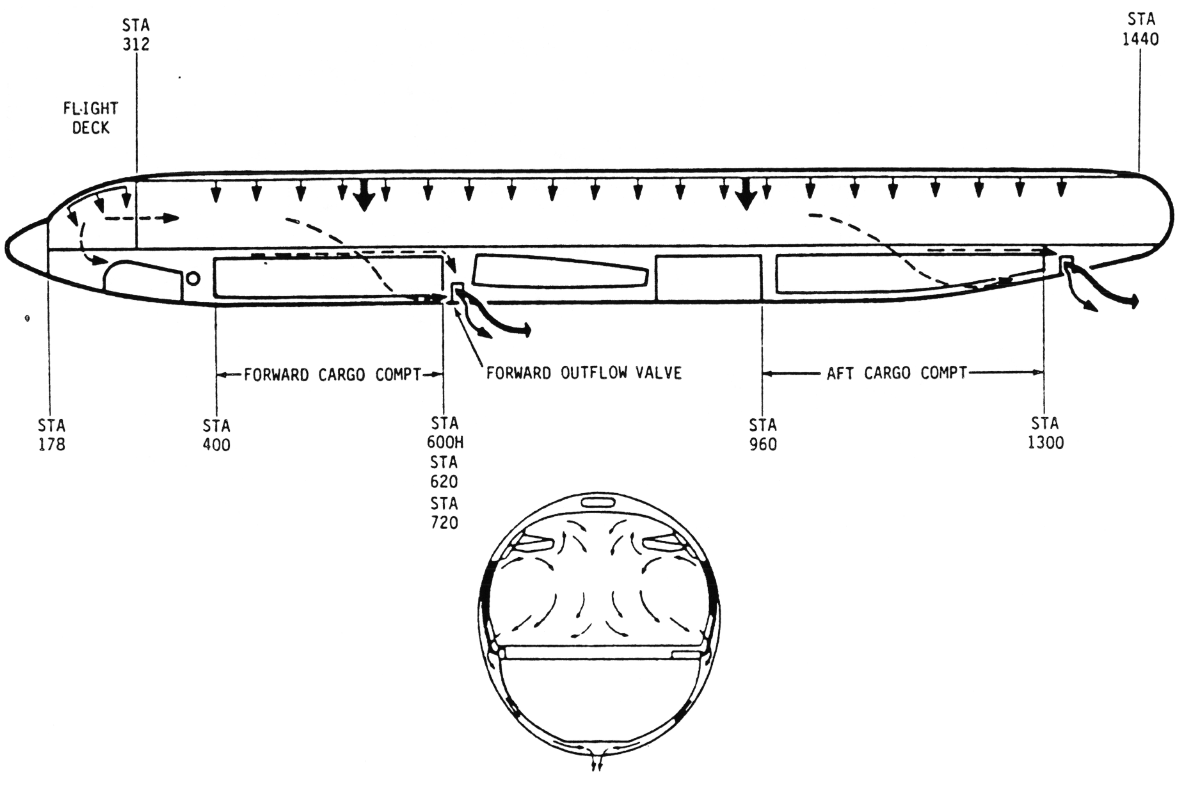


FIGURE 1-10. BOEING 707,720 PASSENGER CABIN AIR FLOW PATTERNS

BOEING 707,720

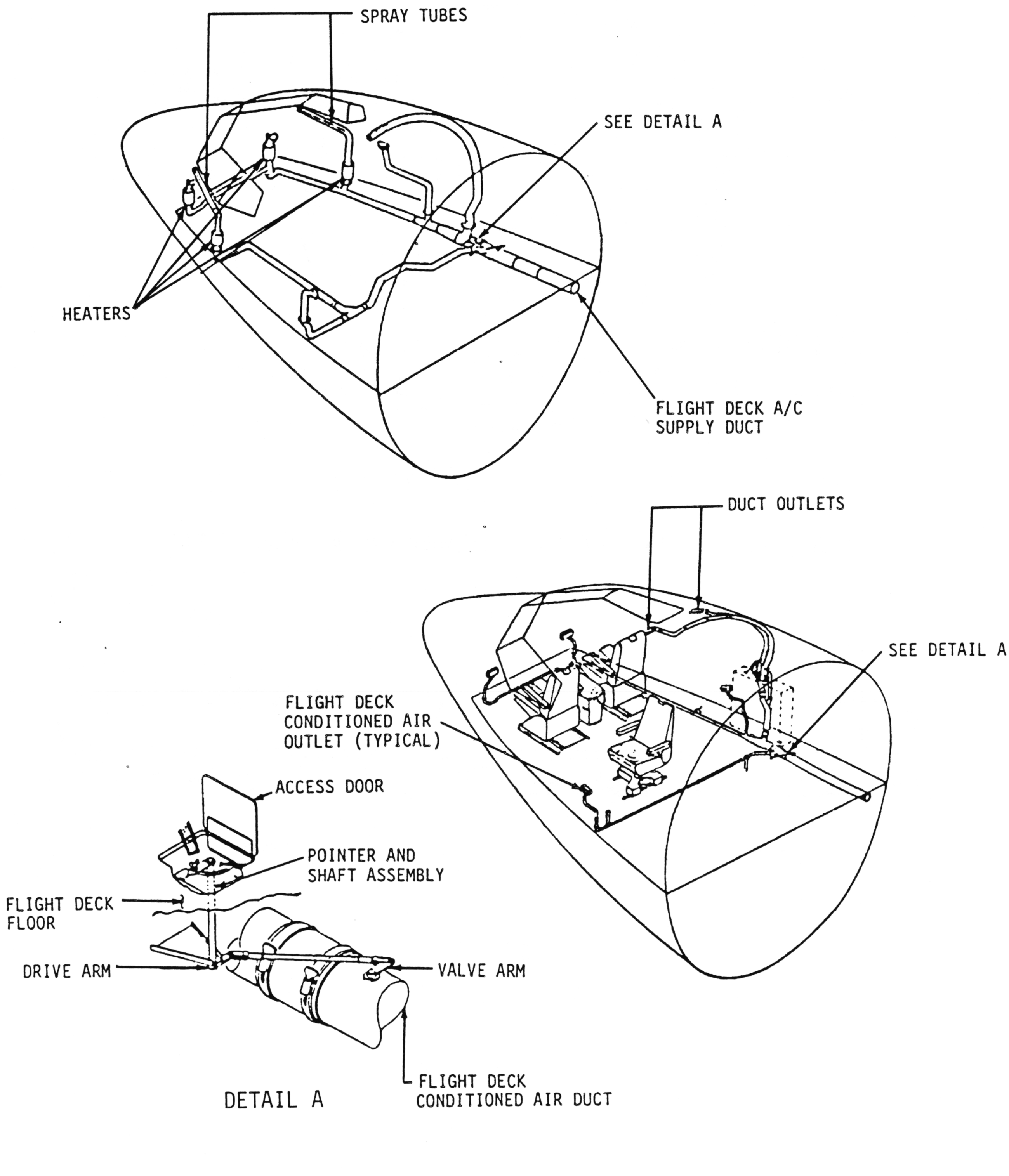


FIGURE 1-11. BOEING 707,720 FLIGHT DECK CONDITIONED AIR DISTRIBUTION

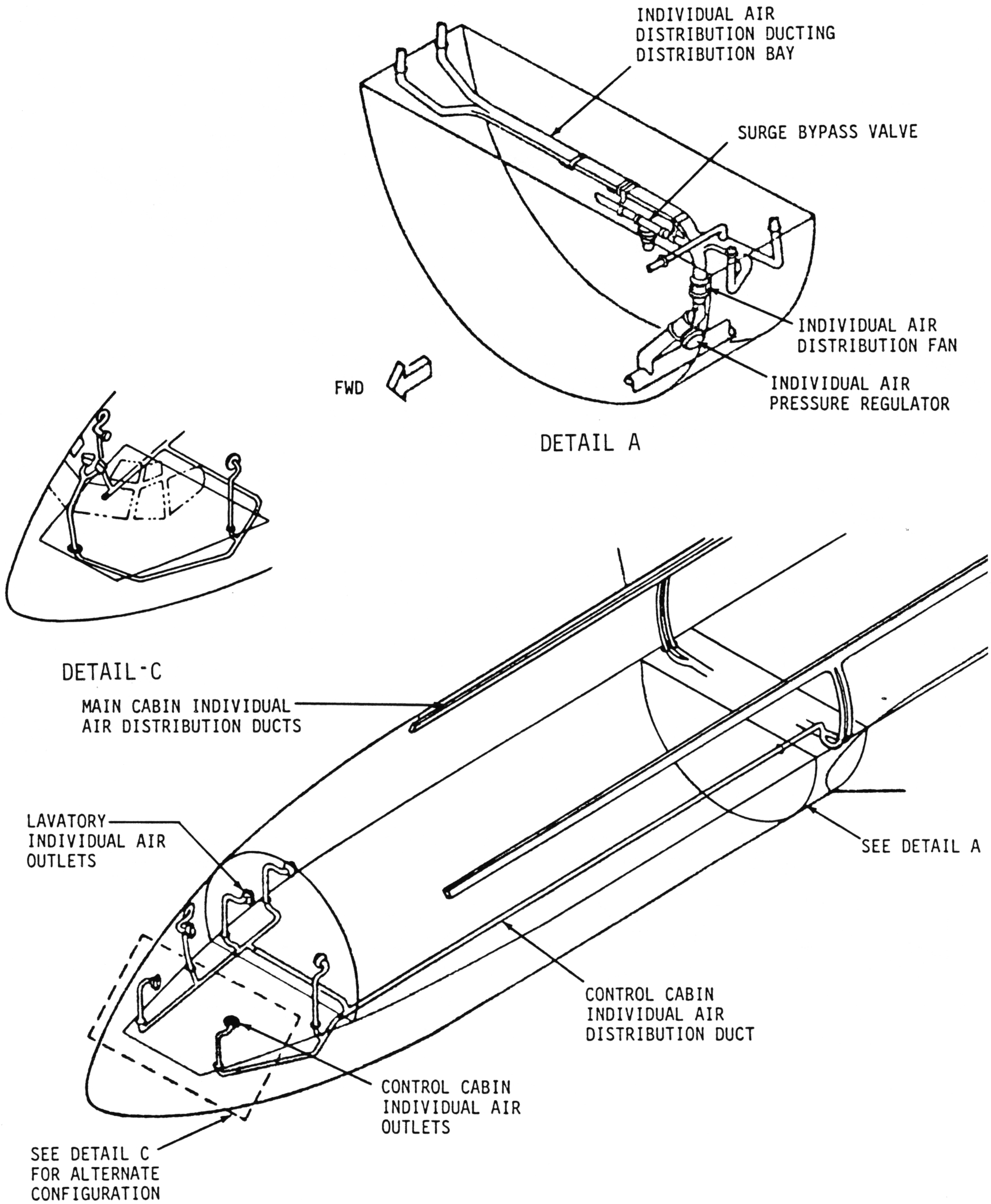
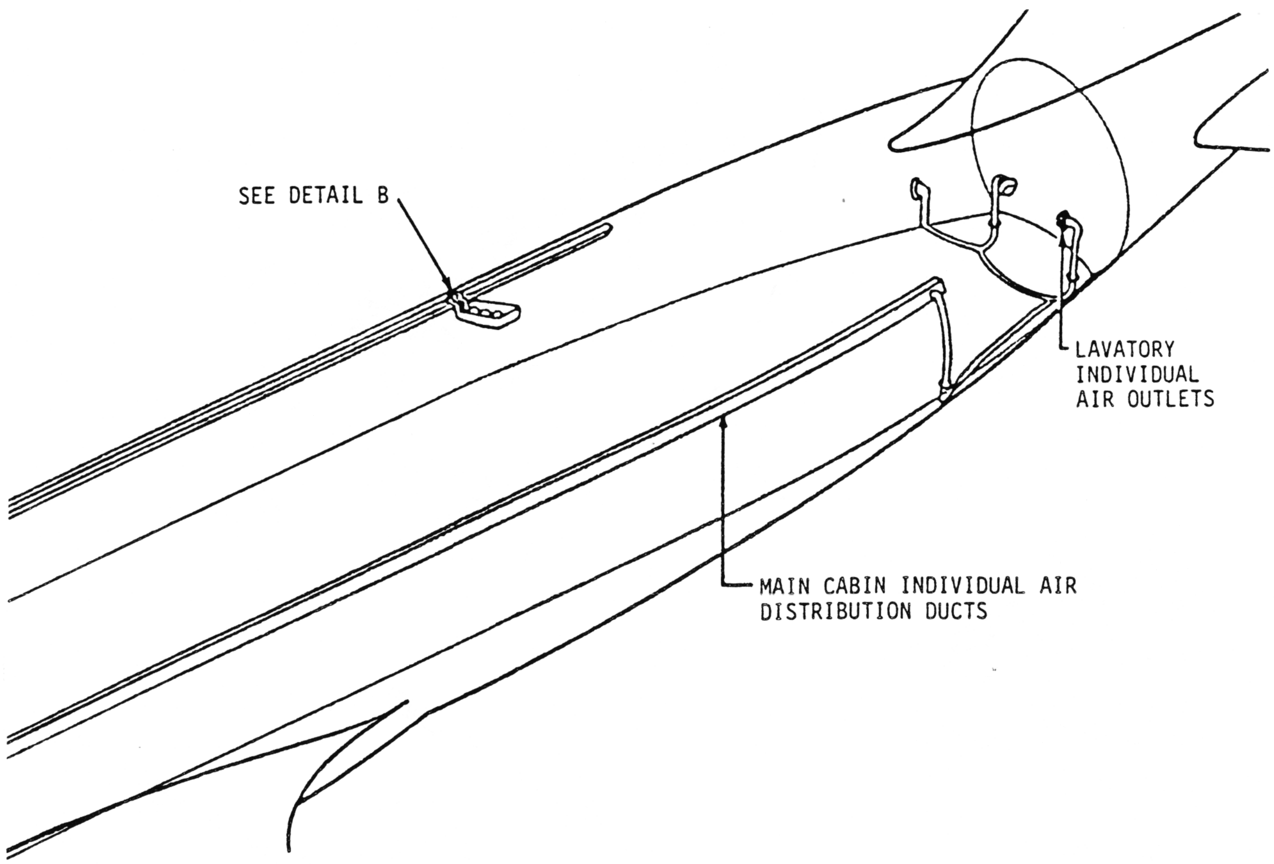
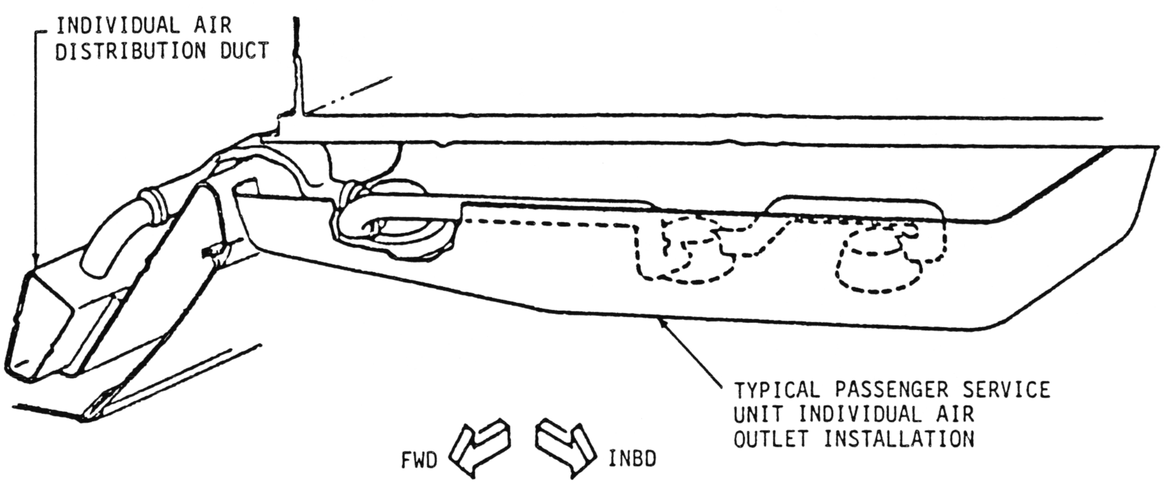


FIGURE 1-12. BOEING 707,720 GASPER AIR DISTRIBUTION (SHEET 1 OF 2)





DETAIL B

FIGURE 1-12. BOEING 707,720 GASPER AIR DISTRIBUTION (SHEET 2 OF 2)

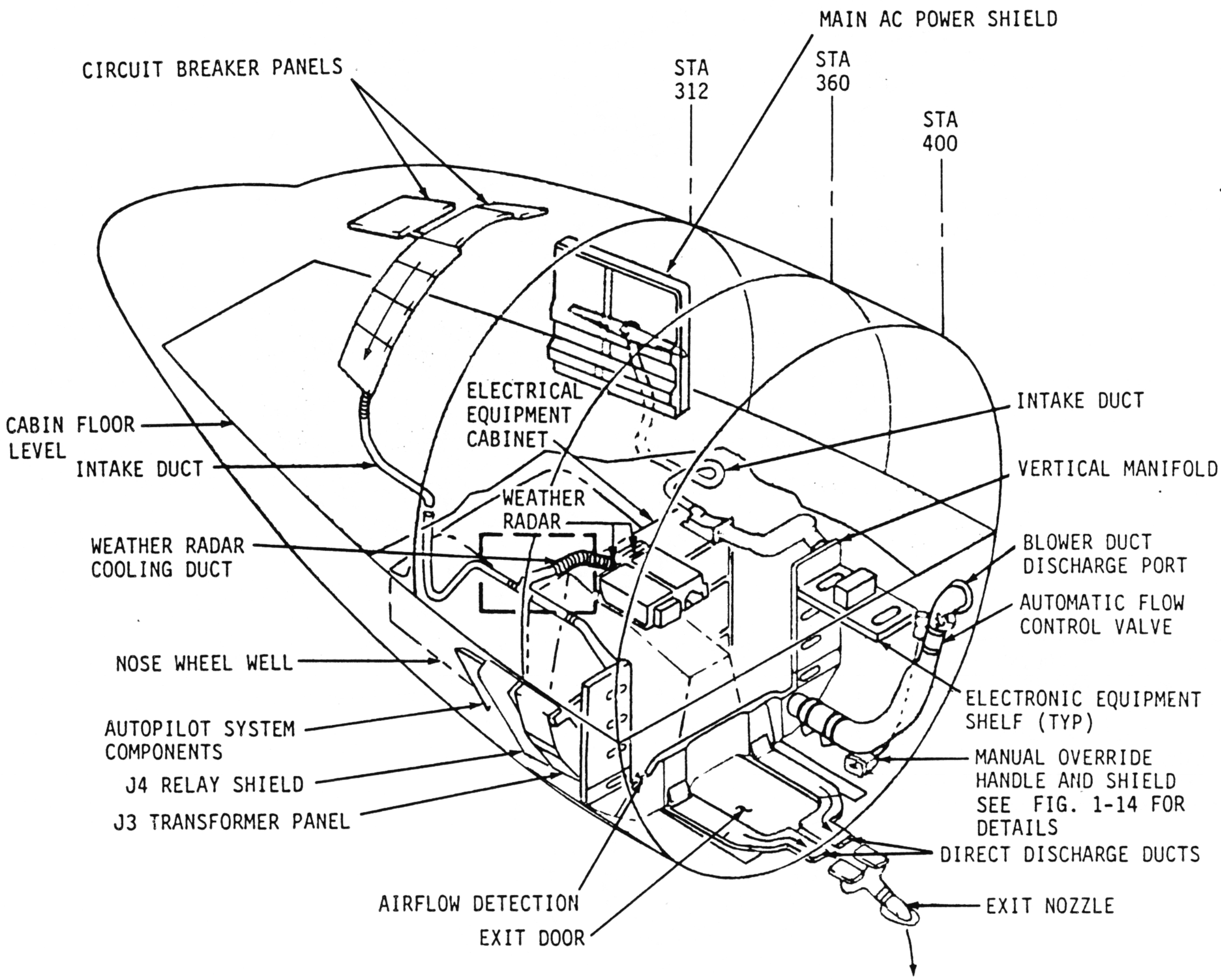


FIGURE 1-13. BOEING 707,720 EQUIPMENT COOLING SYSTEM, DISCHARGE DUCT AIRPLANES

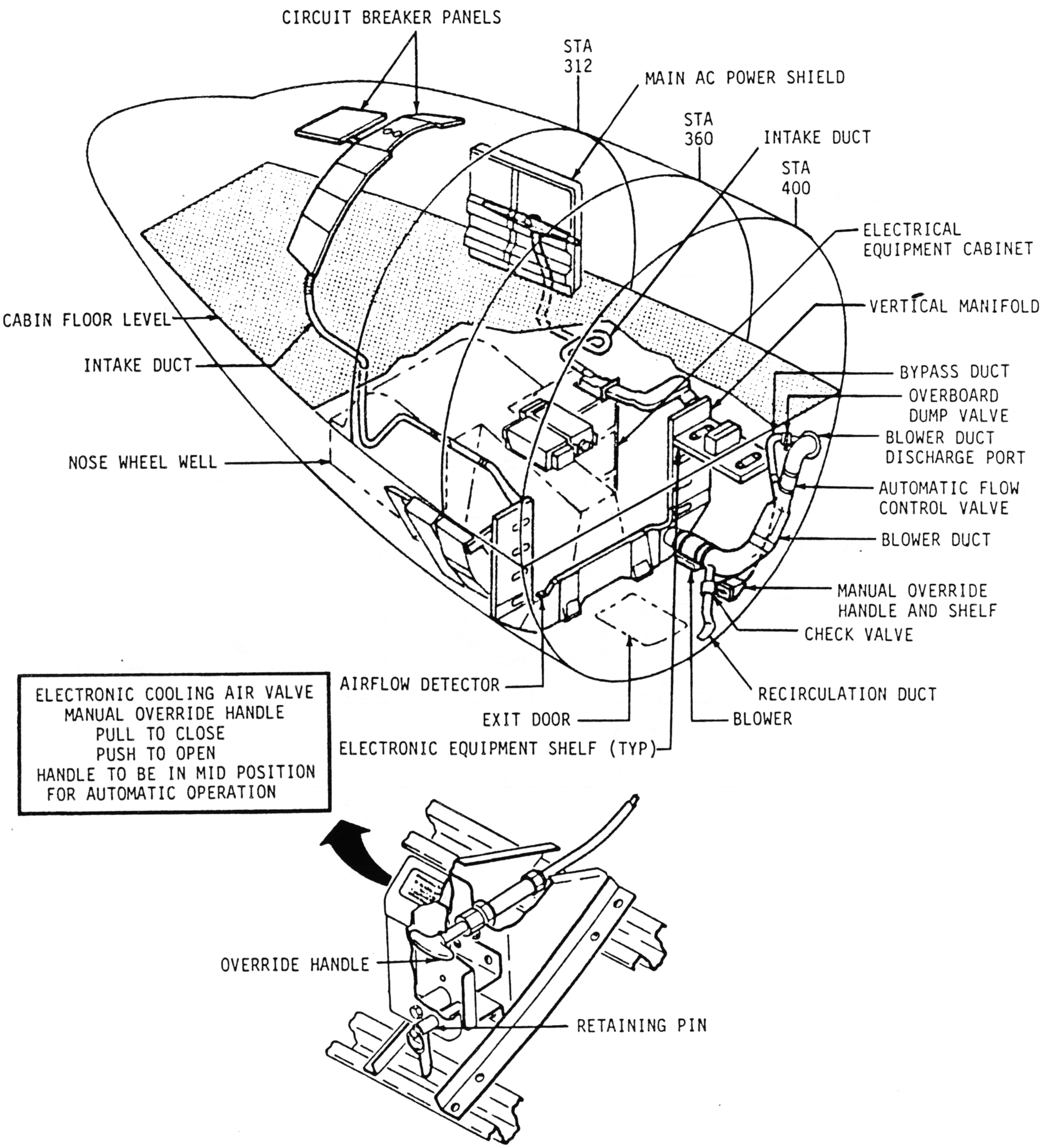


FIGURE 1-14. BOEING 707,720 EQUIPMENT COOLING SYSTEM, RECIRCULATION DUCT AIRPLANES

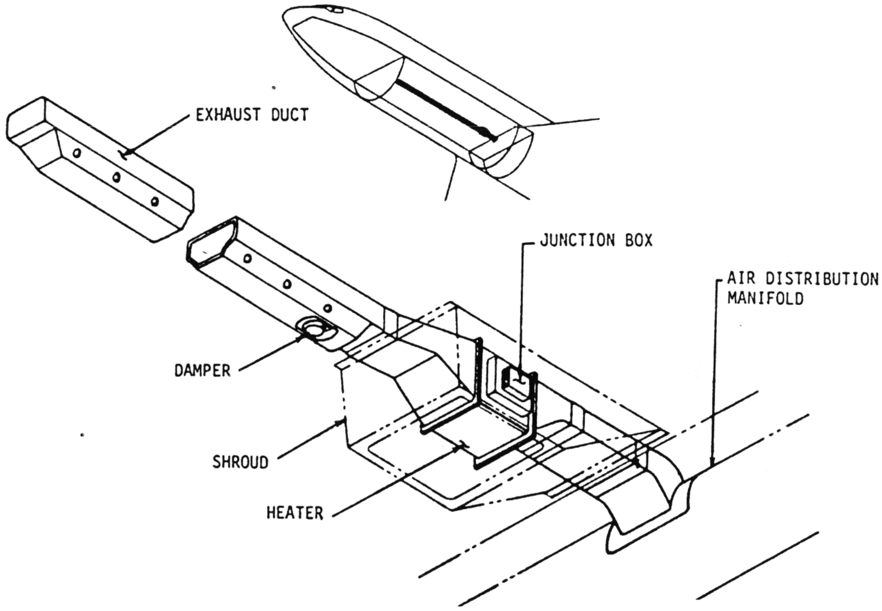


FIGURE 1-15. BOEING 707,720 FORWARD CARGO COMPARTMENT HEATER

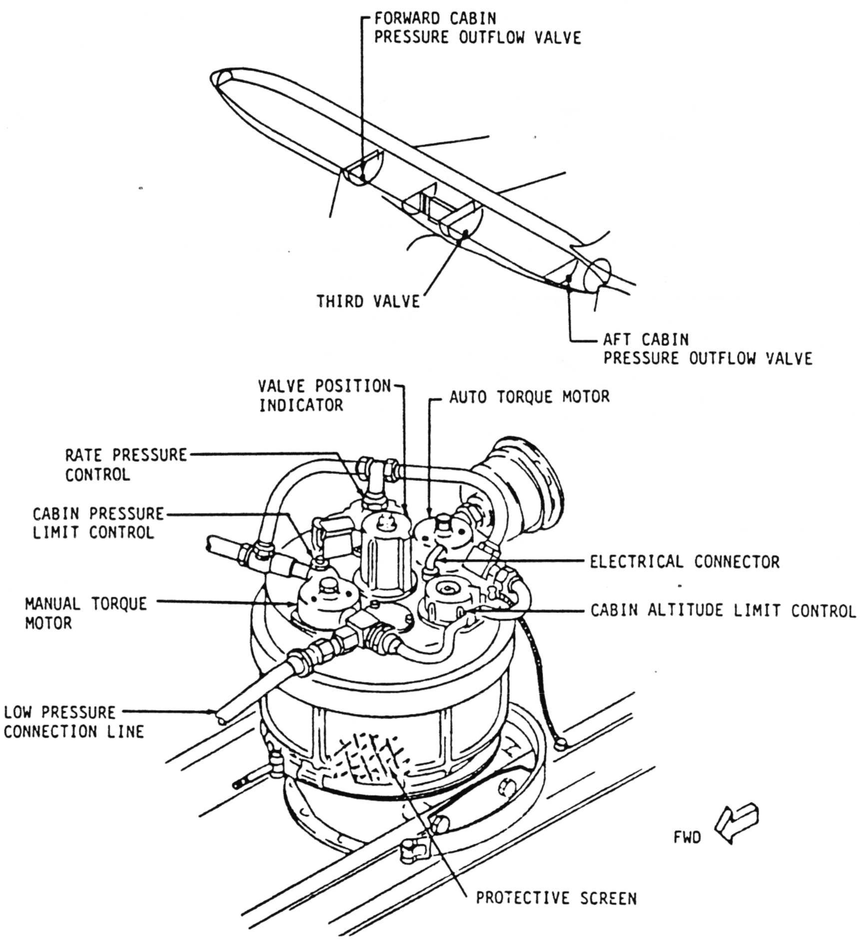


FIGURE 1-16. BOEING 707,720 CABIN PRESSURE OUTFLOW VALVE

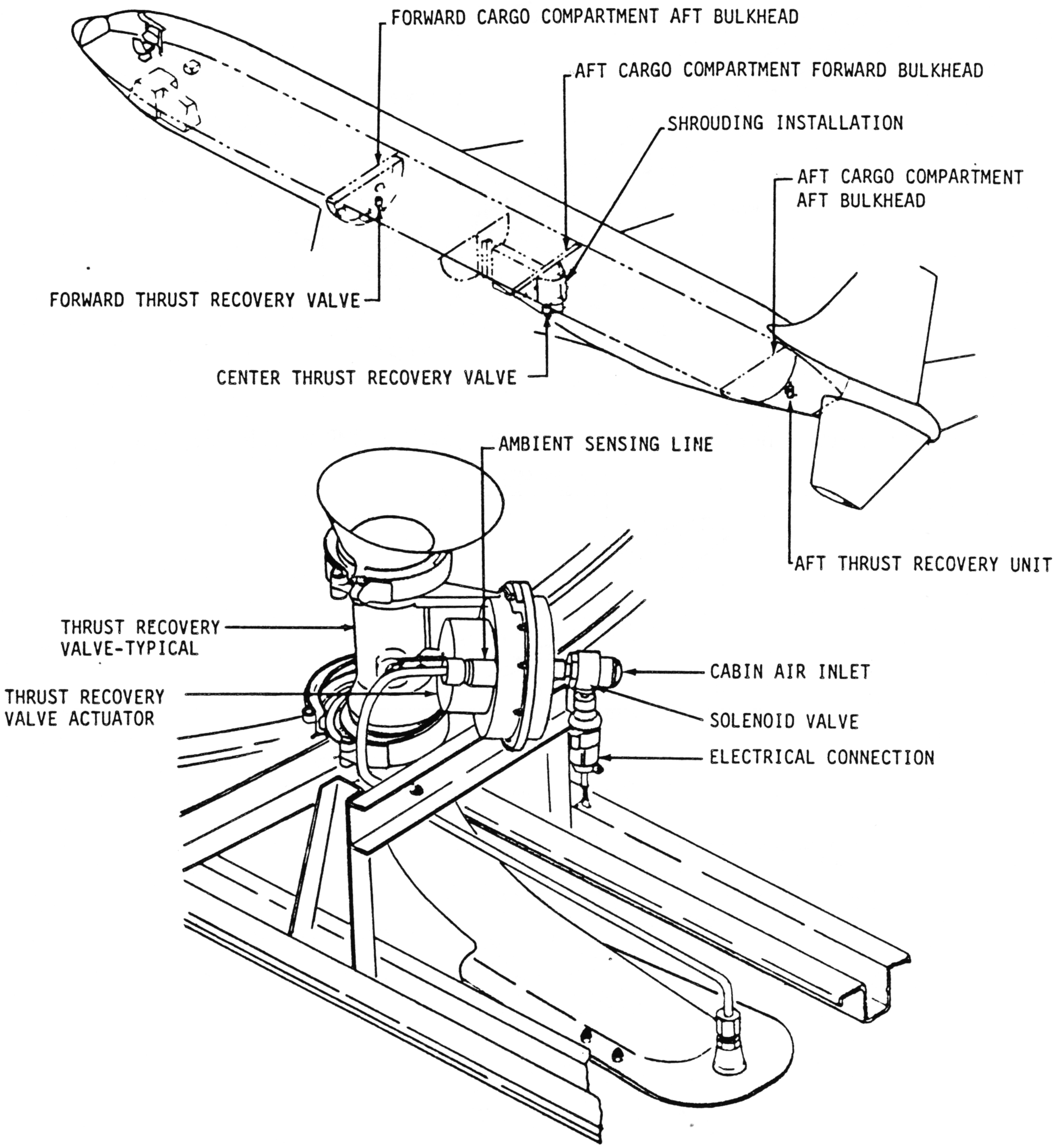
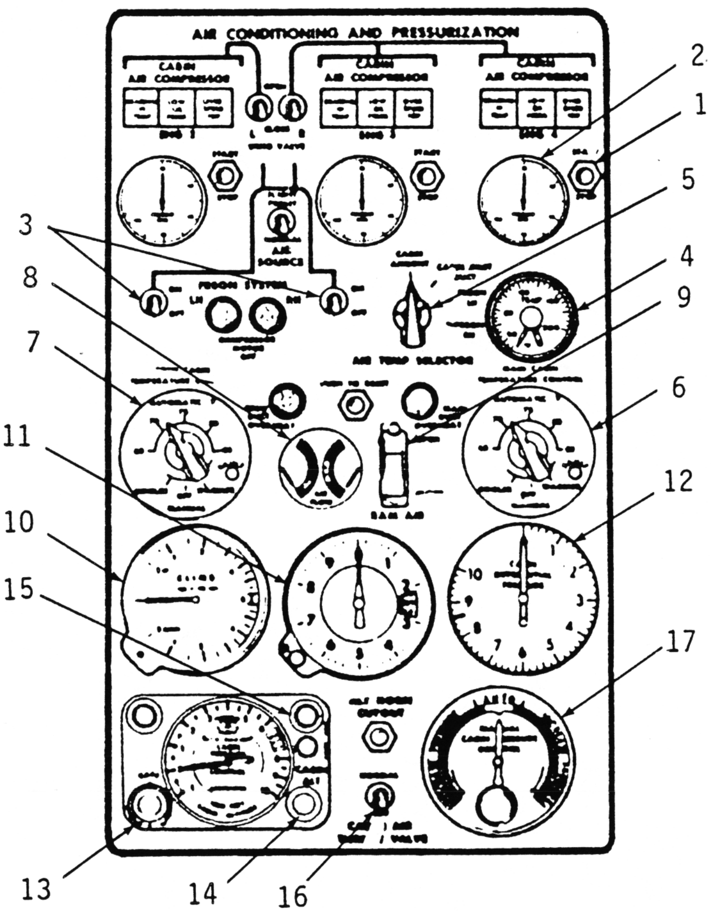


FIGURE 1-17. BOEING 707,720 THRUST RECOVERY VALVE

BOEING 707,720



LEGEND

ECS CONTROLS

1 CABIN COMPRESSOR CONTROL SWITCH
2 COMPRESSOR RPM INDICATOR
3 FREON OR AIR CYCLE PACK START SWITCH
4 TEMPERATURE GAUGE
5 TEMPERATURE DISPLAY SELECTOR
6 MAIN CABIN TEMPERATURE CONTROL
7 FLIGHT DECK TEMPERATURE CONTROL
8 FLOW INDICATOR
9 RAM AIR VALVE CONTROL SWITCH

LEGEND

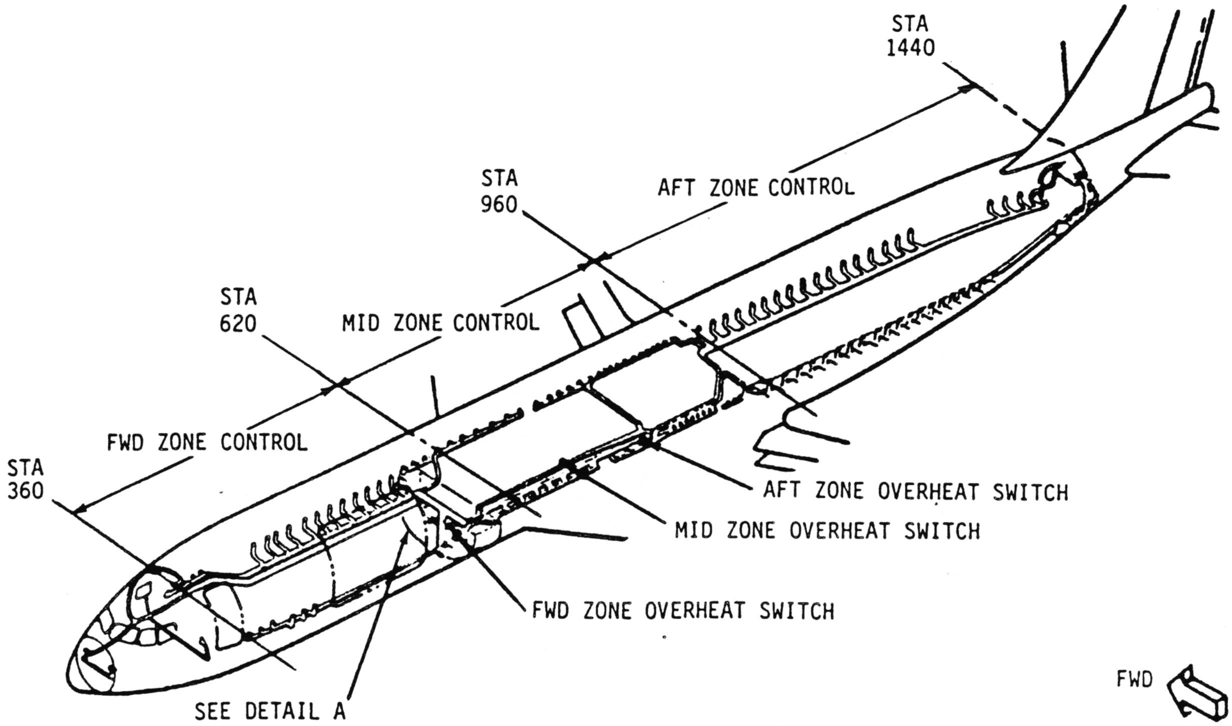
PRESSURIZATION CONTROLS

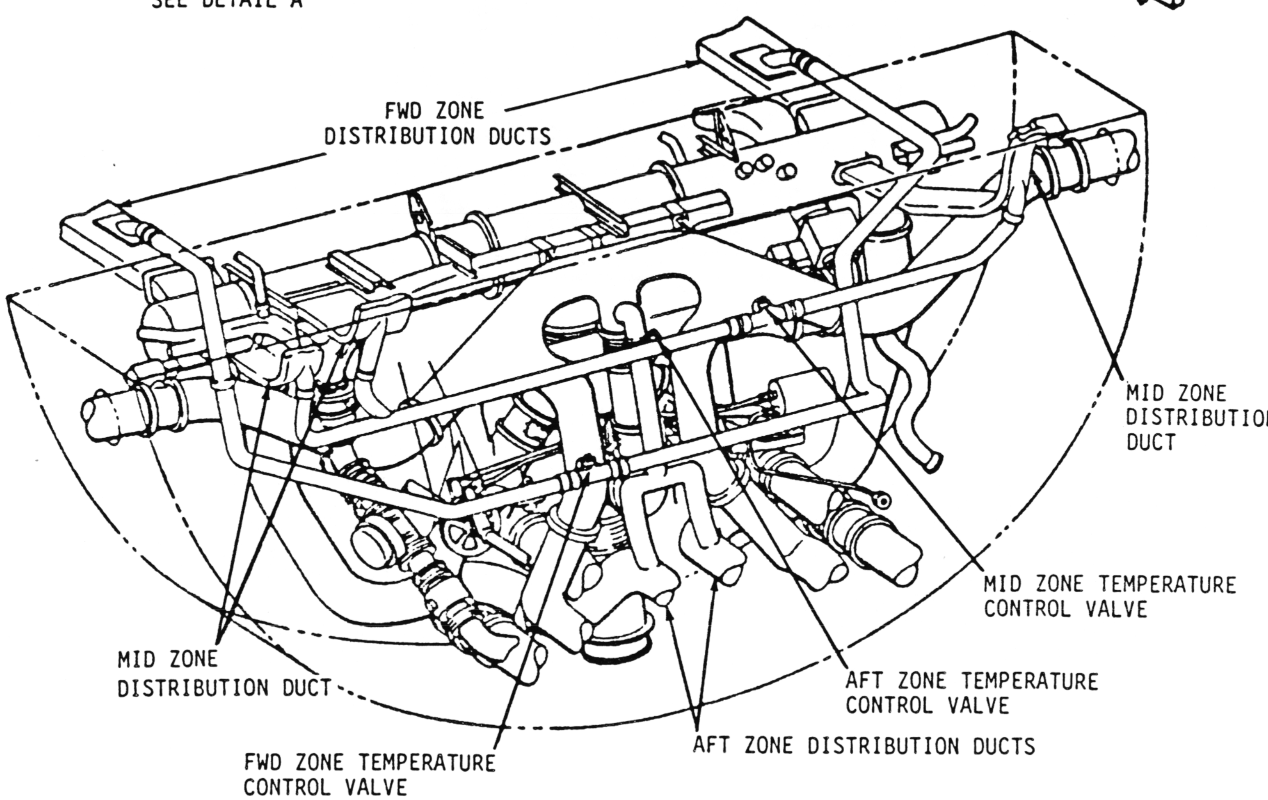
10 CABIN ALTITUDE RATE OF CHANGE GAUGE
11 CABIN ALTITUDE GAUGE
12 DIFFERENTIAL PRESSURE GAUGE
13 CABIN ALTITUDE RATE OF CHANGE SELECTOR KNOB
14 CABIN ALTITUDE SELECTOR KNOB
15 LANDING BAROMETRIC CORRECTION FACTOR
16 THRUST RECOVERY VALVE SWITCH
17 MANUAL PRESSURE CONTROLLER

MISCELLANEOUS CONTROLS

FIGURE 1-18. BOEING 707,720 ECS AND PRESSURIZATION CONTROLS

BOEING 707,720





DETAIL A

FIGURE 1-19. BOEING 707,720 ZONE TEMPERATURE CONTROL DUCTING

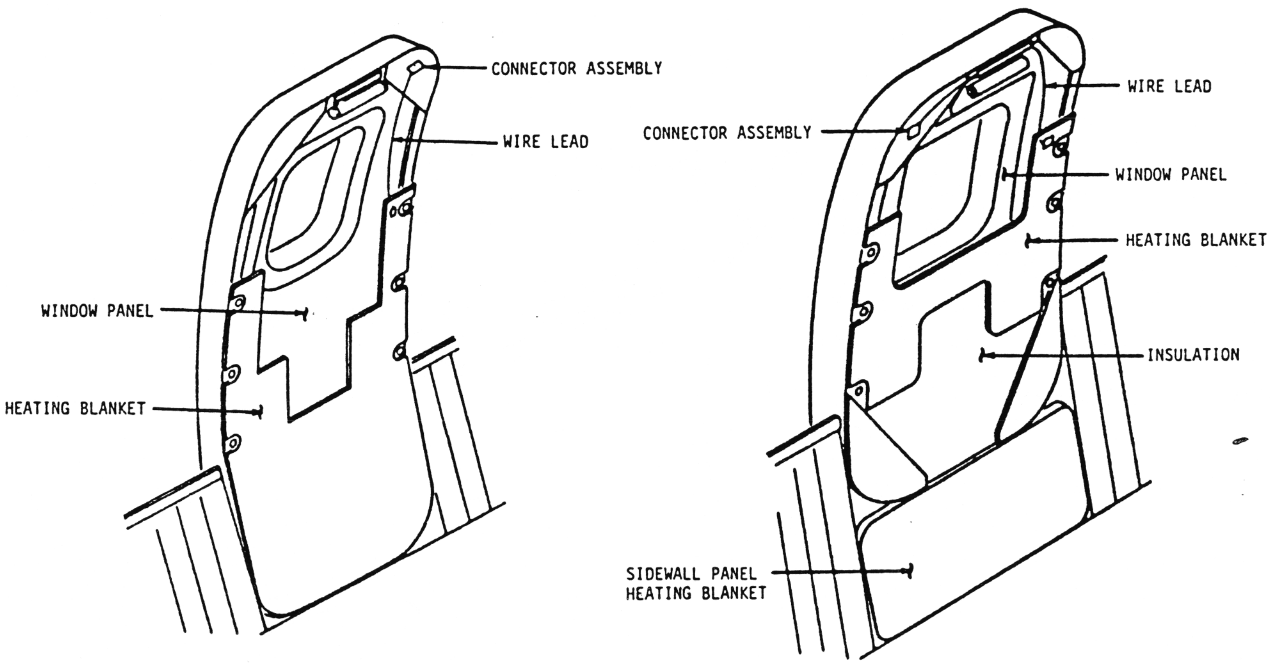


FIGURE 1-20. BOEING 707,720 ESCAPE HATCH HEATING BLANKET

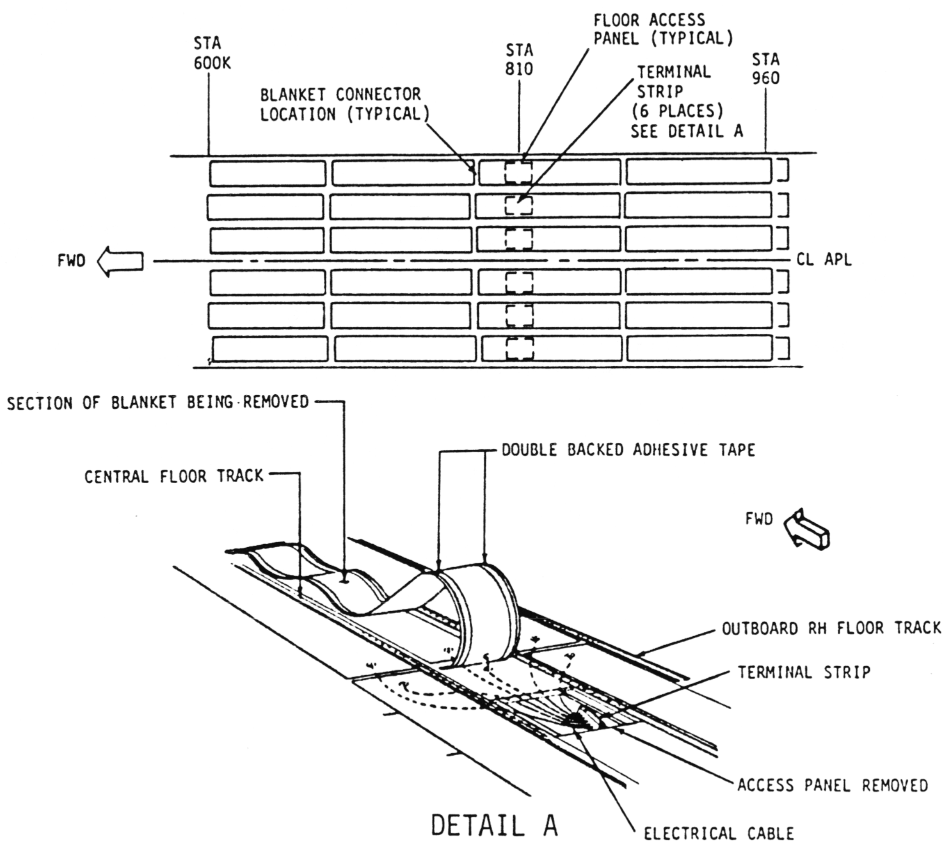


FIGURE 1-21. BOEING 707,720 FLOOR HEATING BLANKET

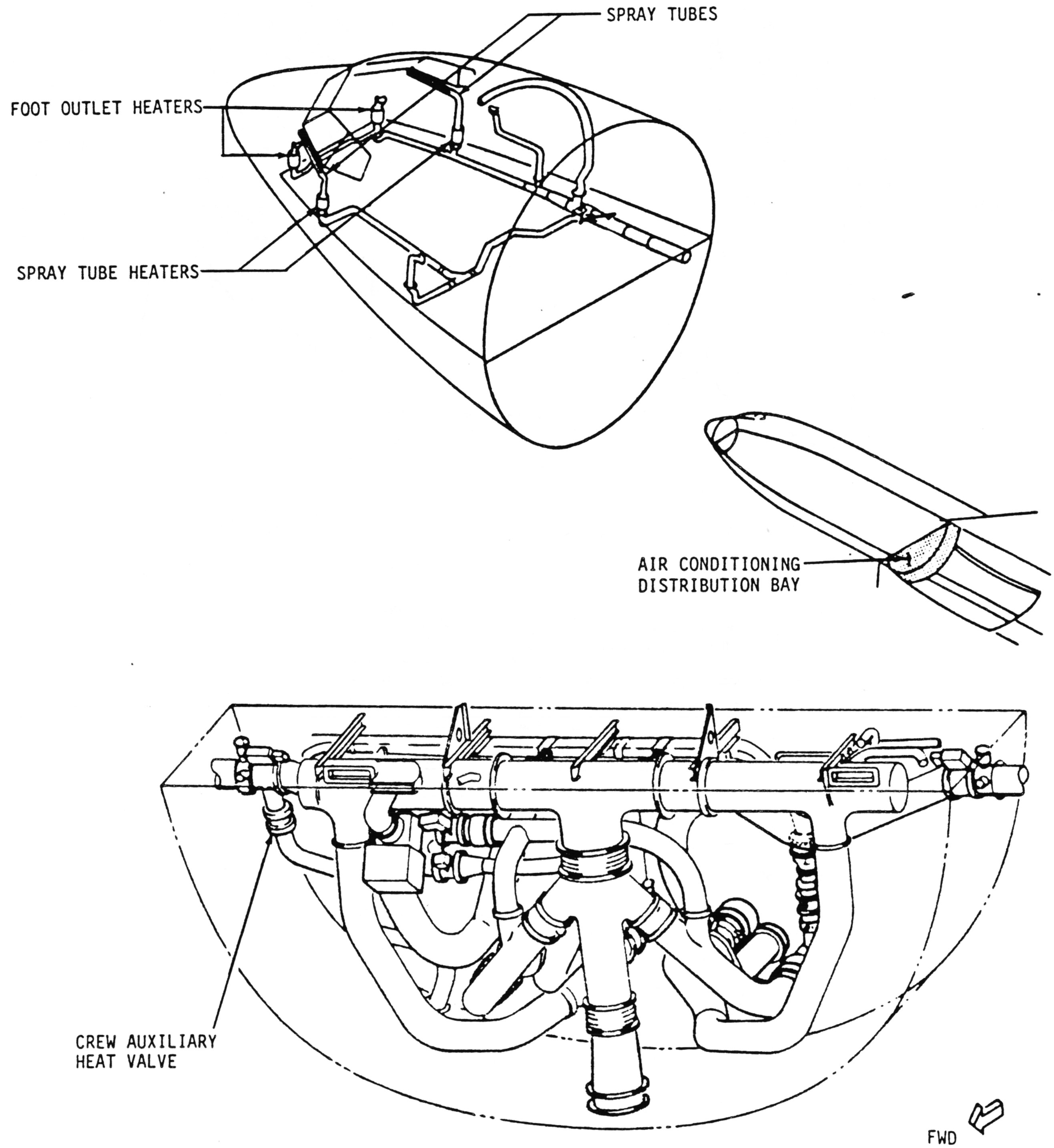


FIGURE 1-22. BOEING 707,720 FLIGHT DECK HEATING EQUIPMENT

SECTION 2

BOEING 727

Model Variation

In the early 1960's, The Boeing Company developed the 727 to serve the medium range segment of the air transport market. This three engine jet transport, one of the most successful designs ever to enter commercial service, has become a world standard for this class of airplane.

The 727 was produced in two models, the -100 and the -200. The -100 was first flown on 2-9-63, and received certification on 12-24-63. It was certified to carry a maximum of 131 passengers, but is usually configured for approximately 100 passengers. The series ended production with 572 units produced. The -200 was first flown on 7-27-67 and received certification on 11-29-67. It was certified to carry a maximum of 189 passengers, but is normally configured in the 150 passenger range. The series ended production with 1,260 units produced.

Both models were offered in three configurations; standard passenger, convertible passenger/cargo, and freighter. The convertible and freighter versions account for approximately 10% of the total production. At a total of 1,832 units produced, the 727 is the best selling commercial jet of all time.

The -200 is a stretched re-engined version of the -100 that incorporates improvements in most major systems. The two models have similar ECS, differing in flow capacity, distribution ducting, and pressurization controls. The distribution ducting is also affected by choice of interior.

The Boeing Company offered three interiors for the 727: the original equipment interior or Hatrack, the new look or SuperJet, and the CarryAll interiors. The Hatrack and SuperJet interiors were offered in both the -100 and -200, and use the same distribution ducting. The CarryAll was offered only in the -200, and has minor differences in ducting locations.

Though the capabilities and limitations of the pressurization control systems are similar, the operation is very different. The -100 system is pneumatically controlled and operated, and requires all parameters be input and monitored during flight. The -200 system is electrically operated and electronically controlled, and requires only flight and landing altitude inputs. Cabin altitude and cabin altitude change rates are determined automatically.

Environmental Control System

The 727 ECS is a two pack air-cycle system which uses engine bleed-air as the air source. A block diagram of the system is shown in Figures 2-1 and 2-2. The air conditioning packs are located below the wing in an unpressurized area of the fuselage, just forward of the wheel well.

The ECS utilizes engine bleed-air from the 8th and 13th compressor stages of engines No. 1 and No. 3. Bleed-air from engine No. 2 is also available during conditions of high bleed-air demand. When the airplane is on the ground, the APU or a ground cart may be used as an air source. Hot bleed-air temperature and pressure are regulated by the pneumatic system before being routed to the flow-control valve. The flow-control valve is a pneumatically operated valve that maintains a constant volumetric flow of air to the air conditioning pack. Air leaving the flow-control valve is routed to the primary heat exchanger and temperature control valve. On -200 models, hot air is also routed to the zone trim system. The primary heat exchanger uses ram air to cool the bleed-air before routing it to the air cycle machine (ACM) compressor. On -200 models, a check valve allows air to bypass the compressor into the secondary heat exchanger when the cooling demands are low.

Air routed to the ACM compressor is compressed to higher pressure and temperature, then routed to the secondary heat exchanger. The air is cooled again by ram air then routed to the ACM turbine. On -200 models, some of the air leaving the secondary heat exchanger is routed to the warm air port of the temperature control valve. Air expands in the ACM turbine to drive the compressor. Cold air exits the ACM turbine, and is routed to the water separator to reduce the humidity then to the individual air system and cold air ports of the mixing valves.

The mixing valves mix hot air (that has bypassed the pack) with cold turbine discharge air (and warm air on -200) to produce conditioned air according to demand by the temperature control system. The left pack discharge temperature is determined by the flight deck temperature selector, and the right pack discharge temperature is determined by the passenger cabin temperature selector. On -200 models, the right pack discharge temperature is determined by the passenger cabin zone demanding the coolest air. The zone temperature control system then adds a controlled amount of hot air to the other passenger cabin zone to provide warmer air to that zone.

The 727 also has provisions for admitting ram air directly to the air conditioning distribution system during unpressurized flight or if both packs fail. A valve located in the right ram heat exchanger cooling duct controls the flow and is operated by a switch on the third crewman's panel.

A schematic of the pack is shown in Figures 2-3, 2-4, 2-5, and 2-6. Pressure and temperature at points, designated on Figures 2-5 and 2-6 are listed in Table 2-1 for varying flight regimes. Note that the maximum supply temperature is governed by the duct overheat limit, and the minimum supply temperature by the water separator anti-ice control. Also note that main distribution manifold pressure is limited to 18 inches of water (.65 psi) above the cabin pressure by a pressure relief valve.

Distribution

Air leaving the temperature control valves enters the main distribution manifold and is divided and routed throughout the airplane. The main distribution system is shown in Figures 2-7 and 2-8. The amount of air diverted to the flight deck and gasper system is controlled by flow limiting venturis, and the remaining air is routed to the passenger cabin. The amount of air entering the sidewall system and overhead system is controlled by manually positioning a lever located on the back wall of the flight deck (see Figure 2-9). The lever may be positioned so that all or any percentage of air can be diverted to either system.

On the -100 the overhead system is fed by a riser located behind the right sidewall and just forward of the wing. On the -200, a plenum under the floor on each side of the forward cabin supplies the overhead duct through ten risers located behind the sidewalls.

The overhead duct is located above the ceiling panels and runs the length of the passenger cabin. Air enters the cabin through a nozzle located on the bottom of the duct (see Figure 2-10) on all styles of interiors. On airplanes with the CarryAll interior, the overhead duct also has droppers that exhaust air into the cabin below the stowage compartments (see Figure 2-11).

On all airplanes except the -200 with the CarryAll interior, the sidewall air outlets (see Figures 2-12 and 2-13) are fed by plenums running fore and aft below the floor on each side of the cabin. Air is routed up to the outlets below the stowage racks by ducting located behind the sidewall. Figure 2-14, 2-15 and 2-16 show variation in air flow patterns in the cabin produced by variation in selector valve setting.

Cross-sections of the passenger cabin showing ducting configuration for both models and all types of interiors is shown in Figures 2-8, 2-17 and 2-18.

The flight deck distribution system is supplied by a separate duct running forward under the left-hand floor. Air enters the flight deck through six outlets, two at the back of the flight deck, two at the pilot and co-pilot's feet, and one each at the pilot and co-pilot's shoulder.

The flow rates entering the compartments are tabulated in Tables 2-2 and 2-3, and air change rates in Tables 2-4 and 2-5 for varying flight regime. Compartment volumes are listed in Table 2-6.

Individual (Gasper) Air

In addition to the compartment conditioned air, the passenger also has a separate air outlet that may be used to further cool his personal space. This air is somewhat cooler than the air supplied to the air conditioning distribution system. Flow rates through the system are included in the numbers in Tables 2-2 and 2-3. With all outlets open, approximately 15% to 20% of the total flow passes through the system.

The gasper system is supplied from the mixing manifold by risers located behind the sidewalls over the wing on both sides of the cabin. Plenums run fore and aft behind the stowage racks (see Figures 2-20 and 2-21), and supply outlets located below the stowage racks (see Figures 2-22 and 2-23). The outlets are ball and socket type, adjustable for flow and direction.

Gasper air is also available to the flight crew. The flight deck has a separate system, supplied from the right-hand passenger cabin system risers by a duct running forward under the right-hand floor. On the -100, the system has four outlets in the cabin, two at shoulder level behind the pilot and co-pilot's seats, and two on the instrument panel forward of the pilot's and co-pilot's seats. The -200 has five outlets, the same four as the -100 plus one additional outlet located at the back of the flight deck.

The gasper system also has a fan for increasing system pressure during conditions of high demand or low supply pressure (for example when only one pack is operating). The fan is controlled by a switch on the third crewman's panel. The fan should not be operated during a smoke situation. This could cause smoke from the lower deck to be drawn into the gasper ducting through the gasper check valve, and be dispersed through the cabin.

Equipment Cooling

Operation of the equipment cooling system is automatic once electric power is applied to the airplane. Instruments and electrical equipment are cooled by drawing flight deck conditioned air through the instrument panel and around the equipment.

On the ground or at low altitude, cabin air is drawn through the equipment panels by a blower located in the equipment cooling discharge duct (see Figure 2-24). As the cabin differential pressure rises above .64 psi, the blower shuts down and cabin pressure drives the airflow through a flow-control valve and out the blower discharge port. At about 3 psi, the flow-control valve closes, and air is exhausted overboard through a flow limiting venturi.

The system has its own airflow detection and will alert the third crewman when airflow is inadequate to provide proper cooling.

Cargo Heating and Ventilation

The 727 cargo compartments are classified in FAR 25.857 as Class D compartments. As such, they are limited in their leakage rates to 1500 cubic feet per hour. There are no provisions for direct ventilation of the cargo compartments. Cargo heating is accomplished in part by exhausting cabin air between the cargo lining and the fuselage skin. Cargo heat provisions are shown in Figure 2-25. Compartment volumes are listed in Table 2-1.

The forward cargo compartment has no supplemental heating, but cabin exhaust airflow is aided by the cargo heat distribution duct. The cargo heat distribution duct draws the cabin air to the bottom of the cargo compartment, then exhausts it overboard through the cargo heat outflow valve.

On all except late production 727-200, the aft cargo compartment is heated in the same manner, except that on some airplanes, air is exhausted through the cabin pressure outflow valve, and the cargo heat outflow valve is omitted.

On late model 727-200, the aft compartment is heated by exposing the air conditioning duct on the left side to warm cabin exhaust air as it passes over the cargo liner. The right side is heated by 15 electric surface heaters mounted between the fuselage skin and cargo liner. The heaters are thermostatically controlled between 80 and 100 ^{o}F.

Ventilation

Air is vented overboard by four systems; pressurization outflow valves, galley ventilation, cargo heat, and equipment cooling. Galley ventilation and equipment cooling are fixed-flow systems in that the crew has no control over the amount of air vented. The cargo heat and pressurization outflow valves are variable flow, and are adjusted from the third crewman's panel. Figure 2-26 shows the outflow points. The galley vent is shown in Figure 2-27. Equipment ventilation is described under Equipment Cooling.

The galley vent system removes air from the top of the galley and vents it overboard through a flow-limiting venturi. The flow is driven by the cabin pressure to atmosphere pressure differential and is not adjustable. There are generally two to four galleys carried aboard the 727, placed in the forward and aft cabin.

The cargo heat outflow valves are located on the bottom of the fuselage, and are operated by a switch on the third crewman's panel. The valves may be operated full open without affecting the pressurization system's ability to maintain low cabin altitude. The valves are normally left in the open position.

The pressurization outflow valves are the primary method of maintaining ventilation. The valves are located on the underside of the fuselage just aft of the aft cargo compartment. The -100 has two pneumatically operated poppet type valves that also incorporate the pressure safety relief valve and vacuum relief valve (see Figure 2-28). The -200 has one electrically operated gate valve, with two separate pressure- and vacuum-safety valves (see Figure 2-29). By responding to signals from the pressure controller, the outflow valve opening is varied to maintain adequate cabin pressure.

The valve opening is usually controlled automatically by the pressure controller. If the pressurization is switched to manual mode, the opening can be controlled from the third crewman's panel.

Pressurization Control

Though the performance and limitations of the pressurization control system (PCS) of the -100 and -200 are similar, their operation is very different and, therefore, is described separately. Both systems have the same safety features to override control selections which may cause damage to the airplane structure or discomfort to the passengers. PCS capabilities are shown in Table 2-6.

The -100 PCS is a pneumatically operated system that controls the amount of air exhausted through the outflow valves. The -100 control panel is shown in Figure 2-30. The bottom two sections house the PCS controls. The pressure controller has two modes, automatic and manual.

When using the automatic mode, the operator selects the desired cabin altitude, cabin altitude rate of change, and inputs a barometric correction factor for landing altitude. The controller then modulates the outflow valve opening as the flight progresses to limit the pressure differential to 8.6 psi or less, and to maintain cabin altitude as requested.

The manual system allows regulation of cabin pressure if the automatic system fails. The manual control can be adjusted only to increase, decrease or maintain cabin pressure. The crew must monitor the gauges to prevent excessive cabin altitude and differential pressure. Safety-pressure relief is provided at 9.42 psi.

The -200 PCS is an electrically operated and electronically controlled system that controls the amount of air passing through the outflow valve. A schematic of the -200 PCS is shown in Figure 2-31. The pressurization-control panel is shown in Figure 2-32. The system has four operating modes, automatic, standby, AC manual, and DC manual. The system transfers to standby if the auto mode fails. The manual modes further back-up the standby mode. An operating mode selector knob, cabin altitude, and cabin altitude change rate gauges are also included on the control panel. Limits of the PCS are shown in Table 2-6.

During normal flight, operation is on the auto controller. The auto mode requires only flight altitude and landing altitude to be entered by the crew. The pressure controller automatically modulates the outflow valve opening to maintain the lowest possible cabin altitude for the selected flight altitude. The controller also acts to minimize the cabin altitude rate of change and differential pressure upon landing. Should the cabin altitude or pressure rate of change limits be exceeded, transfer to standby is automatic.

The standby mode may also be used instead of automatic. The crew is required to set the desired cabin altitude and cabin altitude change rate. The differential pressure gauge and cabin altitude rate of change gauges must be monitored to maintain the cabin conditions within acceptable limits.

The manual systems function in the event of the loss of auto and standby modes. They must be selected by the mode selector knob. The AC and DC modes operate the same, differing only in the source of electricity to drive the outflow valve. The manual mode uses a three-position toggle switch to change the position of the outflow valve. The switch sends one pulse to the valve for each toggle. In use, one toggle will change the cabin pressure, but two or three toggles are required to observe any change in outflow valve position as read on the gauge. The cabin altitude and differential pressure gauges must be monitored to maintain the cabin conditions within acceptable limits.

ECS Controls

The ECS control panel is shown in the upper portion of Figures 2-31 and 2-32. The upper panel has switches to control the source of bleed-air, ram air inlet valve, ram air cooling door opening, gasper fan, cargo heat outflow valve and pack flow. Gauges for monitoring ram air cooling door opening and bleed-air pressure and temperature are provided. The lower panel has controls for adjusting and monitoring the compartment temperatures and mixing valve positions.

Bleed-air is normally taken from engines No. 1 and No. 3, with engine No. 2 available if needed. Engines No. 1 and No. 3 have an automatic flow regulator that selects the correct proportions of 8th and 13th stage bleed-air to minimize variation of bleed-air pressure and flow. The bleed-air is then routed through a pre-cooler heat exchanger. The exchanger uses fan stage engine air to cool the bleed-air to acceptable limits before routing to the pack shut-off valve. Engine No. 2 provides only 8th stage air and has no pre-cooler. Bleed-air temperature and pressure must be carefully monitored to prevent overheat of the pack and ducting when engine No. 2 bleed-air is used.

The ram-air valve, as previously described, allows ram air from the right heat exchanger duct to pass into the distribution system. The valve is for use only during unpressurized flight.

The ram-air cooling door switch allows the crew to vary the amount of ram cooling of the heat exchangers by varying the door opening. Closing the doors will cause the turbine discharge temperature to rise; opening the doors will cause it to fall.

The gasper fan switch controls the gasper fan, and causes the pressure in the gasper ducts to rise when the supply pressure is low. Use of the fan may cause air from the lower hold to be drawn into the gasper system through the gasper system-recirculation check valve.

Operation of the cargo heat outflow valve is described under Cargo Heating. The valves are normally operated open without affecting the pressurization control system.

Pack operation is controlled by the two switches (Item 4 on Figures 2-31 and 2-32). The packs are either on or off. There is no adjustment for flow capacity, or for specifically controlling the flow into individual compartments. The flow through the system is governed by the flow-control valve, the specific ambient conditions, and engine power settings. The flow data, pressures, and temperatures are shown in Tables 2-1, 2-2, and 2-3. The data presented are for a Boeing standard hot day. This condition represents the pack's minimum efficiency operation.

The temperature control systems for the -100 and -200 differ in that the -200 uses a zone-temperature control allowing different inlet temperatures to counteract uneven passenger distribution in the forward cabin and aft cabin.

The -100 has a two zone temperature control system, the flight deck and the passenger cabin. The temperature of each zone can be controlled manually or automatically. In the manual mode, the position of the mix valve is controlled by toggling the switch to either cooler or warmer, and then monitoring the compartment temperature gauge. Automatic mode requires only setting the desired cabin temperature on the control panel. Gauges are provided for checking the mix valve position and compartment temperatures.

The -200 uses a three zone temperature control system, the flight deck, forward passenger cabin and aft passenger cabin. The temperature controls are divided into flight deck and passenger cabin. The temperature of each zone can be controlled automatically or manually, and operates the same as the -100.

The passenger cabin zones have a separate automatic system that senses the temperatures in the two zones, and acts to minimize the sensed-temperature difference. Initially, the air leaving the mixing valve is mixed to coolest temperature demanded by the warmest zone. The zone heating system then adds a controlled amount of warm air to the zone(s) having the lesser cooling needs.

Electrical energy requirements of ECS components and controls are shown in Table 2-7.

TABLE 2-1. BOEING 727-200 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

FLIGHT REGIME	A FLOW CONTROL VALVE INLET		B FLOW CONTROL VALVE OUTLET		C WATER SEPARATOR OUTLET		D FLIGHT DECK SUPPLY		E PASS. CABIN SUPPLY		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP*	PRESS	TEMP
SEA LEVEL TAKEOFF	67	325	41	325	15.9	35	14.7	38	14.7	39	14.7	75	14.7	100
SEA LEVEL CLIMB	61	316	43	316	15.9	41	14.7	43	14.7	45	14.7	75	14.7	100
10,000 FT CLIMB	DATA NOT AVAILABLE													
25,000 FT CRUISE	DATA NOT AVAILABLE													
30,000 FT CRUISE	DATA NOT AVAILABLE													
35,000 FT CRUISE	18.5	280	18.0	280	13.2	86	13.0	91	13.0	83	13.0	75	3.47	-66
40,000 FT CRUISE	DATA NOT AVAILABLE													
20,000 FT DESCENT	DATA NOT AVAILABLE													
10,000 FT DESCENT	DATA NOT AVAILABLE													

MAXIMUM SUPPLY TEMP 190°F

MAXIMUM SUPPLY TEMP 35°F

*TEMP IS A MAXIMUM DURING COOLING

TABLE 2-2. BOEING 727-100 VOLUME FLOW (CFM) (REF 2)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	DATA NOT AVAILABLE	N/A*	NOT APPLICABLE	N/A*	NOT APPLICABLE
5,000 FT CLIMB		N/A*		N/A*	
10,000 FT CLIMB		N/A*		N/A*	
25,000 FT CRUISE		1,921		179	
30,000 FT CRUISE		2,031		189	
35,000 FT CRUISE		2,126		197	
40,000 FT CRUISE		2,200		204	
20,000 FT DESCENT		N/A*		N/A*	
10,000 FT DESCENT		N/A*		N/A*	

*N/A NOT AVAILABLE

TABLE 2-3. BOEING 727-200 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL CLIMB	102	2,386	NOT APPLICABLE	270	NOT APPLICABLE
5,000 FT CLIMB	98	2,296		257	
10,000 FT CLIMB	N/A*	N/A*		N/A*	
25,000 FT CRUISE (REF 4)	N/A*	2,593		240	
30,000 FT CRUISE (REF 4)	N/A*	2,565		238	
35,000 FT CRUISE	104	2,850		320	
40,000 FT CRUISE (REF 4)	N/A*	2,697		250	
20,000 FT DESCENT	N/A*	N/A*		N/A*	
10,000 FT DESCENT	N/A*	N/A*		N/A*	

*N/A NOT AVAILABLE

TABLE 2-4. BOEING 727-100 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	N/A*	N/A*
5,000 FT CLIMB	N/A*	N/A*
10,000 FT CLIMB	N/A*	N/A*
25,000 FT CRUISE	21.6	31.7
30,000 FT CRUISE	22.9	33.6
35,000 FT CRUISE	24.0	35.0
40,000 FT CRUISE	24.8	36.2
20,000 FT DESCENT	N/A*	N/A*
10,000 FT DESCENT	N/A*	N/A*

*N/A NOT AVAILABLE

TABLE 2-5. BOEING 727-200 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	24.5	47.9
SEA LEVEL CLIMB	23.6	45.6
10,000 FT CLIMB	N/A*	N/A*
25,000 FT CRUISE	26.6	42.6
30,000 FT CRUISE	26.3	42.2
35,000 FT CRUISE	29.2	56.8
40,000 FT CRUISE	27.7	44.4
20,000 FT DESCENT	N/A*	N/A*
10,000 FT DESCENT	N/A*	N/A*

*N/A NOT AVAILABLE

TABLE 2-6. BOEING 727 VENTILATION PARAMETERS

VOLUMES (CU FT) (REF 4)			727-100	727-200
Total Pressurized			8,252	10,790
Passenger Cabin			5,320	5,843
Control Cabin (Flight Deck)			338	338
FWD Cargo			425	690
AFT Cargo			485	760
PRESSURIZATION				
Max ΔP (PSI)				
Controller Limited			8.6	8.6
Safety Valve Limited			9.42 ± .15	9.42 ± .15
CABIN ALTITUDE CHANGE RATES (FT/MIN)				
Controller Selected	Max	2,000		
	Min	50		
Manual Selection	Max	10,000		
	Min	0		
MAXIMUM CABIN ALTITUDE (FT)			13,000*	15,000*

*IF PNUEMATIC SYSTEM CAN SUPPLY NEEDED AIR WHEN OTHER COMPONENTS FAIL

TABLE 2-7. BOEING 727 ELECTRICAL ENERGY REQUIREMENTS

727-100 (REF 8)

EQUIPMENT	POWER REQD	LOAD	SOURCE
Gasper Fan	115V 400 Hz 3Ø	1,000 W	AC Bus 3
Equipment Cooling Blower	115V 400 Hz 3Ø	1,660 W	AC Bus 3

727-200 (REF 9)

EQUIPMENT	POWER REQD	LOAD	SOURCE
Pressure Controller			
Auto DC	28 VDC	3.3 A	DC Bus 1
Auto AC	115V 400 Hz 3Ø	87 W	AC Bus 1
Equipment Cooling Blower	115V 400 Hz 3Ø	1,000 W	AC Trans Bus
Gasper Fan	115V 400 Hz 3Ø	1,660 W	AC Bus 3
Aft Cargo Heating	115V 400 Hz 3Ø	1,960 W	AC Bus 3

BOEING 727-100

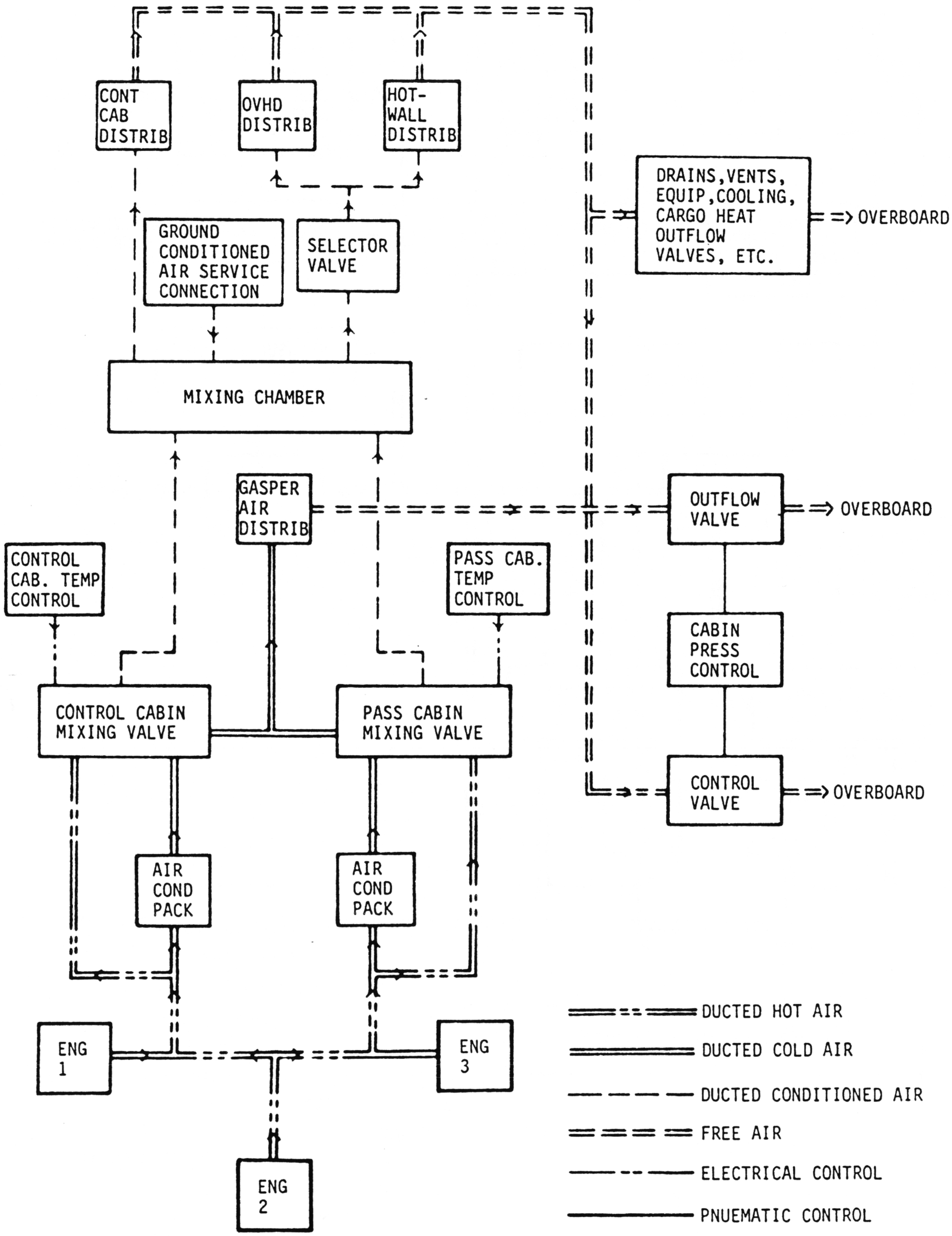


FIGURE 2-1. BOEING 727-100 AIR CONDITIONING AND PRESSURIZATION BLOCK DIAGRAM

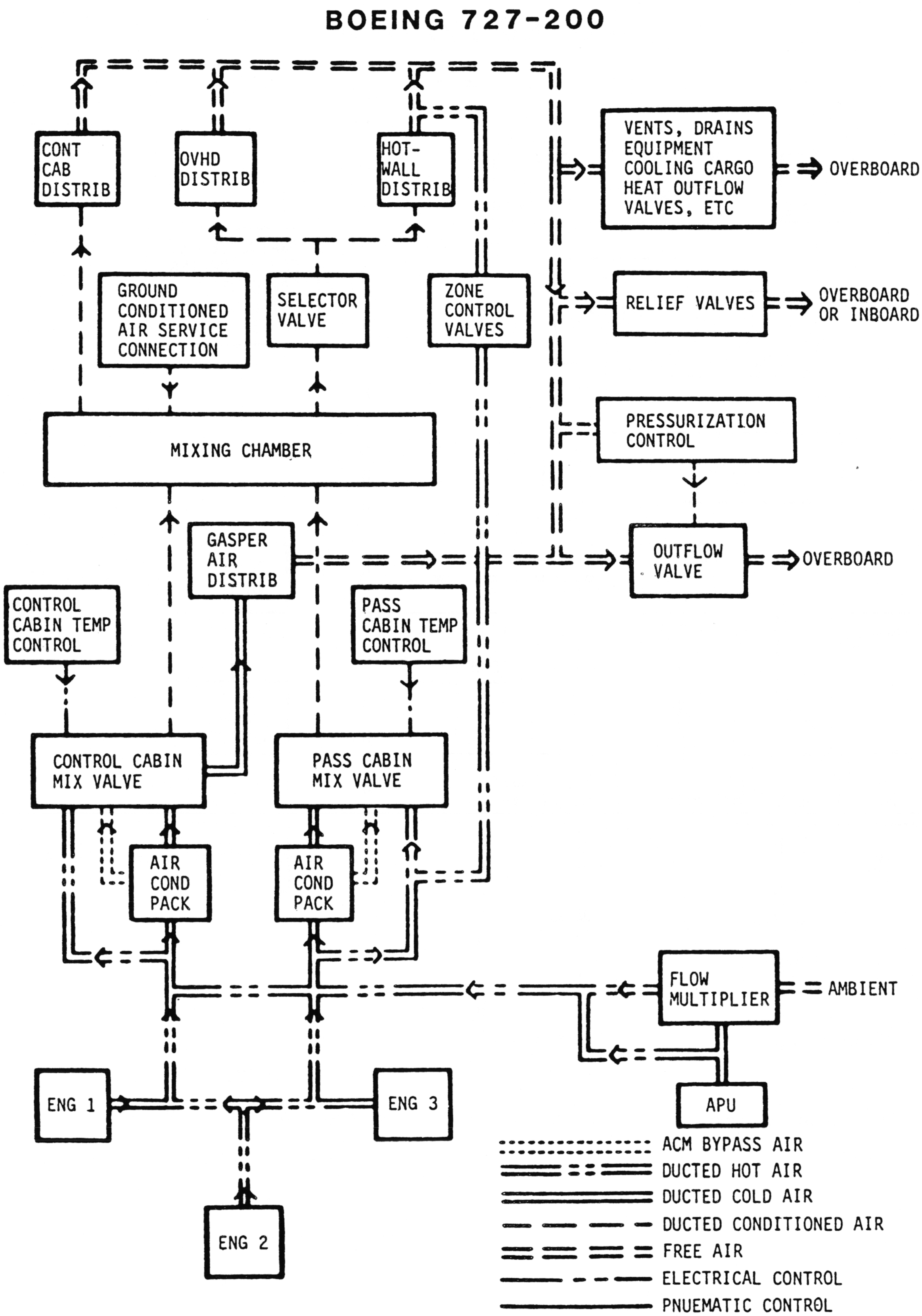


FIGURE 2-2. BOEING 727-200 AIR CONDITIONING AND PRESSURIZATION BLOCK DIAGRAM

BOEING 727-100

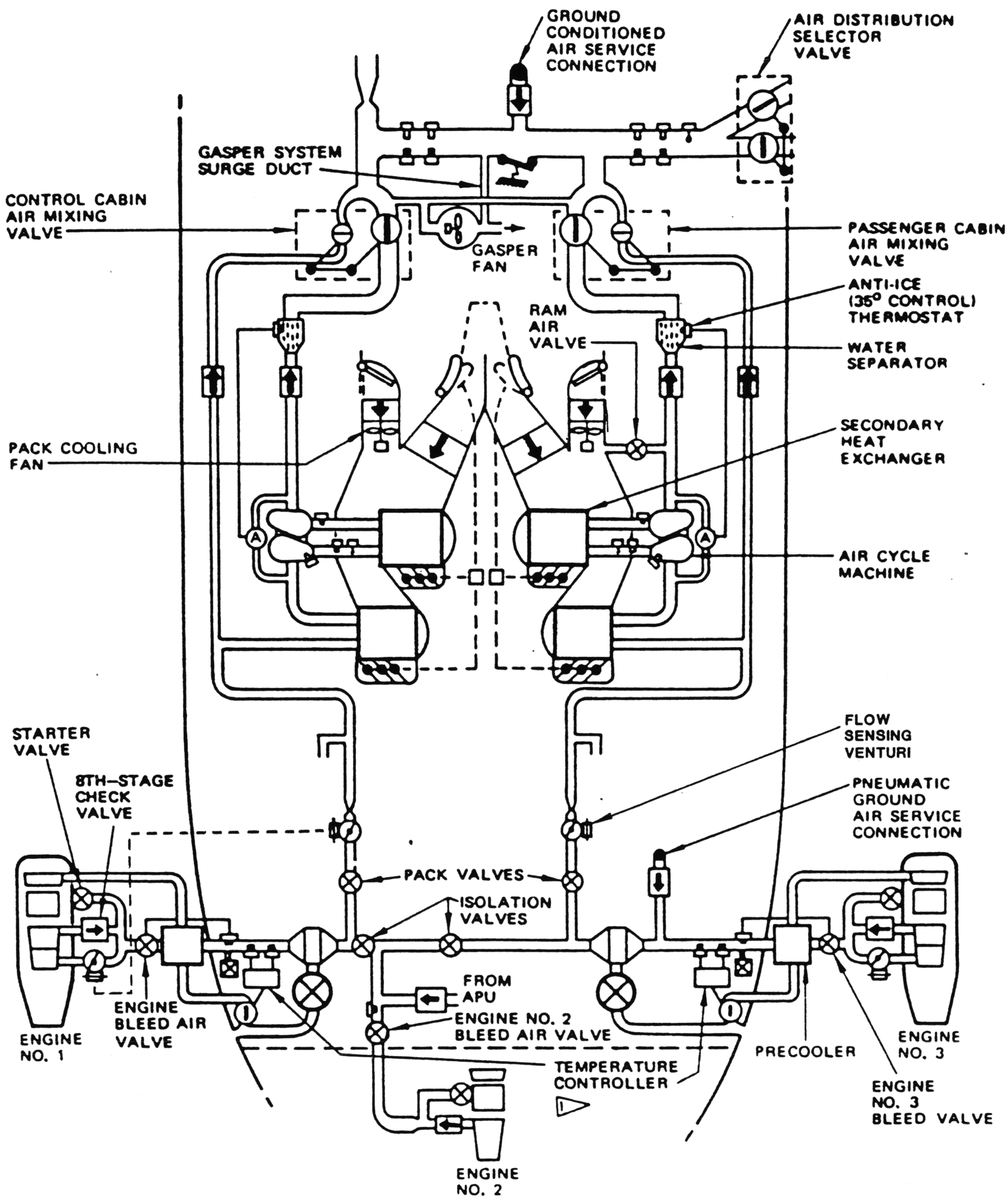


FIGURE 2-3. BOEING 727-100 AIR CONDITIONING SYSTEM SIMPLIFIED SCHEMATIC

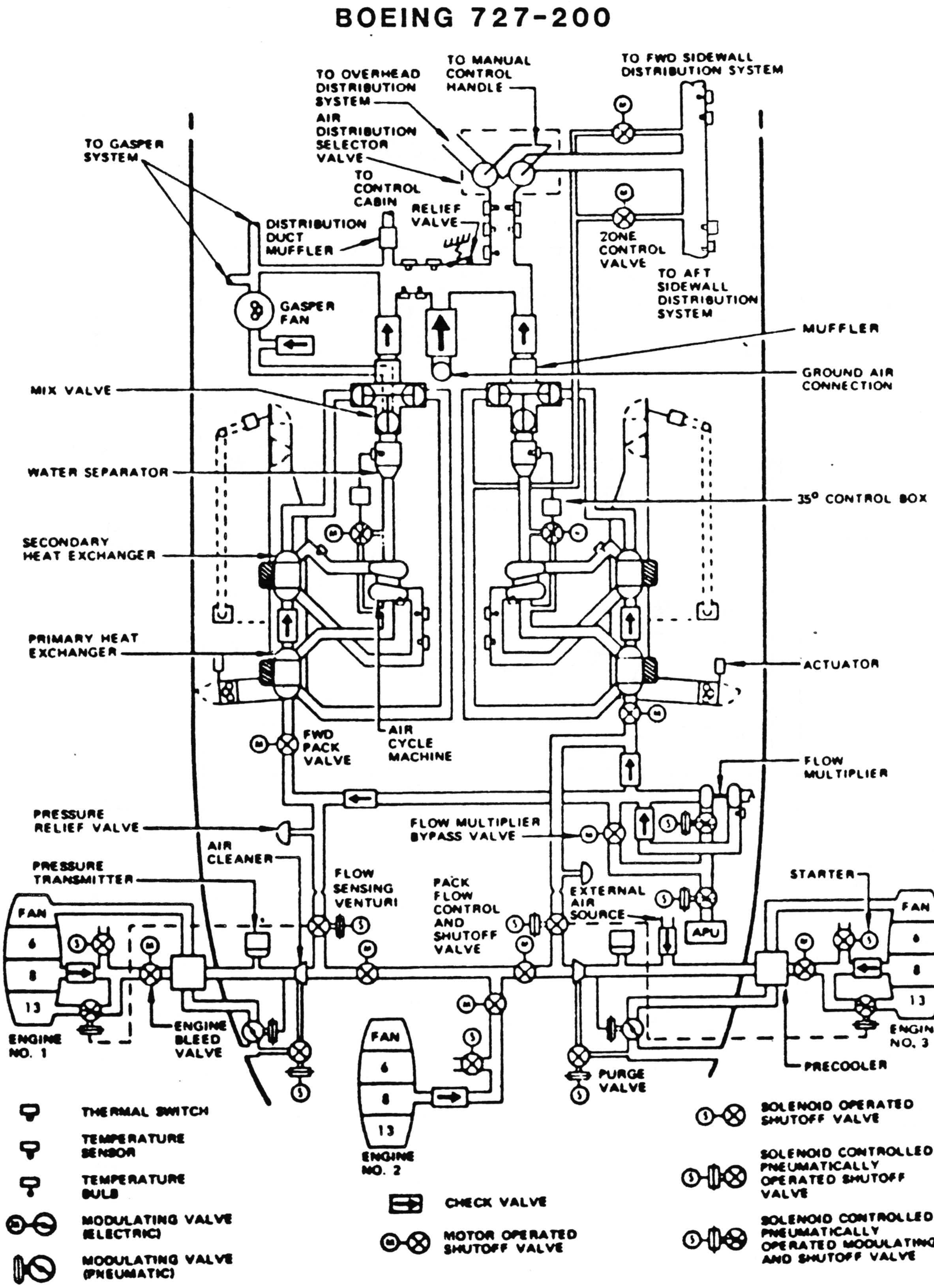


FIGURE 2-4. BOEING 727-200 AIR CONDITIONING SYSTEM SIMPLIFIED SCHEMATIC

BOEING 727-100

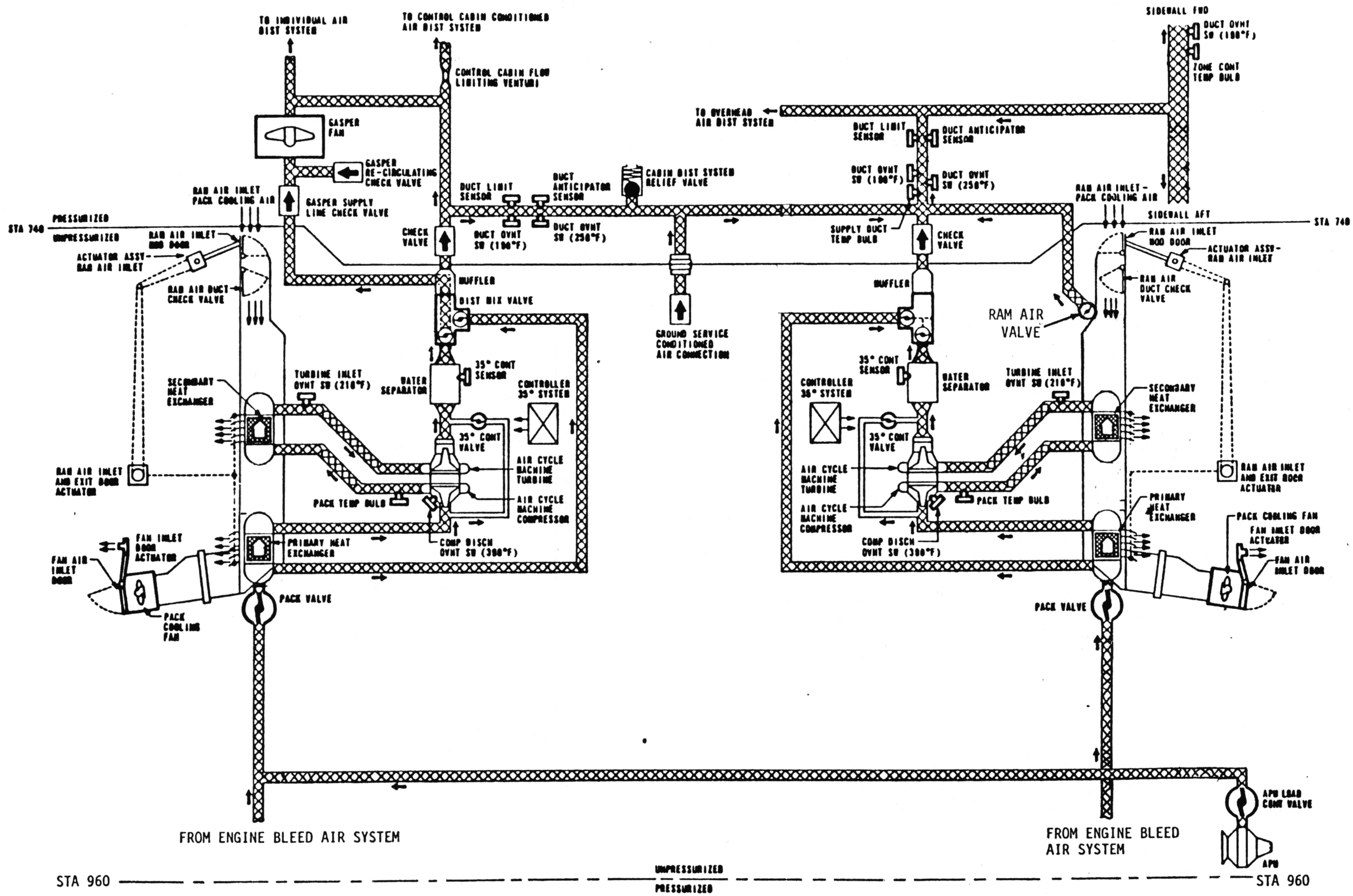


FIGURE 2-5. BOEING 727-100 AIR CONDITIONING PACK SCHEMATIC

BOEING 727-200

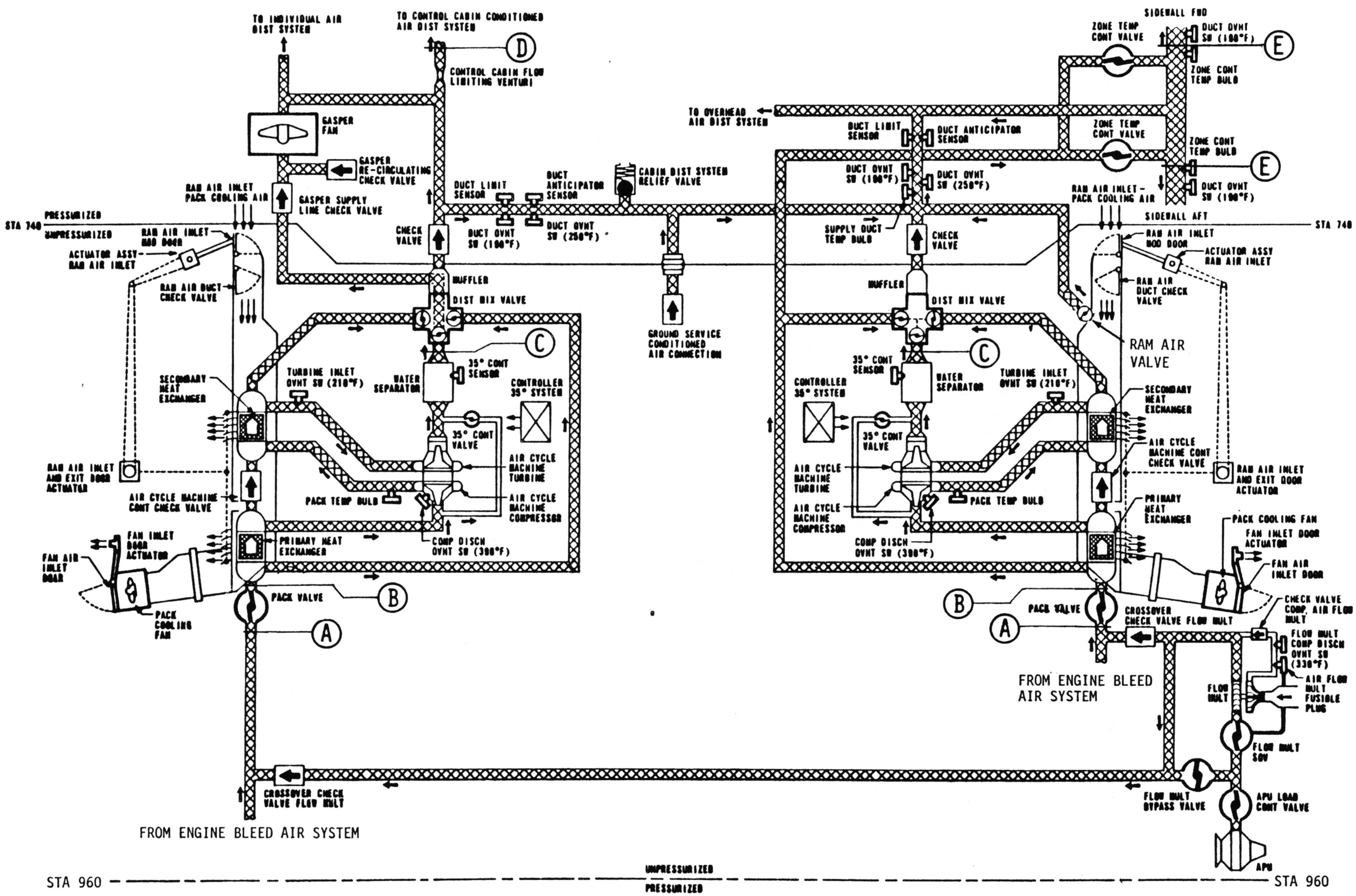


FIGURE 2-6. BOEING 727-200 AIR CONDITIONING PACK SCHEMATIC

BOEING 727-100

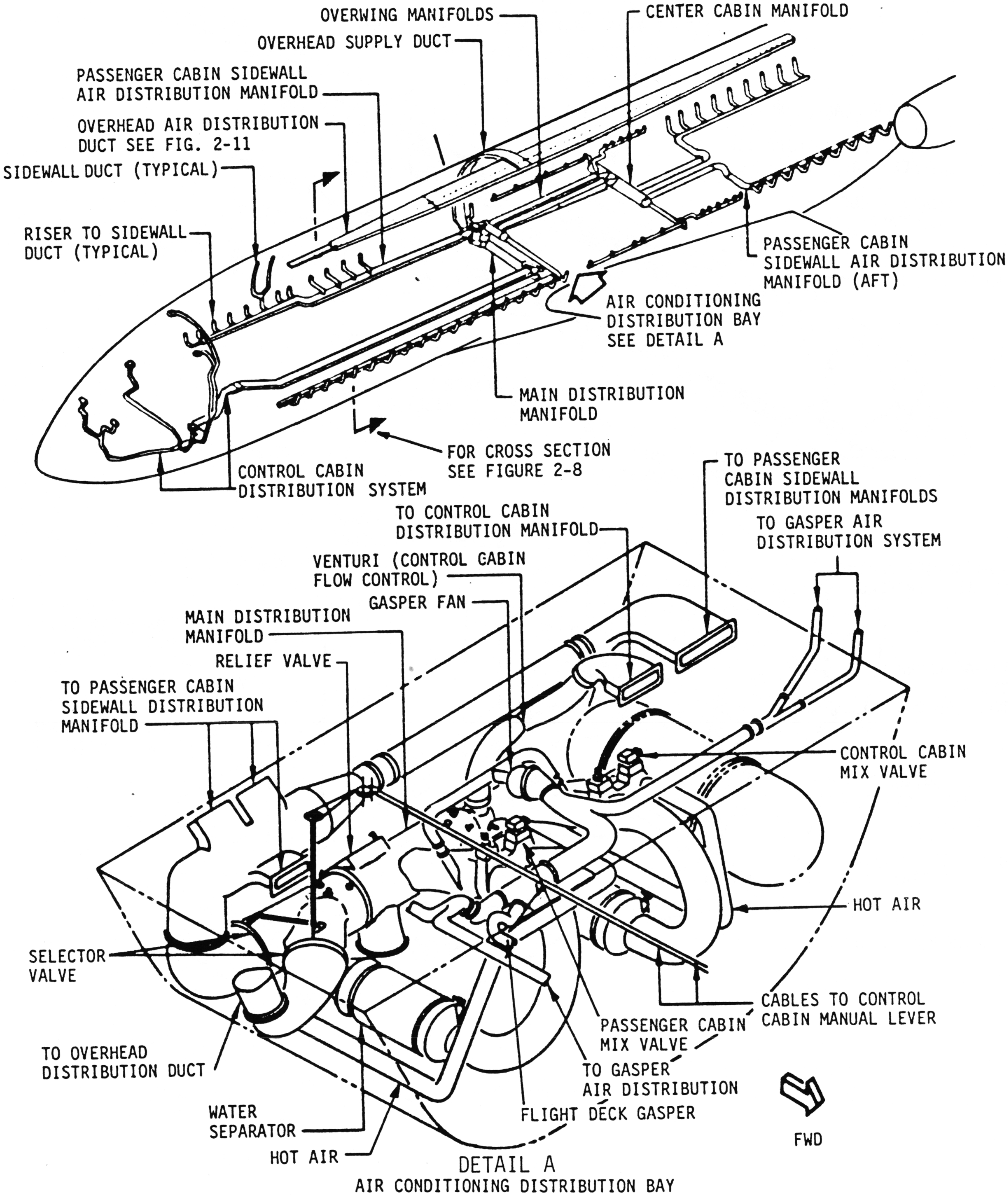
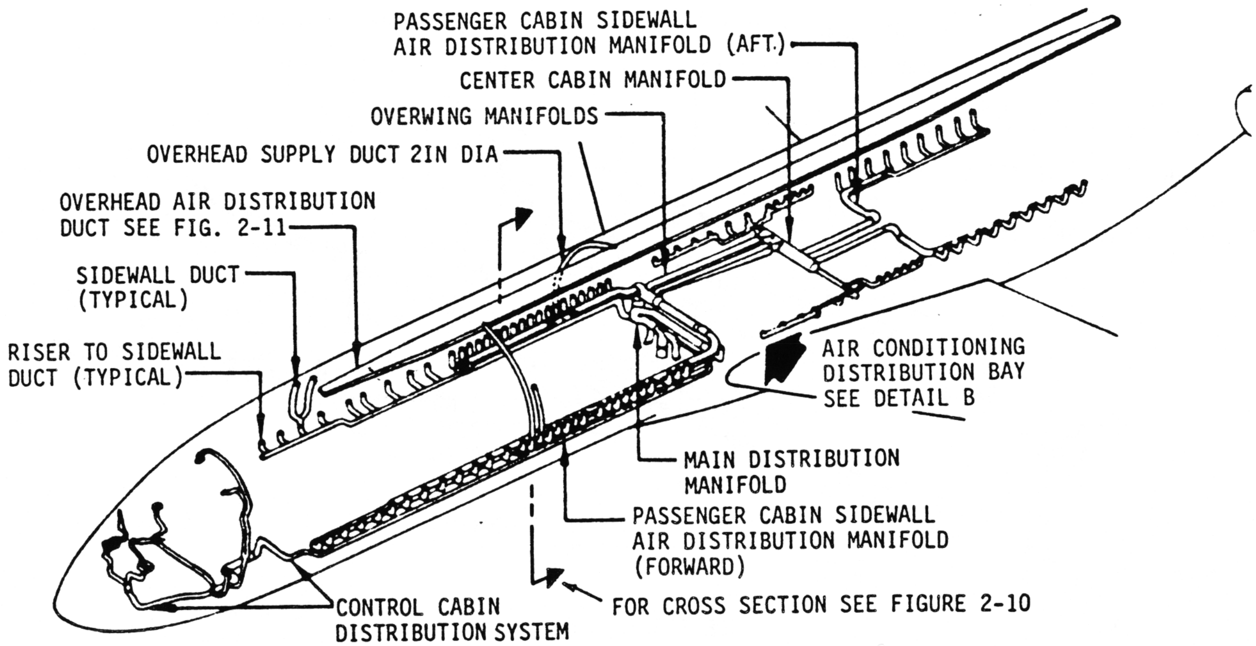
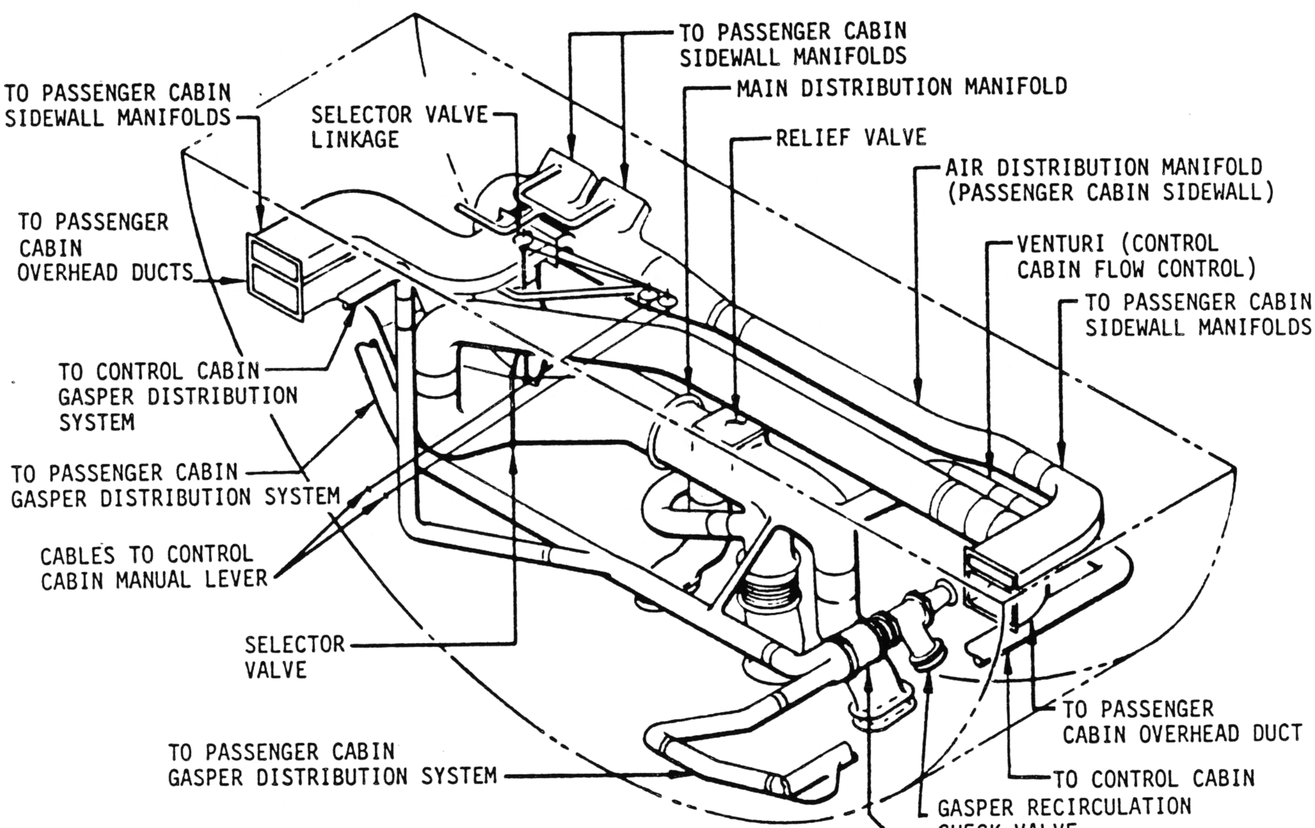


FIGURE 2-7. BOEING 727-100 PASSENGER CABIN CONDITIONED AIR DISTRIBUTION SYSTEM (SHEET 1 OF 2)

BOEING 727-200





DETAIL B
AIR CONDITIONING DISTRIBUTION BAY

FIGURE 2-7. BOEING 727-200 PASSENGER CABIN CONDITIONED AIR DISTRIBUTION SYSTEM (SHEET 2 OF 2)

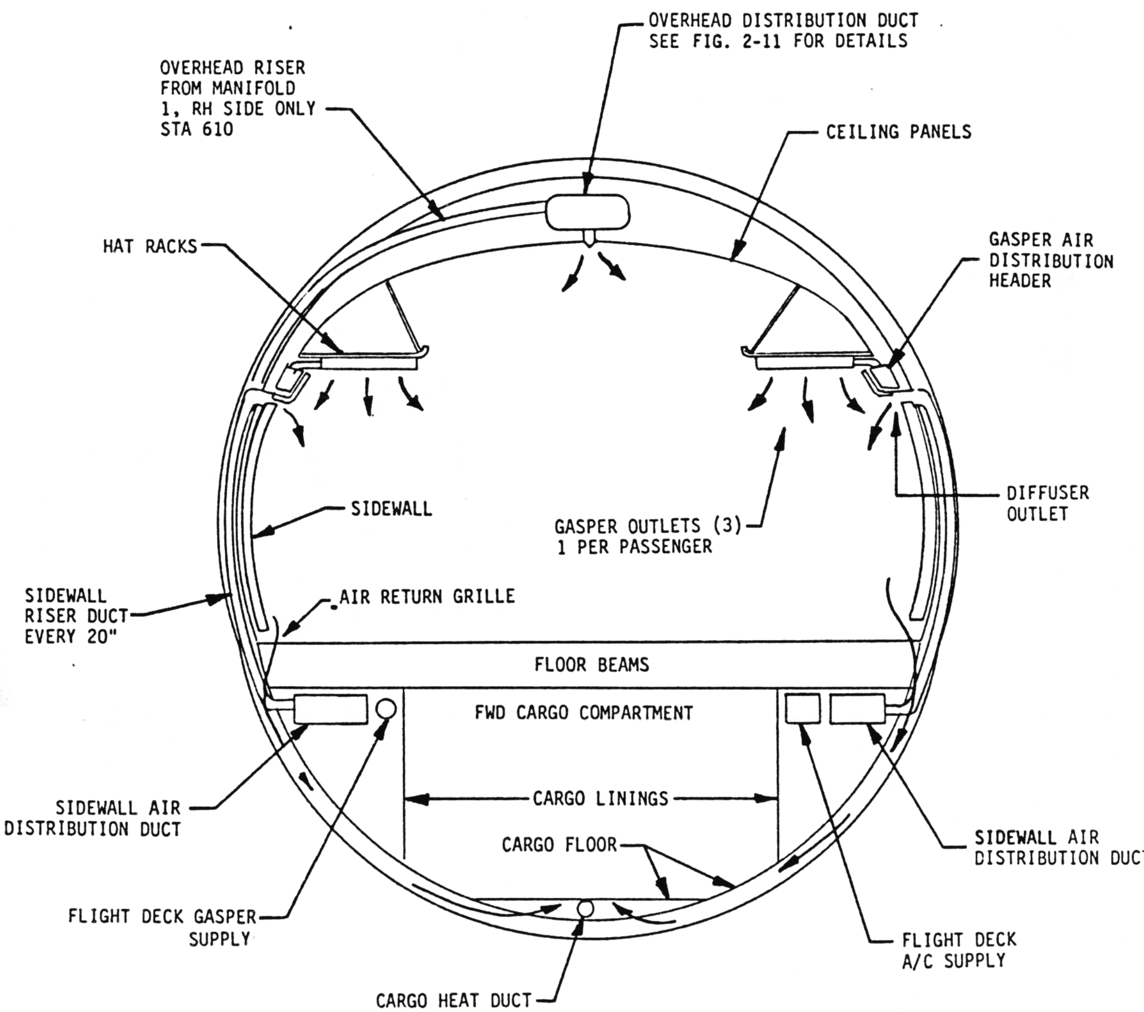


FIGURE 2-8. BOEING 727-100 PASSENGER CABIN CROSS SECTION

BOEING 727

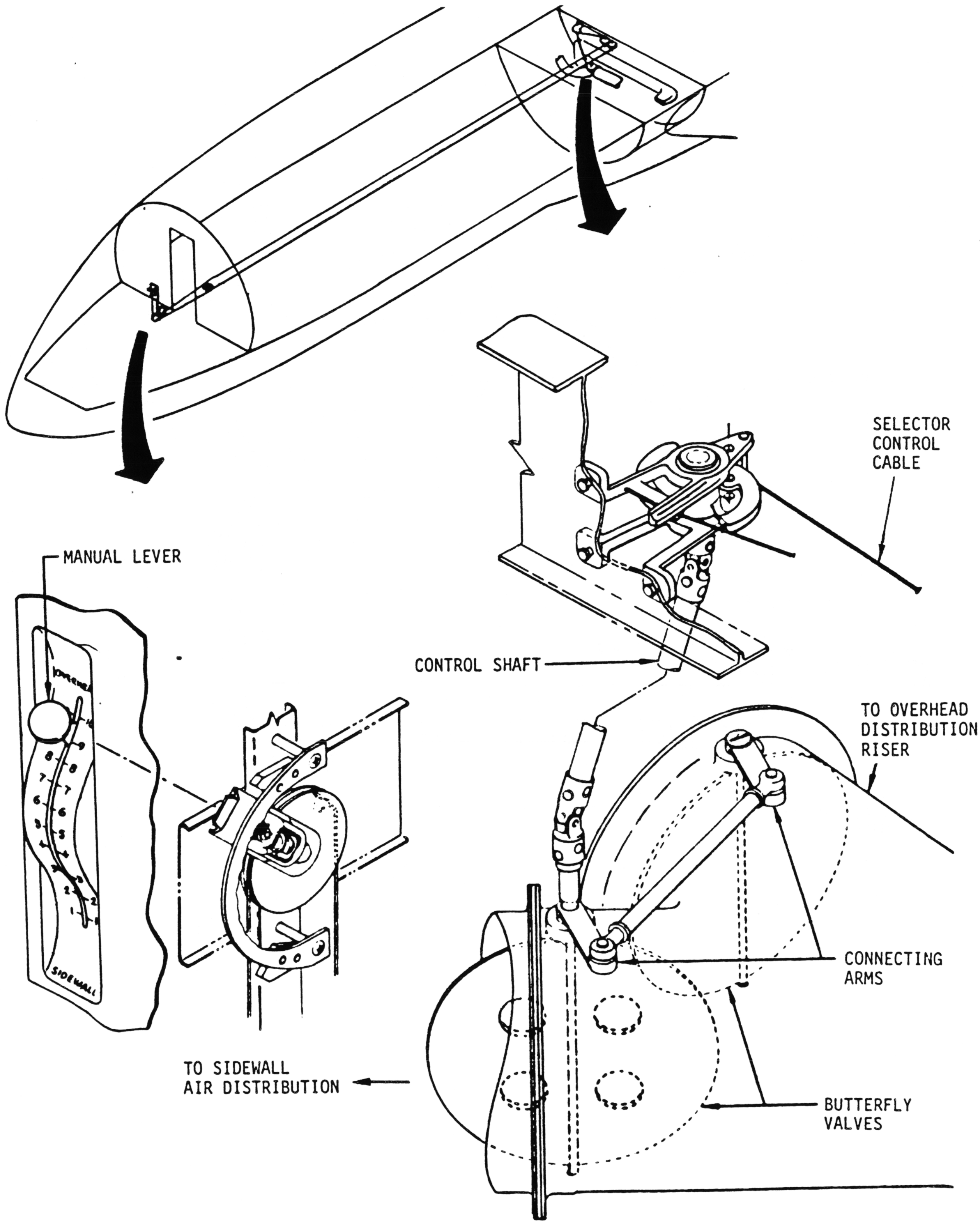
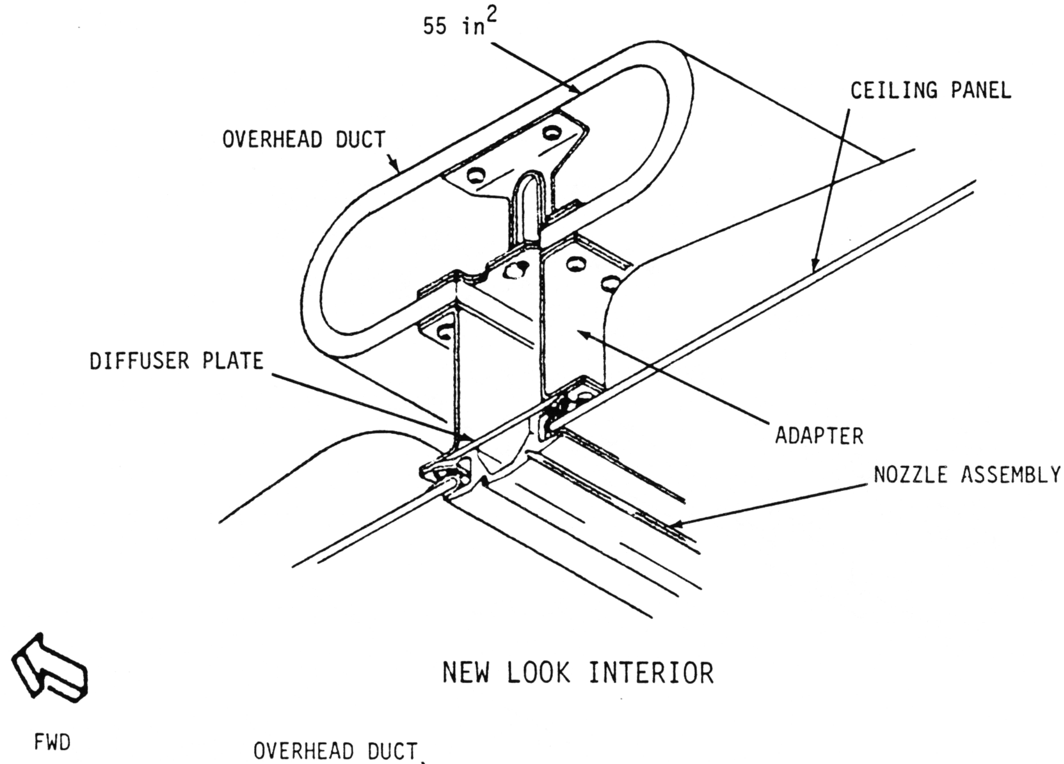
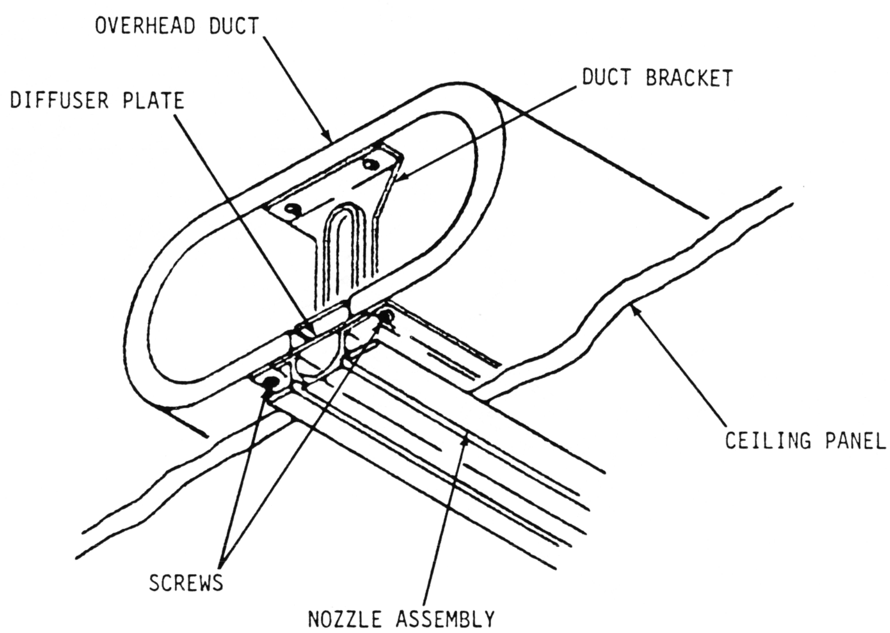


FIGURE 2-9. BOEING 727 PASSENGER CABIN CONDITIONED
AIR DISTRIBUTION SYSTEM, SELECTOR VALVE



NEW LOOK INTERIOR



ORIGINAL INTERIOR

FIGURE 2-10. BOEING 727 PASSENGER CABIN CONDITIONED AIR MAIN SUPPLY DUCT

BOEING 727-200

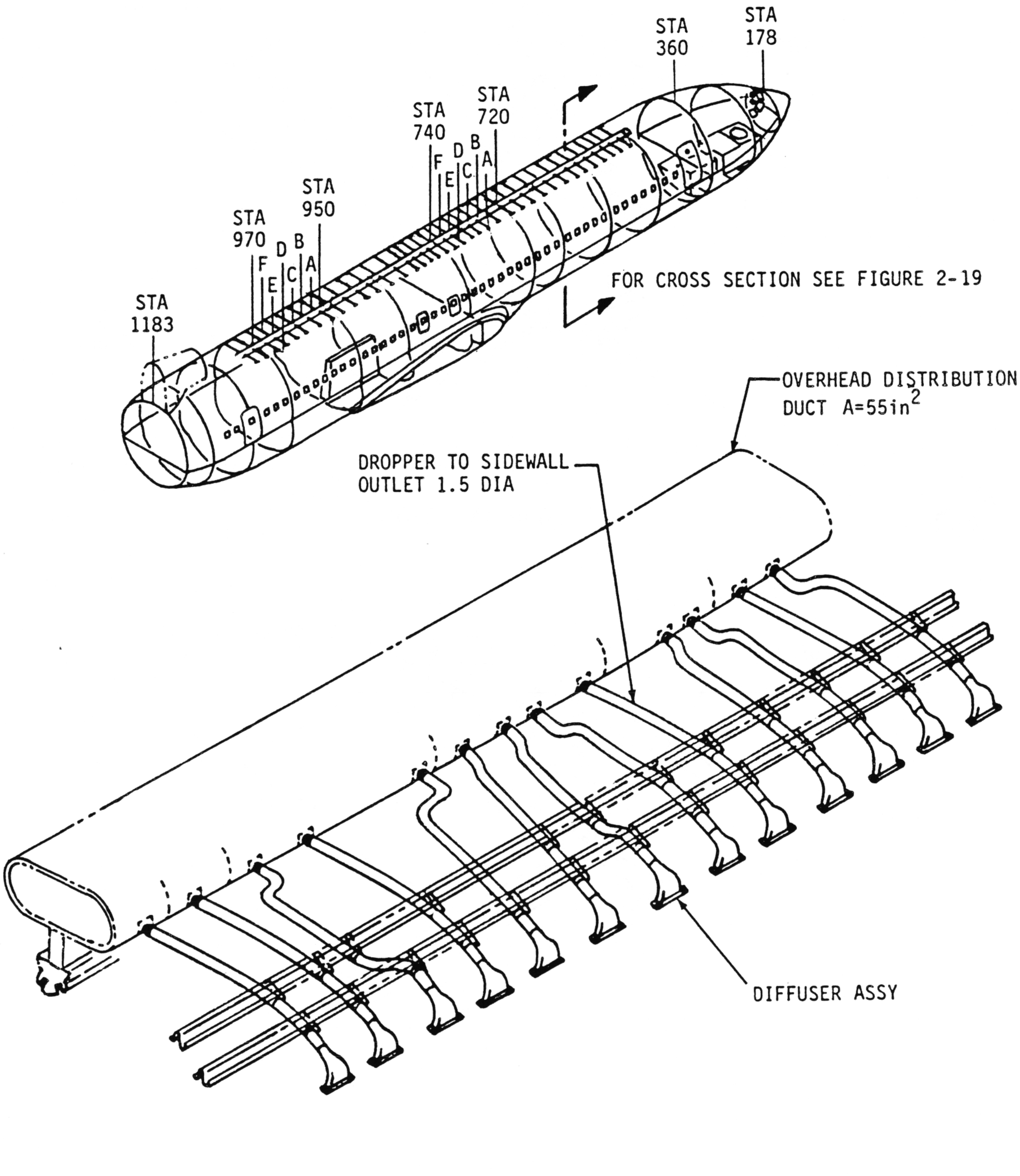


FIGURE 2-11. BOEING 727-200 OVERHEAD AND SIDEWALL AIR DISTRIBUTION DUCT, CARRYALL INTERIOR

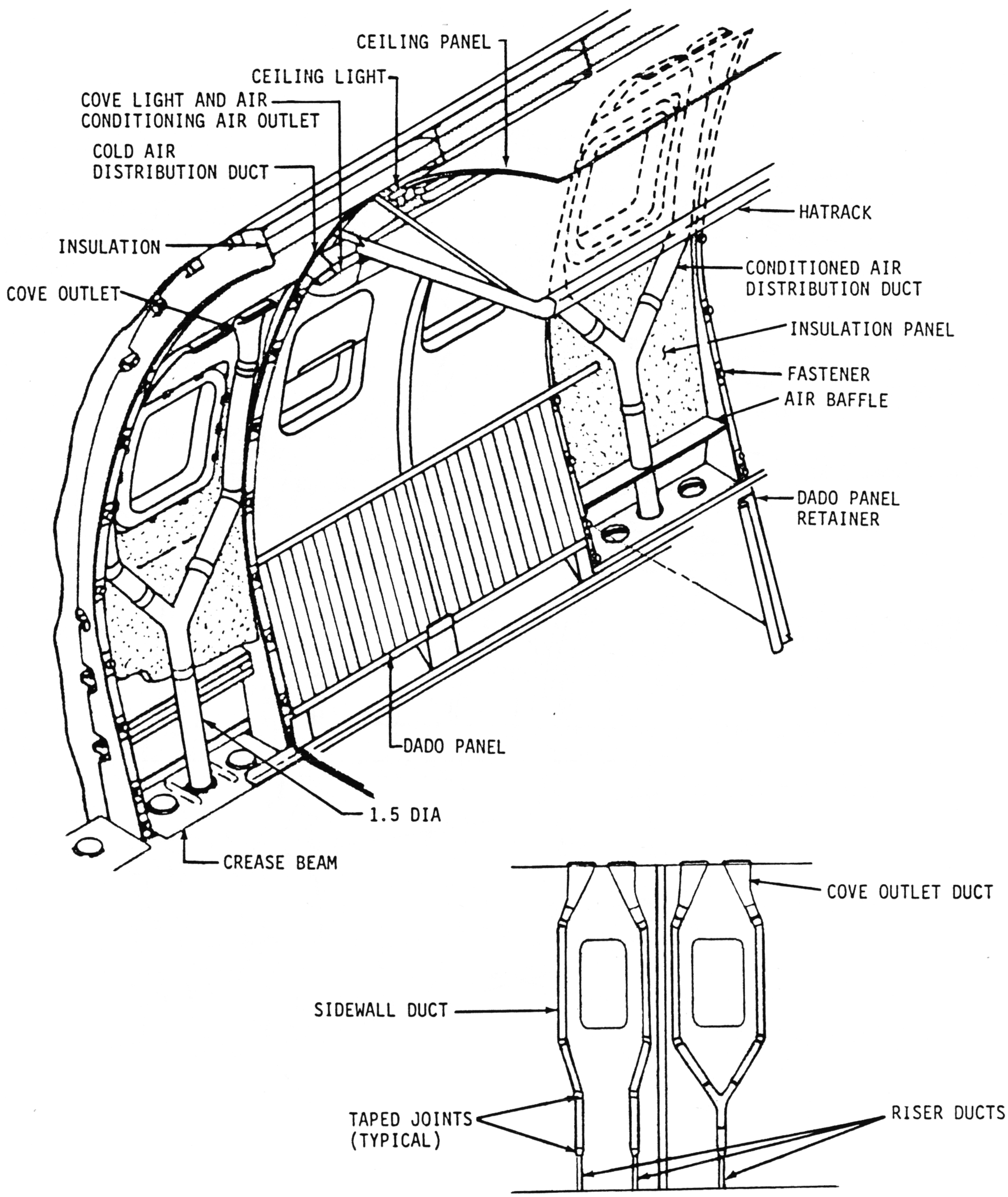


FIGURE 2-12. BOEING 727 SIDEWALL DUCT INSTALLATION, ORIGINAL EQUIPMENT INTERIOR

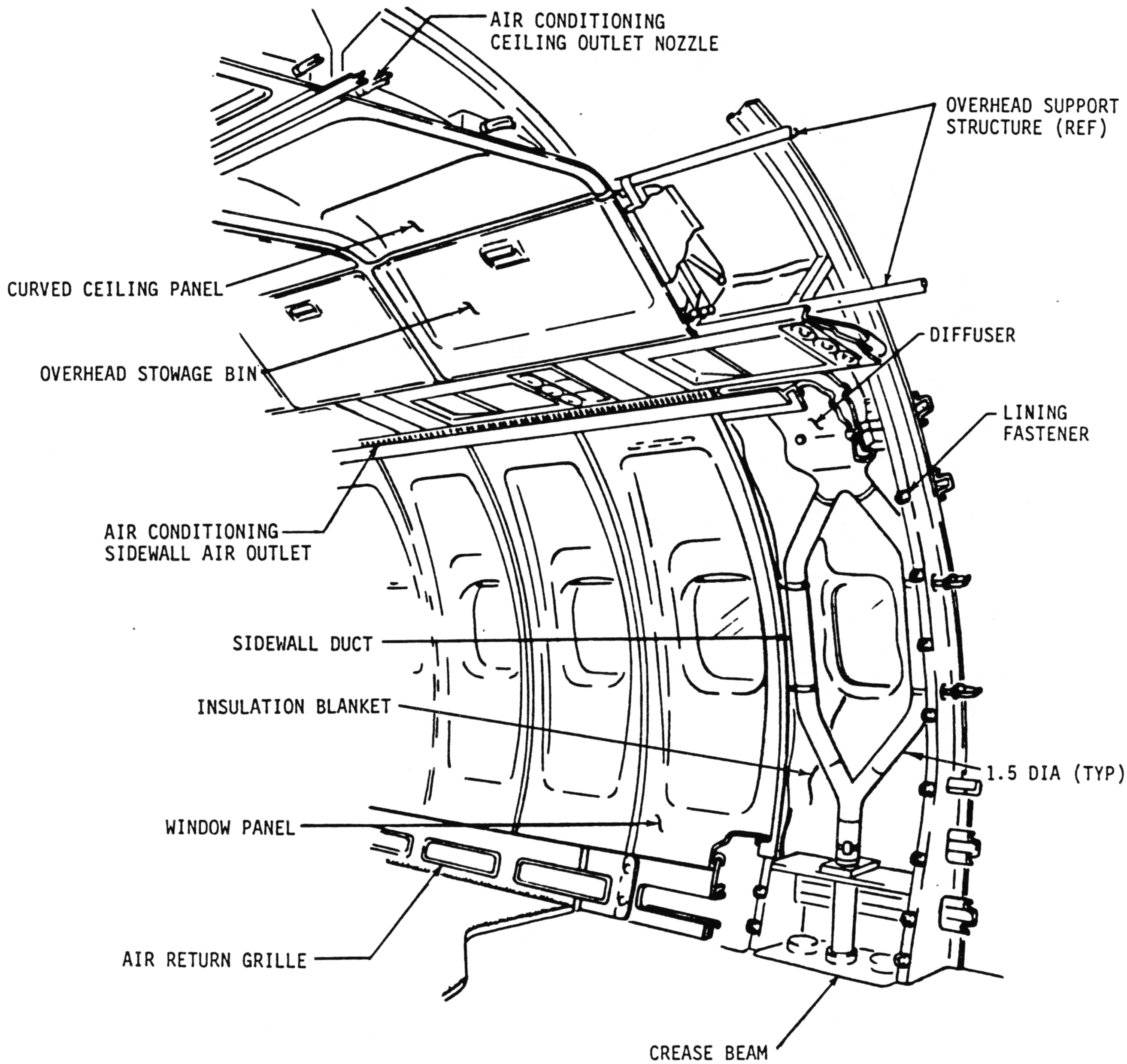
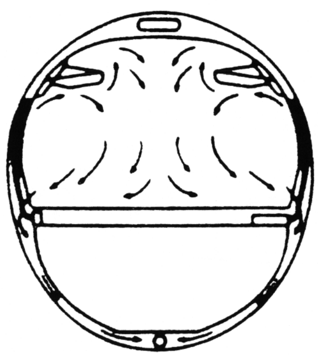
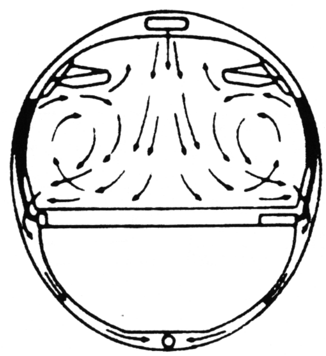


FIGURE 2-13. BOEING 727 SIDEWALL DUCT INSTALLATION, NEWLOOK INTERIOR



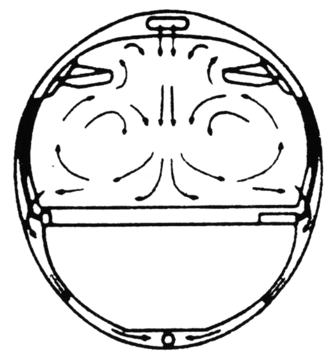
AIRFLOW FROM WALL
OUTLET ONLY

VIEW 1



AIRFLOW FROM COMBINED
OVERHEAD AND WALL OUTLETS

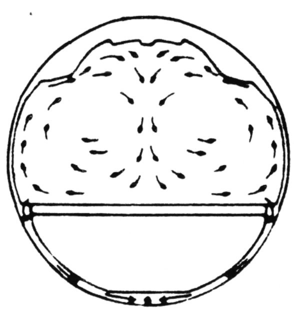
VIEW 2



AIRFLOW FROM OVERHEAD
OUTLETS ONLY

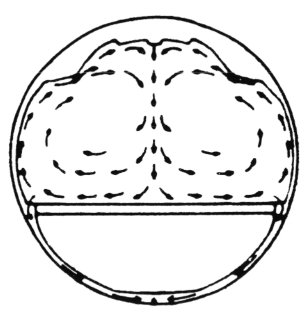
VIEW 3

ORIGINAL INTERIOR



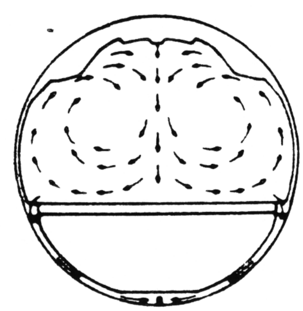
AIRFLOW FROM WALL
OUTLETS ONLY

VIEW 4



AIRFLOW FROM COMBINED
OVERHEAD AND WALL OUTLETS

VIEW 5



AIRFLOW FROM OVERHEAD
OUTLETS ONLY

VIEW 6

NEW LOOK INTERIOR

FIGURE 2-14. BOEING 727 PASSENGER CABIN CROSS SECTION AIR FLOW PATTERNS

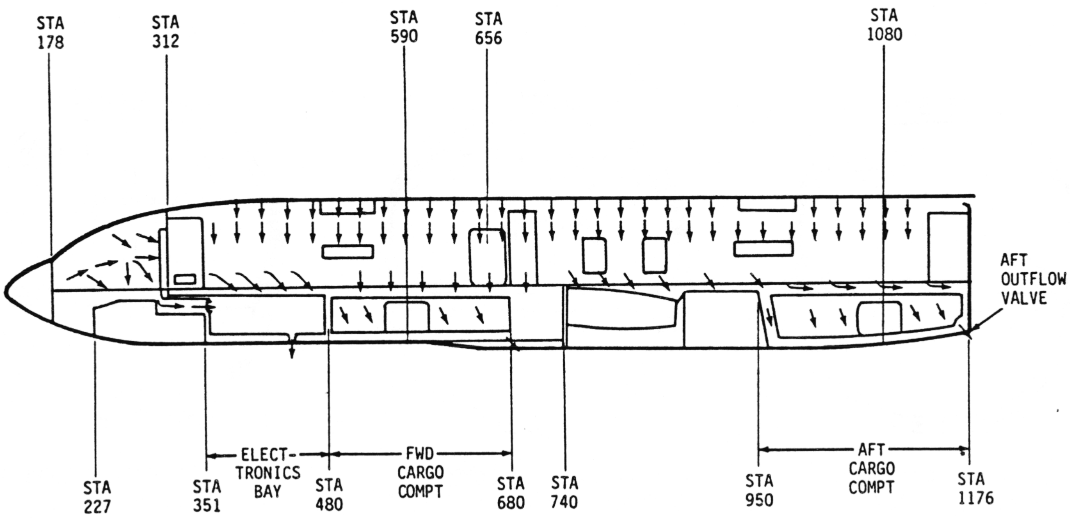


FIGURE 2-15. BOEING 727-100 PASSENGER CABIN SIDE VIEW AIR FLOW PATTERNS

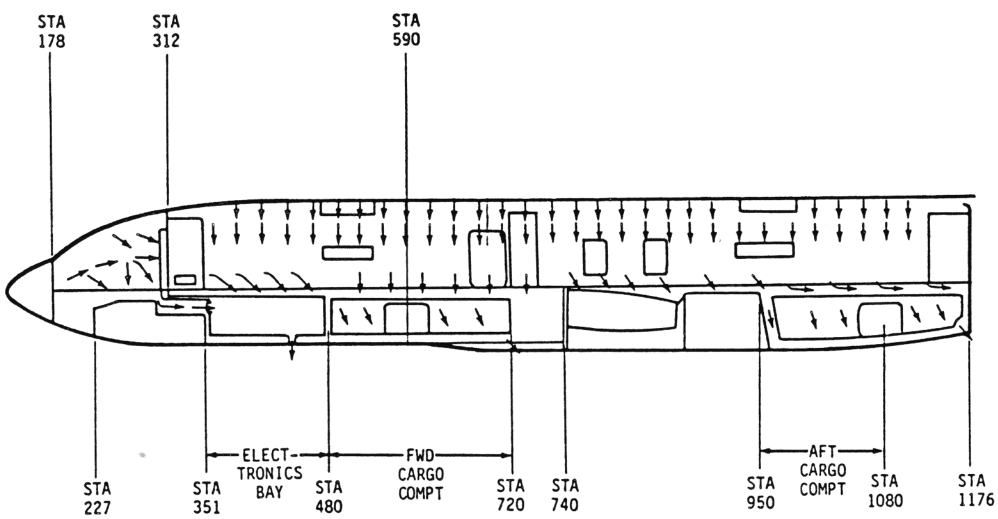


FIGURE 2-16. BOEING 727-200 PASSENGER CABIN SIDE VIEW AIR FLOW PATTERNS

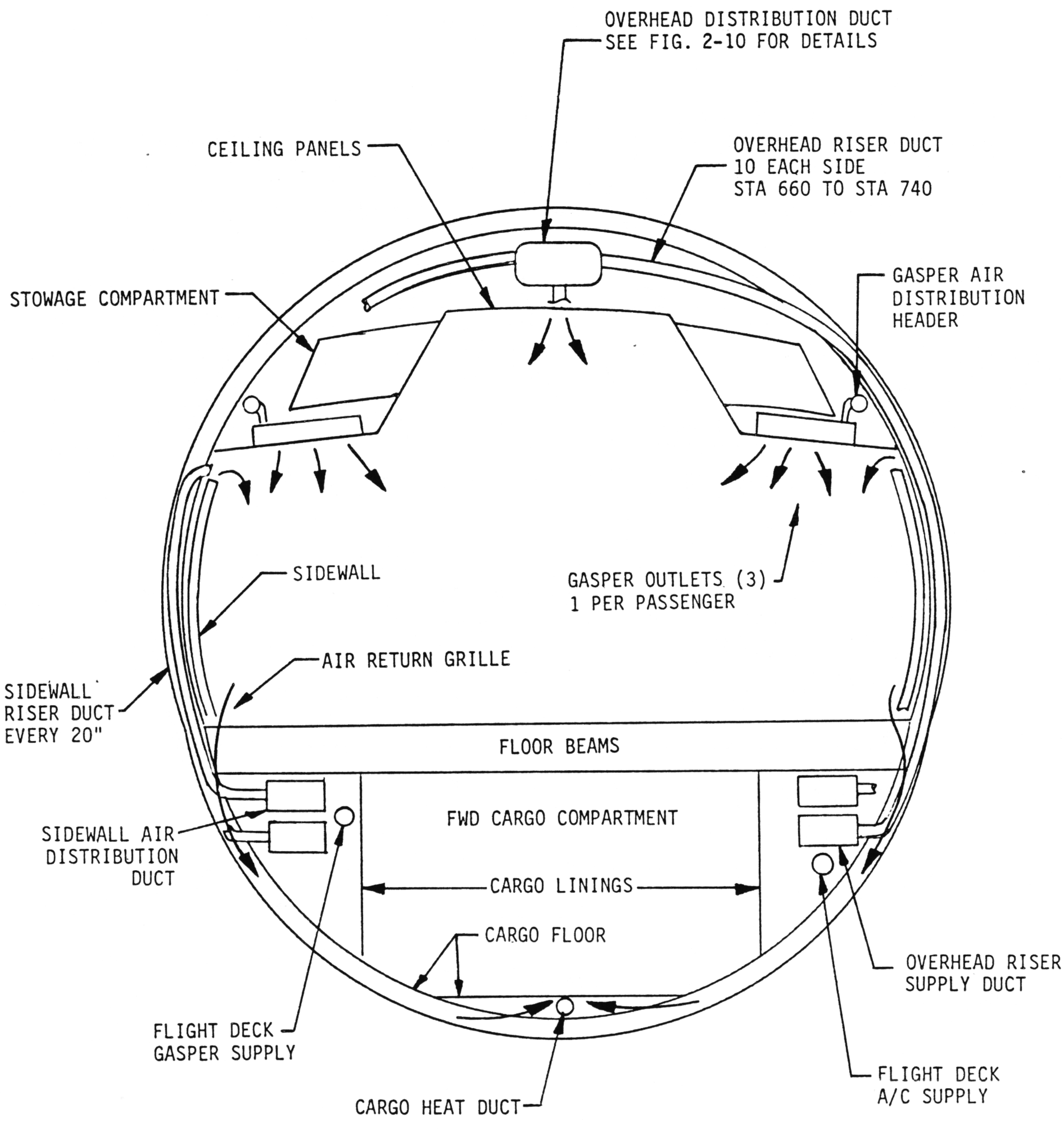
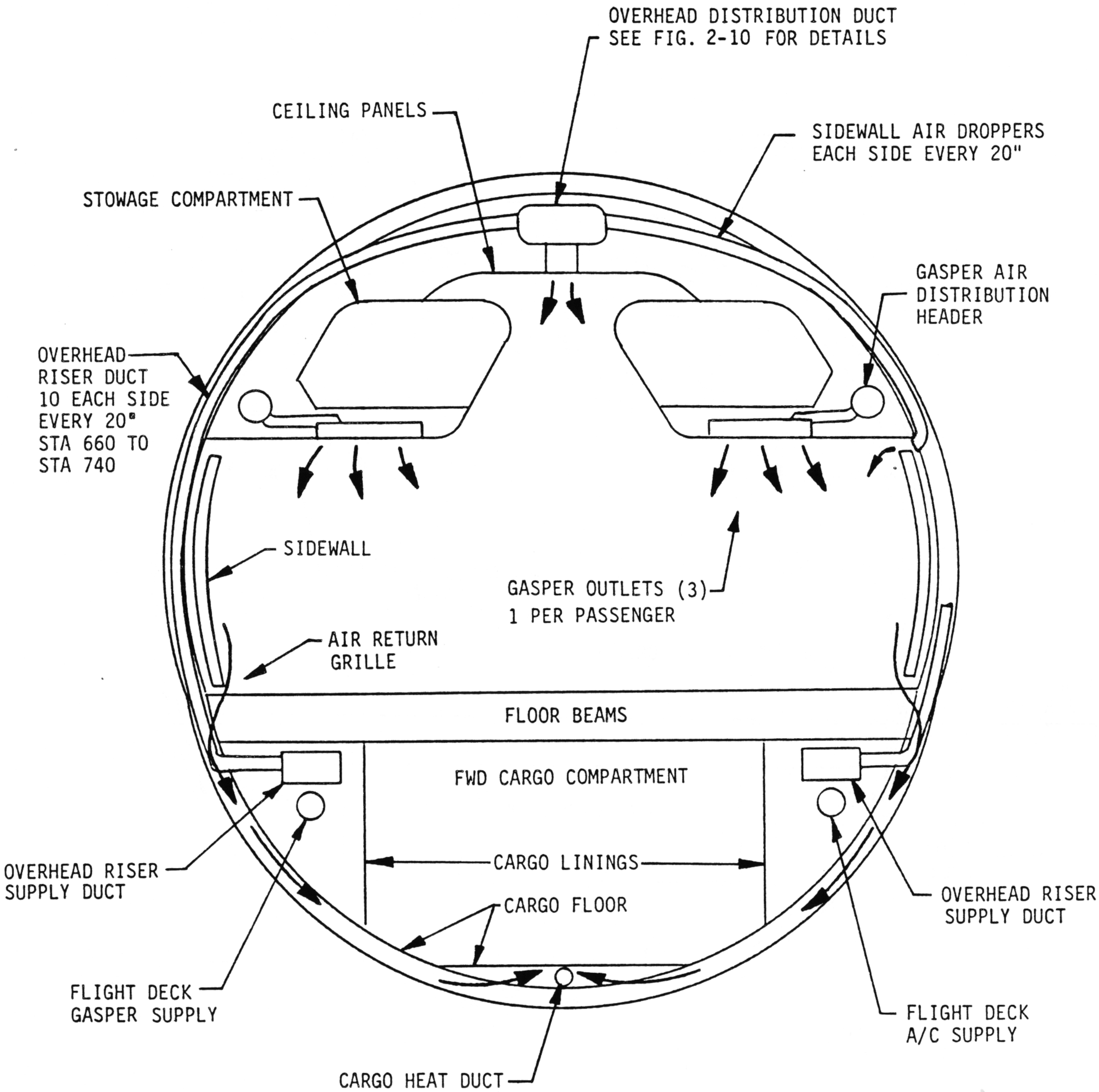


FIGURE 2-17. BOEING 727-200 PASSENGER CABIN CROSS SECTION



WITH CARRYALL INTERIOR

FIGURE 2-18. BOEING 727-200 PASSENGER CABIN CROSS SECTION

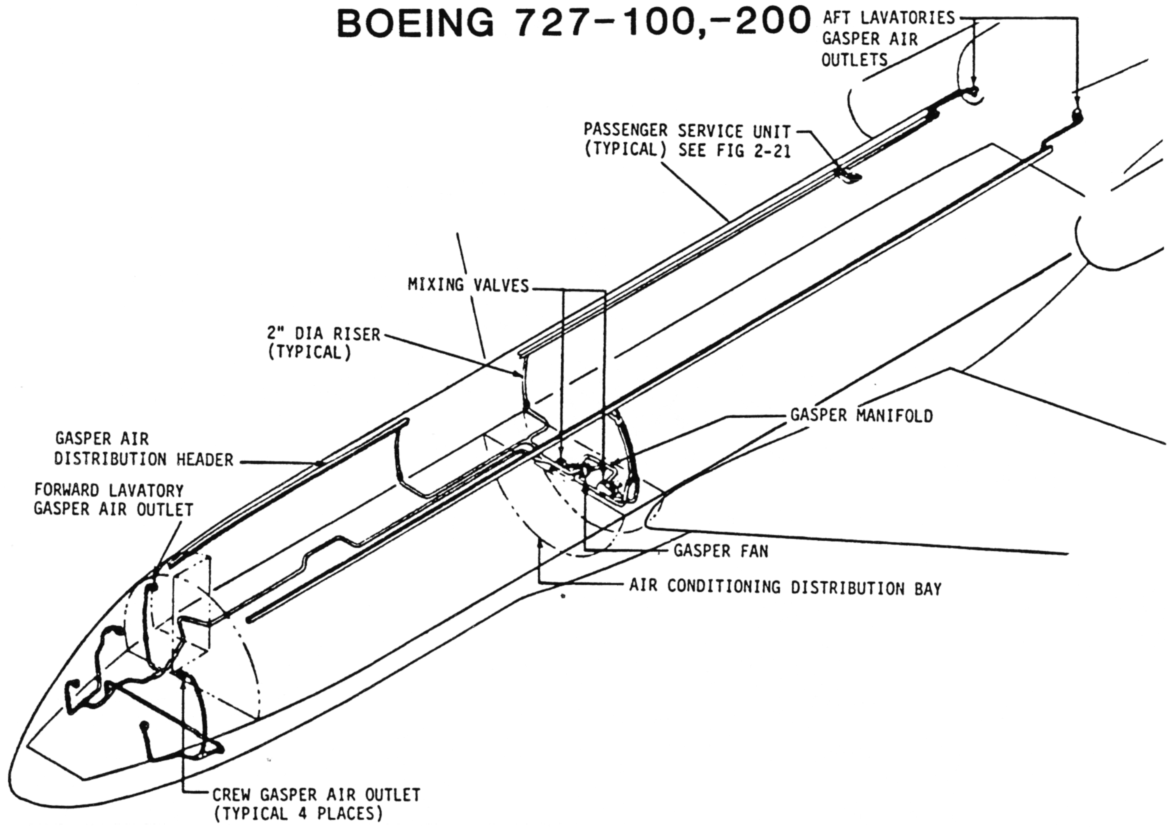


FIGURE 2-19. BOEING 727-100 GASPER AIR SYSTEM DISTRIBUTION DUCTING

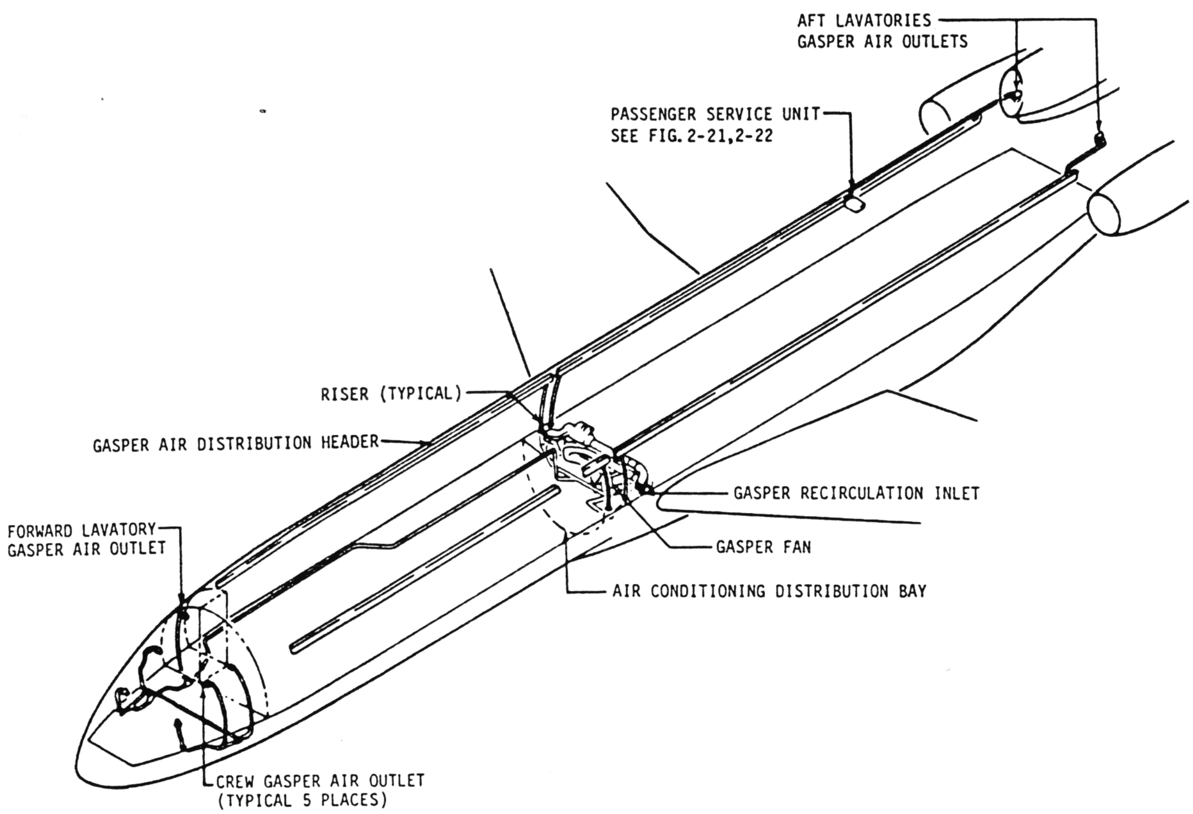
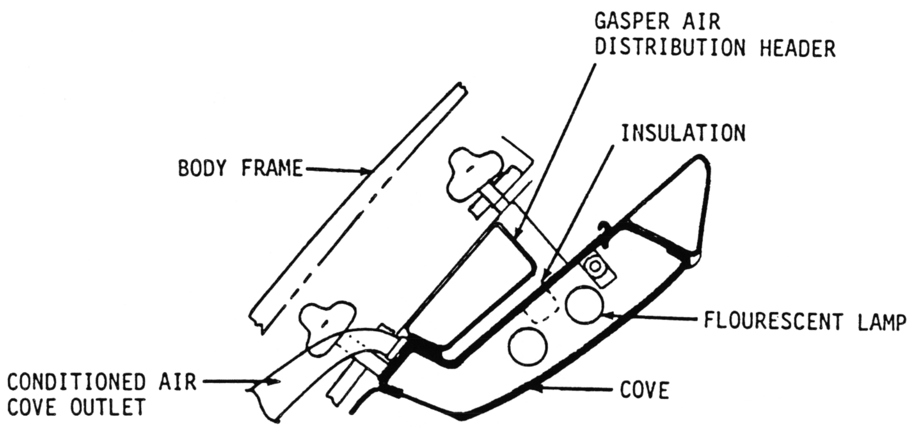
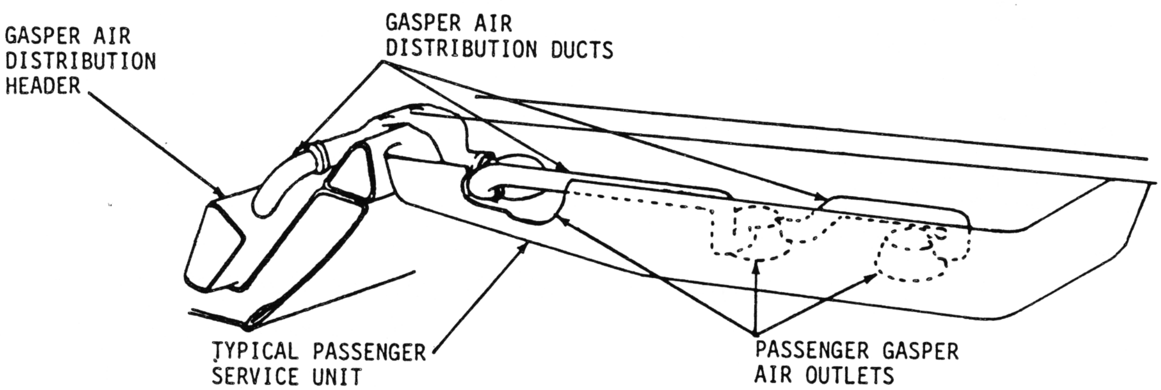
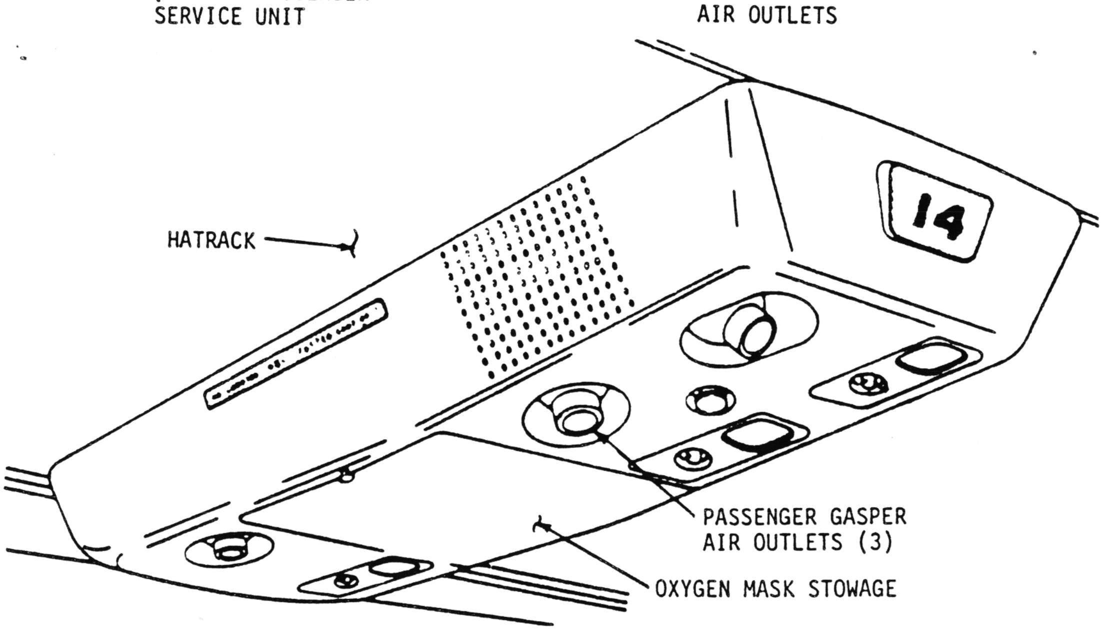


FIGURE 2-20. BOEING 727-200 GASPER AIR SYSTEM DISTRIBUTION DUCTING



GASPER AIR DISTRIBUTION HEADER

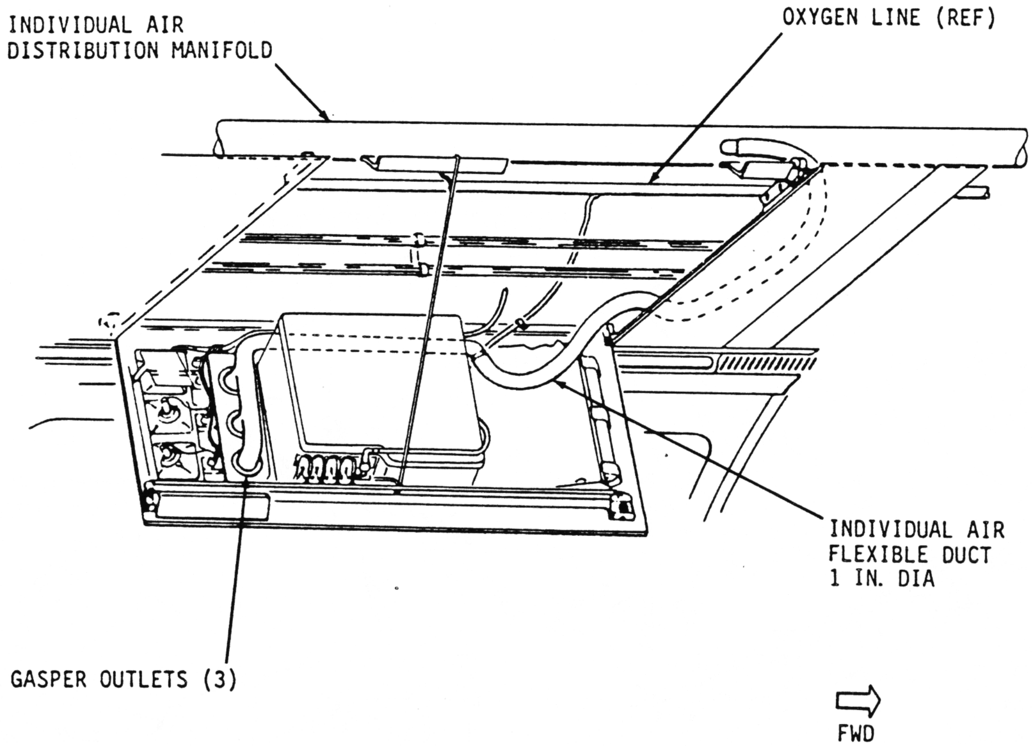


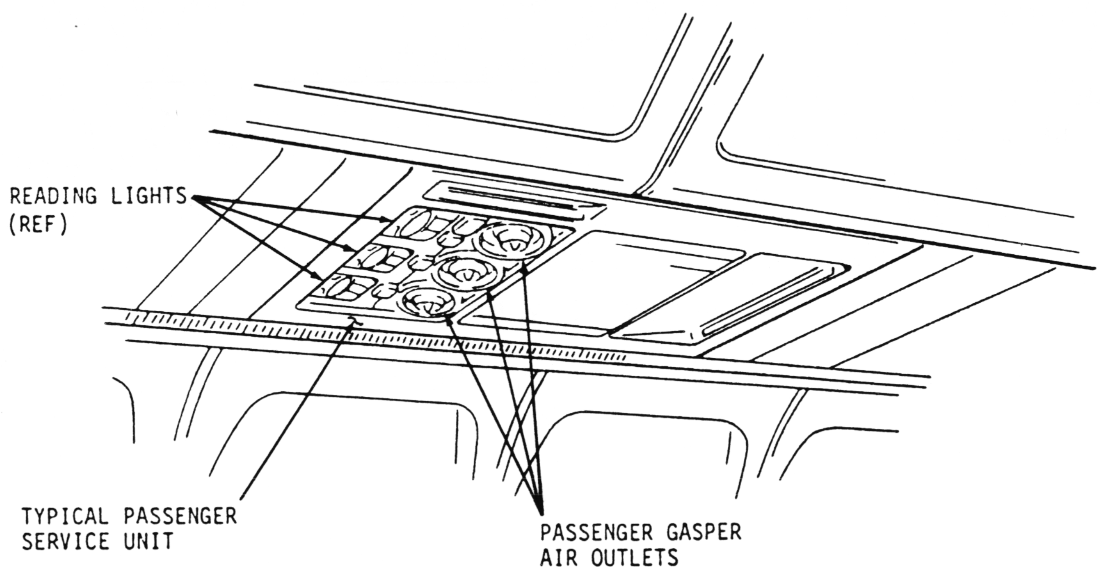


TYPICAL PASSENGER SERVICE UNIT

ORIGINAL INTERIOR AIRPLANES

FIGURE 2-21. BOEING 727 GASPER AIR SYSTEM CABIN OUTLETS





NEW LOOK INTERIOR AIRPLANES

FIGURE 2-22. BOEING 727 GASPER AIR SYSTEM CABIN OUTLETS

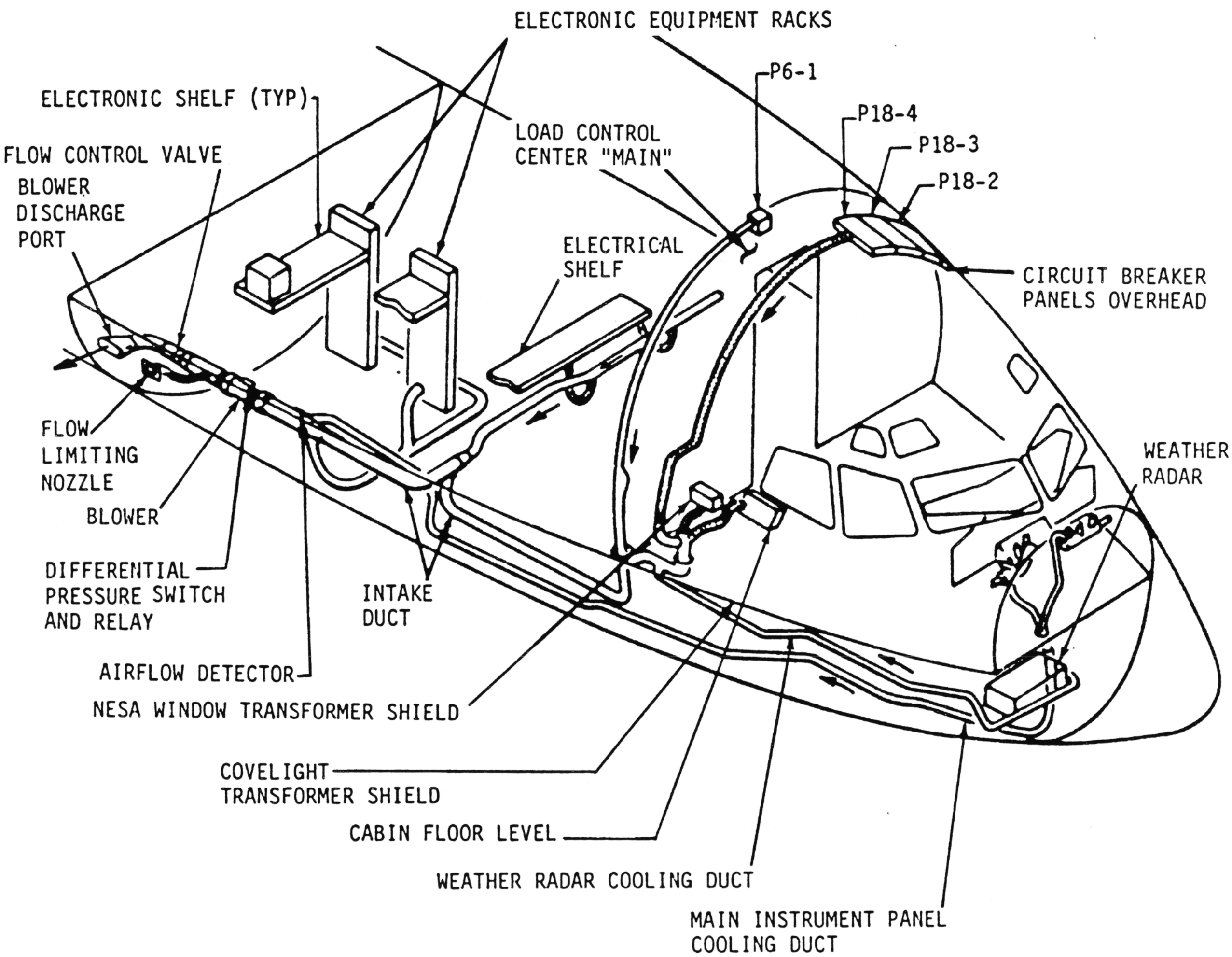


FIGURE 2-23. BOEING 727 EQUIPMENT COOLING SYSTEM

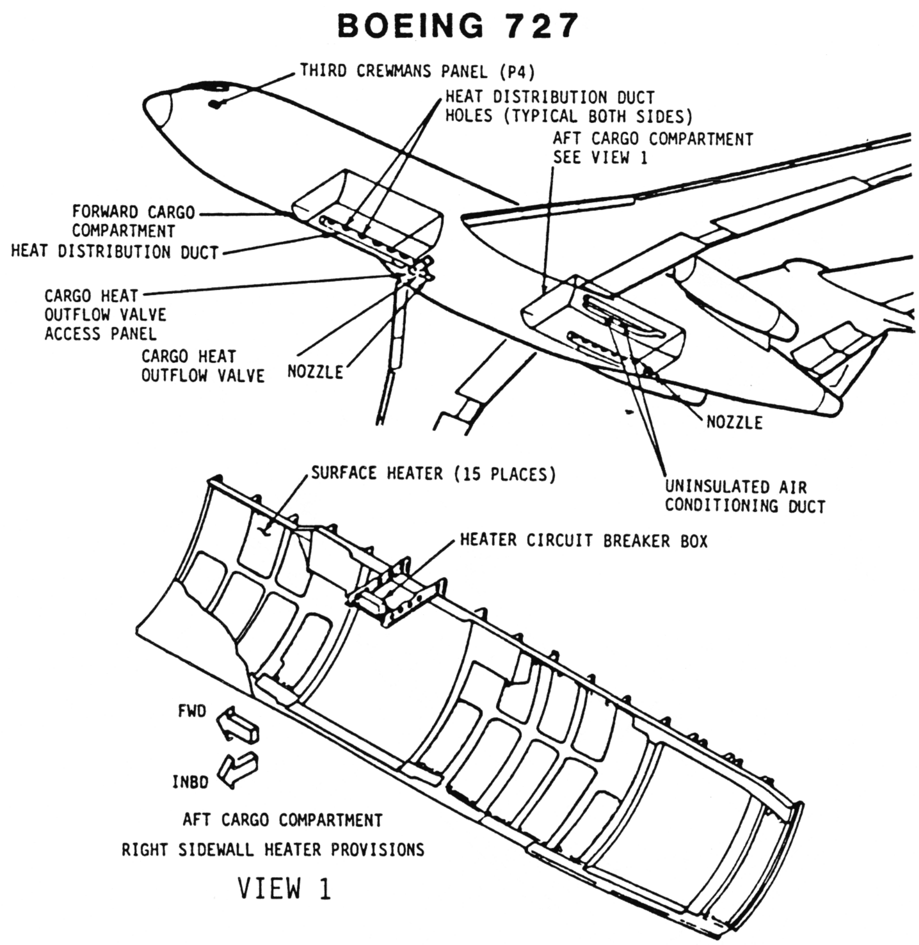


FIGURE 2-24. BOEING 727 CARGO COMPARTMENT HEATING EQUIPMENT LOCATIONS

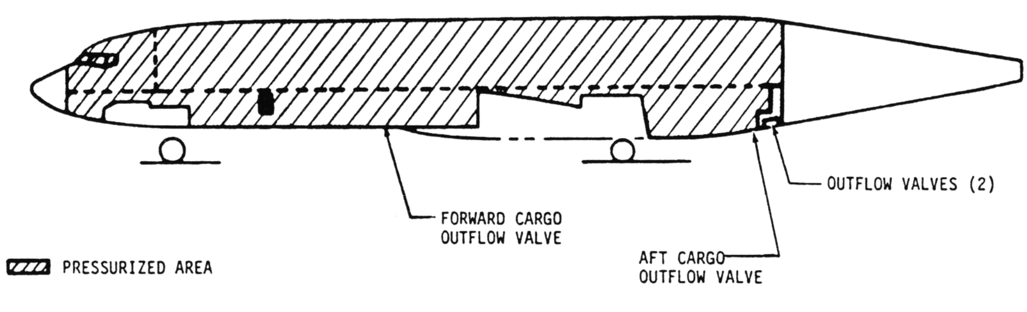


FIGURE 2-25. BOEING 727 OUTFLOW VALVE LOCATION

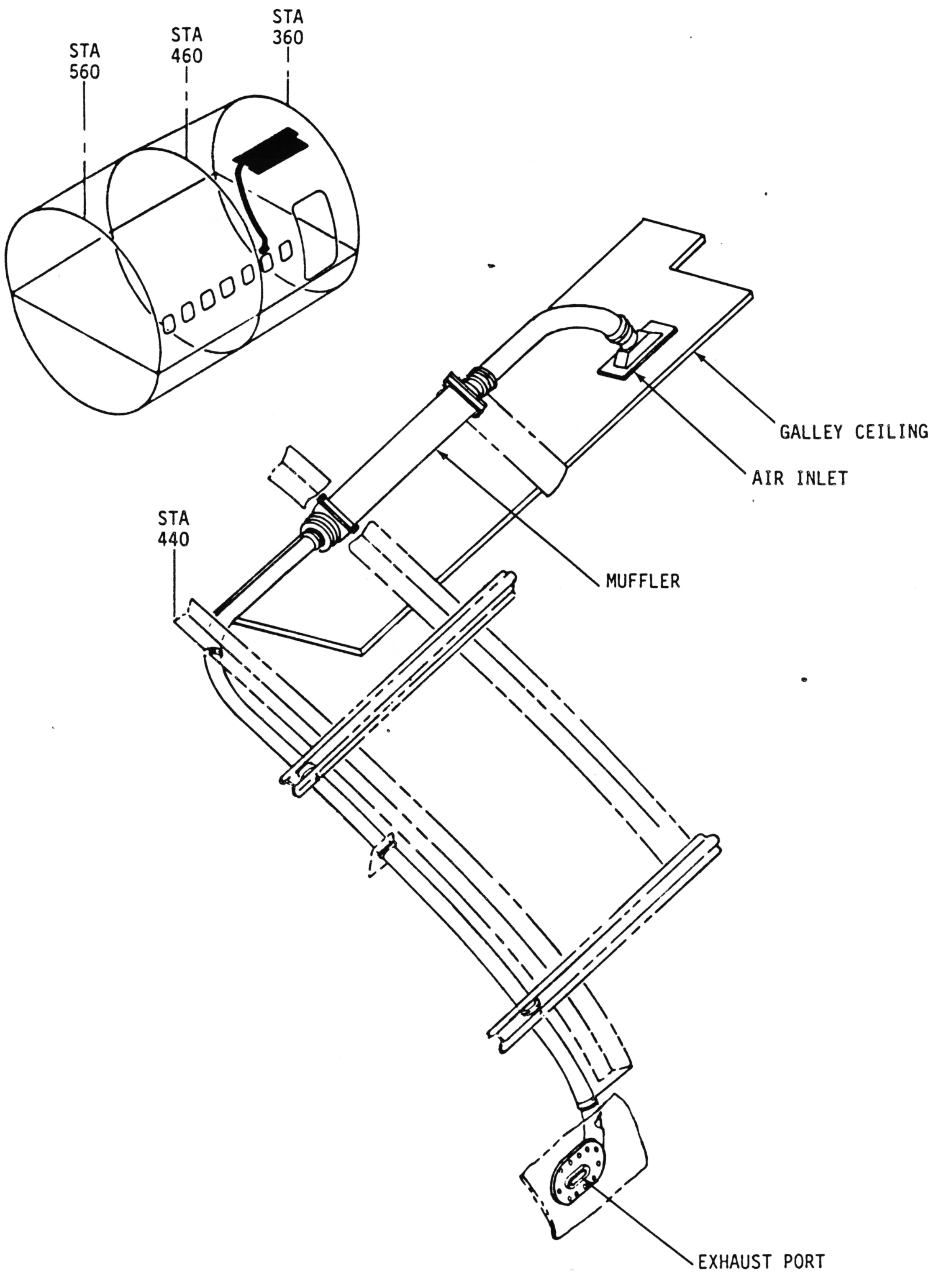


FIGURE 2-26. BOEING 727 GALLEY VENTILATION

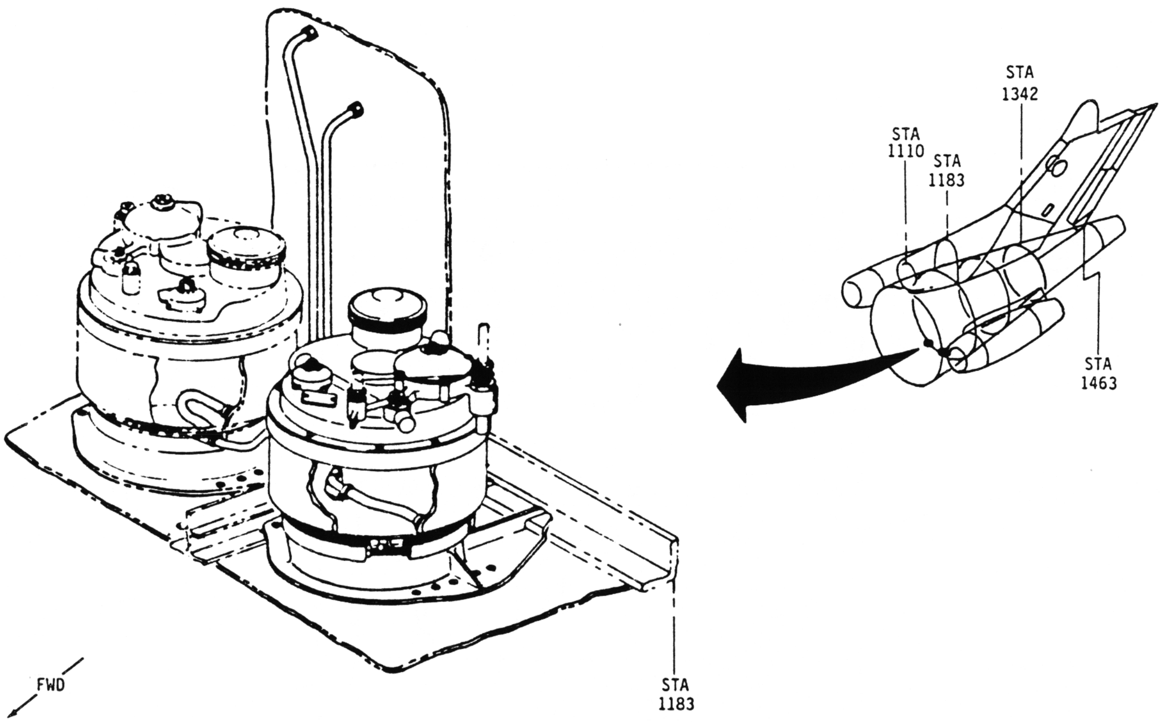


FIGURE 2-27. BOEING 727-100 PRESSURIZATION CONTROL OUTFLOW VALVES

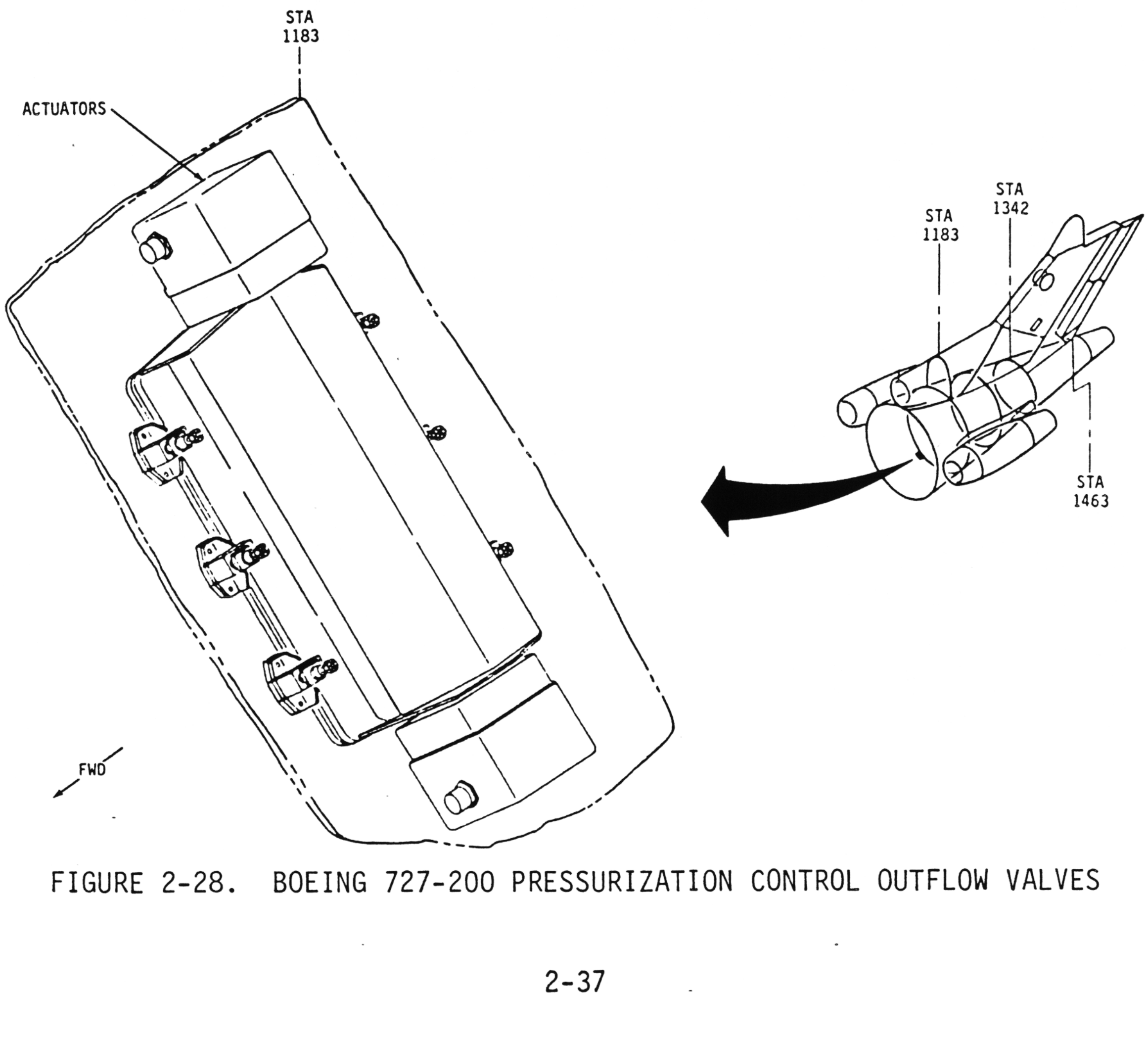
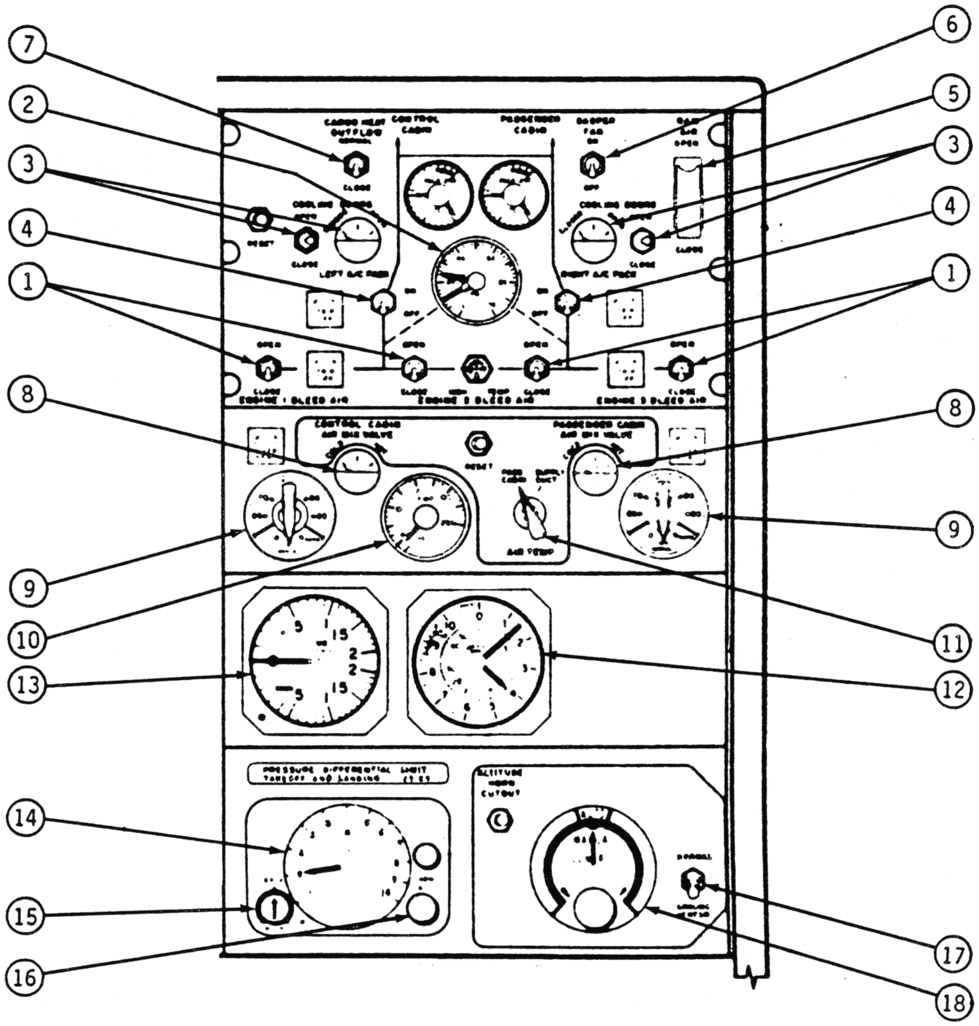


FIGURE 2-28. BOEING 727-200 PRESSURIZATION CONTROL OUTFLOW VALVES



LEGEND

1) BLEED AIR CONTROL SWITCHES
2) BLEED AIR PRESSURE
3) RAM AIR DOOR OPENING CONTROL & INDICATOR
4) PACK FLOW CONTROL VALVE SWITCH
5) RAM AIR INLET VALVE SWITCH
6) GASPER FAN SWITCH
7) CARGO HEAT OUTFLOW VALVE CONTROL
8) MIX VALVE POSITION INDICATOR
9) TEMPERATURE SELECTOR
10) TEMPERATURE GAUGE
11) COMPARTMENT TEMPERATURE SELECTOR
12) CABIN ALTITUDE
13) CABIN ALTITUDE RATE OF CHANGE
14) DIFFERENTIAL PRESSURE
15) CABIN ALTITUDE RATE OF CHANGE CONTROLLER
16) CABIN ALTITUDE SELECTOR
17) GROUND-FLIGHT MODE SELECTOR
18) CABIN PRESSURE MANUAL CONTROL

FIGURE 2-29. BOEING 727-100 THIRD CREWMAN PANEL UPPER

BOEING 727-200

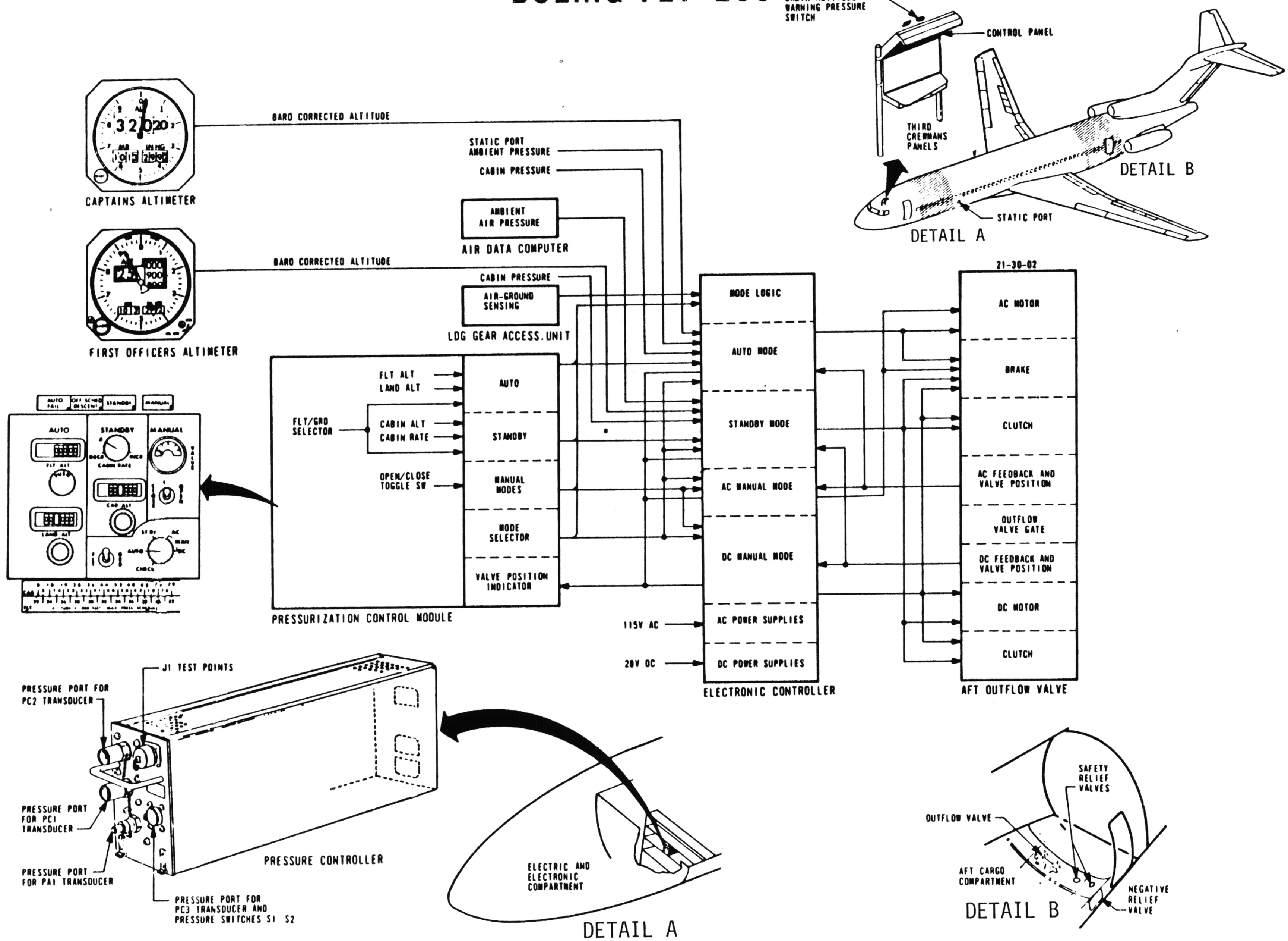
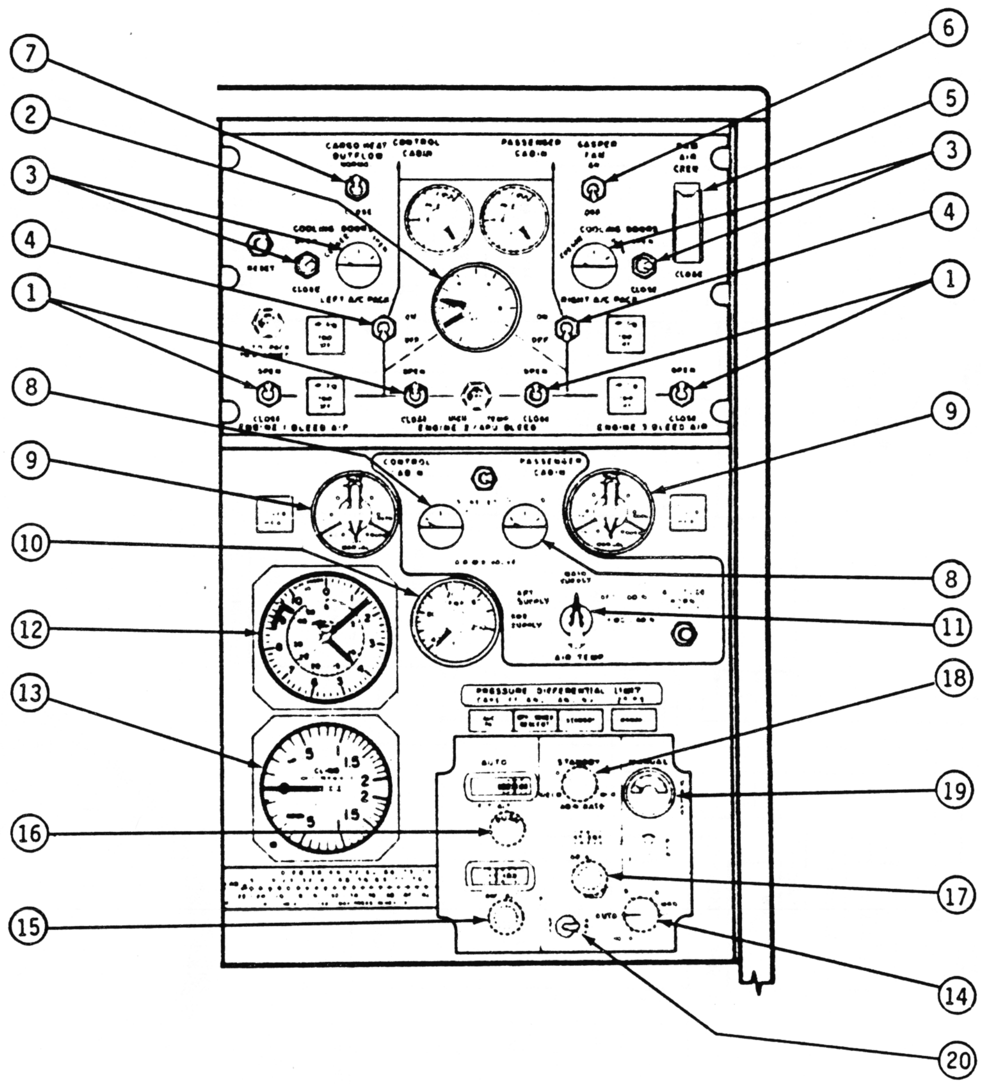


FIGURE 2-30. BOEING 727-200 PRESSURIZATION CONTROL SYSTEM SCHEMATIC

BOEING 727-200



LEGEND

1) BLEED AIR CONTROL SWITCHES
2) BLEED AIR PRESSURE
3) RAM AIR DOOR OPENING CONTROL & INDICATOR
4) PACK FLOW CONTROL VALVE SWITCH
5) RAM AIR INLET VALVE SWITCH
6) GASPER FAN SWITCH
7) CARGO HEAT OUTFLOW VALVE CONTROL
8) MIX VALVE POSITION INDICATOR
9) TEMPERATURE SELECTOR
10) TEMPERATURE GAUGE
11) COMPARTMENT TEMPERATURE SELECTOR
12) CABIN ALTITUDE
13) CABIN ALTITUDE RATE OF CHANGE
14) PRESSURE CONTROL MODE SELECTOR
15) LANDING ALTITUDE SET
16) FLIGHT ALTUTUDE SET
17) CABIN ALTITUDE SET
18) CABIN ALTITUDE RATE OF CHANGE CONTROL
19) MANUAL CONTROL & INDICATOR
20) GROUND-FLIGHT MODE SELECTOR

FIGURE 2-31. BOEING 727-200 THIRD CREWMAN PANEL UPPER

SECTION 3

BOEING 737

Model Variation

The 737 was produced in three models, the -100, -200, and -300. The -100 first flew on 4-9-67, and was certified on 12-16-67 to carry up to 115 passengers, although it is usually configured to carry approximately 100. Production of the -100 was terminated after only 30 airplanes.

The -200 first flew on 8-8-67, and was certified on 12-21-67. The -200 was produced in four configurations designated; the -200, the -200C, a convertible passenger/cargo model, the -200 Advanced, and the -200C Advanced. Total -200 production as of 10-1-84 was 1,013 delivered, 55 on order, and 37 on option.

The -300 was first flown on 2-24-84, and was certified on 11-14-84. Passenger capacity can vary from 130 to a maximum of 149. Production of the -300 is just beginning, with two deliveries as of 10-1-84, 154 on order, and 73 on option.

Total 737 production is 1,045 delivered, 209 on order, and 110 on option. At the current rate, the 737 series may replace the 727 as the world's most popular airliner.

The -100 and -200 are almost identical airplanes except for a 6-foot fuselage extension. They have the same ECS in terms of flow capacity, distribution ducting and pressurization control system. The -300 is an advanced model incorporating new engines, an additional 8-foot fuselage extension and an improved wing. The -300 also has a new ECS that includes new packs and ducting, but retains the same pressurization control system.

Within this group, the distribution ducting configuration is also determined by the choice of interior. The Boeing Company offered four interiors: the original interior or Hatrack, the new look or SuperJet, the CarryAll, and the -300 interior. The Hatrack was offered in the -100 and -200, the SuperJet and CarryAll were offered in the -200 only, and the -300 interior is offered in the -300 and in any post 1984 production -200. The SuperJet, CarryAll and -300 interior all use the same ducting except for overhead riser ducting. The Hatrack differs from the others in that there are no air outlets above the sidewall.

737 ECS

The 737 ECS is a two pack air cycle system using bleed-air as the air source. A block diagram of the system is shown in Figures 3-1 and 3-2. The air conditioning packs are located just below the wing in an unpressurized area of the fuselage just forward of the wheel well.

The ECS utilizes engine bleed-air from the 8th and 13th compressor stages as an air source. When on the ground, the APU or a ground cart may be used as an air source. In addition, the APU may be used during takeoff to increase engine thrust.

Hot bleed-air temperature and pressure are regulated by the pneumatic system before being routed to the pack flow-control valve. The flow-control valve is a pneumatically operated valve that acts to maintain a constant volumetric flow of air to the pack in response to varying bleed-air conditions. Air leaving the flow-control valve is routed to the temperature control valve and primary heat exchanger.

The primary heat exchanger uses ram air to cool the bleed-air before routing it to the air cycle machine (ACM). The temperature control valve controls the flow of air from the primary heat exchanger to the compressor; and, thus controls the amount of cold air produced. The ACM compresses the bleed-air then routes it to the secondary heat exchanger. A small amount of air bypasses the ACM, and is added to the turbine discharge to prevent ice formation in the water separator.

The secondary heat exchanger uses ram air to cool the compressor discharge air then directs air to the ACM turbine inlet. Air expands in the turbine to produce cold air at the turbine outlet. The cold air then passes to the water separator to remove the water, and continues on to the mixing chambers. Cold air is mixed with hot air that has bypassed the pack to produce temperature-conditioned air for distribution to the flight deck and passenger cabin. A schematic of the pack is shown in Figures 3-3 and 3-4. Pressure and temperature at points designated on Figures 3-3 and 3-4 are listed in Tables 3-1 and 3-2 for various flight regimes. Note that maximum supply temperature is limited by the duct overheat switch, and the minimum supply temperature by water separator anti-ice control. Main duct pressure is limited to approximately 17 inches of water (.64 psi) by a pressure relief valve.

Distribution

Air leaving the mixing chamber enters the main distribution manifold where it is divided and routed through the airplane. The mixing and distribution manifolds are shown in Figures 3-5 and 3-6. The amount of air diverted to the flight deck and, on -100 and -200, to the gasper system is controlled by flow limiting venturis. The remaining air is directed to the passenger cabin. The passenger cabin distribution systems are shown in Figures 3-7, 3-8 and 3-9. On the -100 and -200, a plenum located below the right forward cabin floor supplies air to the overhead duct through 14 risers located behind the right sidewall of the forward cabin. On the -300, two large rectangular risers, located behind the sidewall just forward of the wing on both sides of the cabin, supply the overhead duct. The overhead duct is located above the ceiling panels (see Figure 3-10) and directs air to the cabin through a nozzle located at the bottom of the duct.

On all -200 airplanes except Hatrack interior airplanes and on -300 airplanes, the overhead duct also supplies outlets located at the top of the sidewall. The sidewall outlets are connected to the overhead by dropper ducts located above the ceiling panel and behind the stowage compartments. Cross-sections showing ducting locations are shown in Figures 3-11, 3-12 and 3-13. Airflow patterns produced in the cabin are shown in Figure 3-14.

The flight deck distribution system is supplied through a duct located beneath the left forward cabin floor. Air enters the flight deck through six outlets. Two are located in the overhead behind the pilot and co-pilot's seats, one on the floor under each seat, and one outlet at the pilot and co-pilot's feet. The flight deck distribution ducting is shown in Figures 3-15 and 3-16.

The foot outlets have a manually controlled flapper valve that can be used to divert some or all of the foot air to the windshield. The control is a push-pull cable type and is located below the control column.

Airflow rates entering the compartments are listed in Tables 3-3 and 3-4. Compartment air change rates are listed in Tables 3-5, 3-6 and 3-7. Compartment volumes including cargo compartments are listed in Table 3-8.

<u>Individual (Gasper) Air</u>

In addition to compartment conditioned air, the passenger also has a separate outlet that he may use to cool his personal space. On the -100 and -200, the air supplied to the gasper air system is somewhat cooler than the air supplied to the air-conditioning system. The gasper system is supplied from the cold air lines by risers located behind the sidewall, just forward of the wing on both sides of the airplane. The risers feed supply ducts that run fore and aft behind the stowage compartments, and feed outlets located below the stowage compartments (see Figures 3-17, 3-18 and 3-19). The outlets are ball and socket type adjustable for flow rate and direction.

On the -300, the passenger cabin gasper outlets are supplied from the sidewall air dropper ducts and are located below the stowage bin, see Figures 3-20 and 3-21.

Flow rates through the system are provided in Tables 3-3 and 3-4. With all outlets open, approximately 15% to 20% of the total flow passes through the gasper air system.

Gasper air is also available to the flight crew. On -100 and -200 airplanes, the flight deck gasper system is supplied from the left passenger cabin gasper riser by a duct running forward under the left-hand floor. Air is available to the crew from four outlets, two located in the ceiling behind pilot and co-pilot's seats, and one at each outboard side of the control panel (see Figure 3-17).

On -300 airplanes, the flight deck gasper is supplied from the flight deck air conditioning supply duct (see Figure 3-16). The -300 retains the same four outlets as the -100 and -200 airplanes.

The -100 and -200 gasper systems have a fan to increase system pressure during conditions of high demand or low supply pressure. The fan is controlled by a switch on the overhead panel.

Equipment Cooling

The operation of the equipment cooling system is automatic once electrical power is applied to the airplane. Instruments and electrical equipment are cooled by exhausting flight deck conditioned air through the instrument panel and around the equipment (see Figures 3-22 and 3-23). On the ground or at low altitude, cabin air is drawn through the equipment panels by a blower located in the discharge duct. An alternate blower is provided in case of failure, switch over is made by selecting "alternate" on the blower selector switch. The blower operates continuously, and discharges overboard through a flow-control valve. As the airplane climbs and the cabin differential pressure rises to 2.0 to 2.8 psi, the flow-control valve closes. The blower discharge then exhausts beneath the forward cargo compartment. The system also incorporates an airflow sensor to alert the crew when cooling airflow is inadequate.

Cargo Heating

The cargo compartments on the 737 are classified as FAR Class D compartments. Cargo compartment volumes are shown in Table 3-8. The cargo compartments are not ventilated, and do not have a separate heating system.

The forward-cargo compartment is heated by exhausting equipment cooling air below the cargo compartment, and then circulating it upward between the fuselage skin insulation and cargo-compartment lining. Air is drawn upward by a collector shroud, then vented overboard through the forward outflow valve (see Figures 3-22 and 3-23).

The aft cargo compartment is heated by air exhausted from the passenger cabin air at floor level, then passing between the fuselage skin insulation and cargo compartment lining. The air is then dumped overboard through the pressurization system aft outflow valves.

Recirculation Systems

The -300 is the only model incorporating recirculation features. The recirculation system actually functions as a part of the equipment cooling/cargo heating system. When the recirculation system is on, a fan at the aft-right corner of the collector shroud draws air from the shroud through a filter, and exhausts it into the main mixing manifold (see Figures 3-6 and 3-23). When the recirculation system is off, the collector shroud exhausts air through the forward outflow valve as on the -100 and -200.

Ventilation

Air is vented overboard by two systems, galley ventilation and pressurization-outflow valves (forward and aft). The galley ventilation system is essentially fixed-flow in that the crew has no control over the amount of air vented. The outflow valves are variable flow, and respond to signals from the pressure controller.

The galley vent system removes air from the top of the galley and vents it overboard through a flow limiting venturi in the skin. The flow is driven by the cabin pressure to the ambient pressure differential. This prevents food odors from entering the passenger area. There are generally 2-4 galleys carried aboard the 737, placed in the forward and aft cabins. The typical vent is shown in Figure 3-24.

The pressurization-outflow valves are the primary method of maintaining ventilation. One is mounted on the forward left-hand side of the fuselage and the other is located aft of the aft cargo compartment on the uderside of the fuselage (see Figure 3-25). The forward valve vents air from collector shroud above the forward cargo compartment. The aft valve vents air from the lower portion of the aft fuselage. The outflow valves are shown in Figures 3-26 and 3-27.

Pressurization Control

The pressurization control systems are the same for all three 737 models. The system is an electrically operated and electronically controlled system that regulates the amount of air passing through the outflow valves. A schematic of the pressurizatin control system is shown in Figure 3-28. The pressurization system control panel is shown in Figure 3-29. The system has four operating modes; automatic (auto), standby, AC manual and DC manual. The system transfers to standby if the auto mode should fail, and the manual modes further back-up the standby modes. A knob is provided to manually select the desired mode. Gauges are provided to monitor cabin altitude change rate and cabin altitude. Pressurization system capabilities are shown in Table 3-8.

During normal flight, the auto mode is used. The auto mode requires only flight altitude and landing altitude to be entered by the crew. The pressure controller automatically modulates the outflow valves to maintain the lowest possible cabin altitude for the selected flight altitude, and ensures that the cabin differential pressure is small at landing. The pressure controller also acts to minimize the cabin altitude rate of change as the airplane climbs or descends. If the cabin altitude or pressure rate-of-change limits are exceeded, or if the auto system fails, transfer to standby mode is automatic.

The standby mode may also be used instead of the auto mode. The crew is required to set the desired cabin altitude and cabin altitude rate of change. The safety systems prevent over-pressurization or excessive differential pressure at landing.

The manual systems function in the event of the loss of the auto and standby modes. They must be selected using the mode selector knob. The AC and DC modes function the same, differing only in the source of electricity used to drive the outflow valve. The manual mode uses a three-position switch to change the outflow valve position. The switch sends a pulse to the outflow valve each time it is toggled. One toggle is sufficient to change the cabin pressure, but two or three are required to see any change in valve position. The cabin altimeter and differential pressure must be monitored to maintain cabin conditions within adequate limits.

ECS Controls

The -100 and -200 ECS control panel is shown in Figure 3-30 and -300 is shown in Figure 3-31. The upper panel houses the cabin temperature controls, mixing valve position gauges and compartment temperature gauge. The lower panel houses switches to control pack operation, bleed-air source, and gasper fan on -100 and -200, or recirculation fan on the -300. A gauge for monitoring bleed-air pressure is also provided.

The 737 has a two-zone temperature control system, the two zones being the passenger cabin and the flight deck. The flight deck air is taken from the left pack and the passenger cabin air from the right pack, thus, the temperature is controlled by adjusting the respective pack temperature. Compartment temperature can be controlled thermostatically or manually. In the manual mode, the position of the mixing valve is controlled by toggling the switch to either cooler or warmer and then monitoring compartment temperature on the gauge provided. Thermostatic control requires setting the desired temperature on the control panel.

Pack operation is controlled by the switches (Item 12, Figures 30 and 31). On the -100 and -200, the pack is either on or off; there is no adjustment of flow rate, or for controlling the flow rate entering a selected compartment. Flow rate may be varied only by selecting one-pack or two-packs operation. On the -300, the packs have two operating modes, normal and high flow. The mode of operation is controlled by the crew when both packs are in use.

If one pack fails, the other pack will switch to high flow mode. In addition, flow rate in the passenger cabin can be increased by use of the recirculation fan. The flow data and system temperatures are shown in Tables 3-1, 3-2, 3-3, and 3-4. The data presented are for a Boeing standard hot day.

Bleed-air for air conditioning is taken from the 8th and 13th compressor stages of both engines. An engine-mounted control system automatically selects the correct proportions to provide air at the correct pressure for the packs. The bleed-air is routed through a pre-cooler heat exchanger to reduce its temperature before delivery to the pack. The exchanger uses fan stage engine air to cool bleed-air. Flow through the system is regulated by the flow-control and pack shut-off valve. A gauge is provided to monitor bleed-air pressure.

The -100 and -200 models have a gasper fan to increase system pressure under conditions of high demand or low supply pressure. The -300 models do not have this feature, and the switch is replaced by the recirculation fan switch.

Electrical energy requirements of various ECS components and control systems are shown in Tables 3-9, 3-10, 3-11 and 3-12. Data are for cruise operation, unless otherwise noted. Some components do not operate continuously; when this is the case, the values in the table are for the electrical load when operating.

TABLE 3-1. BOEING 737-100,-200 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(^{o}F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	55	432	38	432	14.9	39	14.7	62	14.7	43	14.7	75	14.7	100
5,000 FT CLIMB	DATA NOT AVAILABLE													
10,000 FT CLIMB	53	353	35	353	15.1	46	14.7	54	14.7	48	14.7	75	10.1	63
25,000 FT CRUISE	26	289	21	289	13.3	71	12.9	60	12.9	68	12.9	75	5.5	-15
30,000 FT CRUISE	22	294	19	294	12.2	74	11.9	60	11.9	70	11.9	75	4.4	-24
35,000 FT CRUISE	47	407	20	407	11.3	78	11.0	60	11.0	73	11.0	75	3.5	-34
40,000 FT CRUISE														
18,500 FT DESCENT	22	285	22	285	14.8	35	14.7	46	14.7	38	14.7	75	7.2	33
10,000 FT DESCENT	DATA NOT AVAILABLE													

MAXIMUM SUPPLY TEMP 190^{O}F

MINIMUM SUPPLY TEMP 35^{O}F

TABLE 3-2. BOEING 737-300 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(^{o}F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	59	395	33	395	15.3	44	14.7	52	14.7	56	14.7	75	14.7	100
5,000 FT CLIMB	DATA NOT AVAILABLE													
10,000 FT CLIMB	54	397	29	397	15.1	35	14.7	43	14.7	52	14.7	75	10.11	64
25,000 FT CRUISE	DATA NOT AVAILABLE													
30,000 FT CRUISE	DATA NOT AVAILABLE													
35,000 FT CRUISE	DATA NOT AVAILABLE													
37,000 FT CRUISE	44	401	17	401	11.3	35	10.9	74	10.9	57	10.9	75	3.16	-30
20,000 FT DESCENT	20	292	20	292	15.1	35	14.7	35	14.7	45	14.7	75	6.75	-13
10,000 FT DESCENT	28	377	27	377	15.1	35	14.7	43	14.7	53	14.7	75	10.11	64

MAXIMUM SUPPLY TEMP 190^{o} F

MINIMUM SUPPLY TEMP 35^{o} F

TABLE 3-3. BOEING 737-100,-200 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN/PACK)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	76	1,840	NOT APPLICABLE	174	NOT APPLICABLE
5,000 FT CLIMB	N/A*	N/A*		N/A*	
10,000 FT CLIMB	76	1,847		154	
25,000 FT CRUISE	64	1,802		144	
30,000 FT CRUISE	60	1,850		147	
35,000 FT CRUISE	53	1,778		140	
40,000 FT CRUISE (REF 4)	N/A*	1,739		139	
18,500 FT DESCENT	34	847		70	
10,000 FT DESCENT	N/A*	N/A*		N/A*	

*NOT AVAILABLE

TABLE 3-4. BOEING 737-300 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN/PACK)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	58	2,106	37	157	0
5,000 FT CLIMB	N/A*	N/A*	N/A*	N/A*	0
10,000 FT CLIMB	53	2,003	41	148	0
25,000 FT CRUISE (REF 4)	N/A*	2,100	42	158	0
30,000 FT CRUISE (REF 4)	N/A*	2,154	42	162	0
35,000 FT CRUISE (REF 4)	N/A*	2,168	42	163	0
37,000 FT CRUISE	39	2,120	42	162	0
20,000 FT DESCENT	45	1,907	47	140	0
10,000 FT DESCENT	48	1,921	44	142	0

*NOT AVAILABLE

TABLE 3-5. BOEING 737-100 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	26.0	43.5
5,000 FT CLIMB	N/A*	N/A*
10,000 FT CLIMB	26.1	38.5
25,000 FT CRUISE	25.5	36.0
30,000 FT CRUISE	26.1	36.8
35,000 FT CRUISE	25.1	35.0
40,000 FT CRUISE	24.6	34.8
18,500 FT DESCENT	12.0	17.5
10,000 FT DESCENT	N/A*	N/A*

*NOT AVAILABLE

TABLE 3-6. BOEING 737-200 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	23.8	43.5
5,000 FT CLIMB	N/A*	N/A*
10,000 FT CLIMB	23.9	38.5
25,000 FT CRUISE	23.3	36.0
30,000 FT CRUISE	23.9	36.8
35,000 FT CRUISE	23.0	35.0
40,000 FT CRUISE	22.5	30.0
18,500 FT DESCENT	11.0	17.5
10,000 FT DESCENT	N/A*	N/A*

*NOT AVAILABLE

TABLE 3-7. BOEING 737-300 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	15.2	24.1	39.3
5,000 FT CLIMB	N/A*	N/A*	N/A*
10,000 FT CLIMB	13.5	22.9	37.0
25,000 FT CRUISE	13.9	24.0	39.5
30,000 FT CRUISE	14.3	24.6	40.5
37,000 FT CRUISE	14.4	24.8	40.5
40,000 FT CRUISE	14.0	24.2	40.5
20,000 FT DESCENT	11.6	21.8	35.0
10,000 FT DESCENT	12.3	22.0	35.5

*NOT AVAILABLE

TABLE 3-8. BOEING 737 VENTILATION PARAMETERS

VOLUMES (CU FT)	737-100	737-200	737-300
TOTAL PRESSURIZED	6,897	7,635	8,740
PASSENGER CABIN	4,240	4,636	5,248
CONTROL CABIN	240	240	240
FWD CARGO	650 TOTAL	370	425
AFT CARGO		505	643
PRESSURIZATION			
MAX ΔP (PSI)			
CONTROLLER LIMITED	7.45	7.45	7.5 - 7.8*
SAFETY VALVE LIMITED	8.35	8.35	8.35

CABIN ALTITUDE CHANGE RATES (FT/MIN)		
CONTOLLER SELECTED	MAX	2,000
	MIN	50
MANUAL SELECTED	MAX	10,000
	MIN	0
MAXIMUM CABIN ALTITUDE (FT)		15,000**

*Above 29,000 ft flight altitude.

**If pneumatic system can supply needed air flow when other components fail.

TABLE 3-9. BOEING 737-100,-200 AC ELECTRICAL ENERGY REQUIREMENTS (REF 10)

EQUIPMENT	POWER REQD	LOAD	SOURCE
Fwd Outflow Valve	115V 400 Hz 1Ø	100 W	AC Bus 1
Manual Temp Control	115V 400 Hz 1Ø	420 W	AC Transf Bus 1
Auto Temp Control - Left	115V 400 Hz 1Ø	57 W	AC Transf Bus 1
Pressure Controller - Auto A/C	115V 400 Hz 3Ø	75 W	AC Transf Bus 1
Flight Deck Boost Fan	115V 400 Hz 3Ø	1,035 W	AC Transf Bus 1
Left 35 degree Temp Control	28V 400 Hz	Negl	AC Transf Bus 1
A/C Pressure Indication	28V 400 Hz	Negl	AC Transf Bus 1
Air Data Computer	115V 400 Hz 3Ø	49 W	AC Standby Bus
Equipment Cooling Blower	115V 400 Hz 3Ø	800 W	AC Ground Service Bus
Gasper Fan	115V 400 Hz 3Ø	1,660 W	AC Bus 2
Pressure Controller Standby	115V 400 Hz 3Ø	65 W	AC Transf Bus 2
Pressure Controller Manual AC	115V 400 Hz 1Ø	65 W	AC Transf Bus 2
Auto Temp Control - Right	115V 400 Hz 3Ø	57 W	AC Transf Bus 2
Right 35 degree Temp Control	115V 400 Hz 3Ø	Negl	AC Transf Bus 2

TABLE 3-10. BOEING 737-100,-200 DC ELECTRICAL ENERGY REQUIREMENTS (REF 10)

EQUIPMENT	POWER REQD	LOAD	SOURCE
A/C Temp Indication	28V DC	.25 A	DC Bus 1
Pressure Controller Auto DC	28V DC	2.75 A	DC Bus 1
Pressurization - Manual DC	28V DC	.71 A	DC Standby
Equipment Cooling Fan Control	28V DC	.18 A	DC Bus 2
Pressurization Standby DC	28V DC	.5 A	DC Bus 2
A/C Valve Position Indication	28V DC	.25 A	DC Bus 2
Left A/C Pack Valve	28V DC	.5 A	Battery Bus
Right A/C Pack Valve	28V DC	.5 A	Battery Bus

TABLE 3-11. BOEING 737-300 AC ELECTRICAL ENERGY REQUIREMENTS (REF 11)

EQUIPMENT	POWER REQD	WATTS	VARS	SOURCE
Fwd Outflow Valve	115V 400 Hz 1Ø	90	44	AC Main 1 ØA
Equip Cooling Blower - Normal	115V 400 Hz 3Ø	810	392	AC Ground Service
Manual Temp Control	115V 400 Hz 1Ø	420	-	AC Transfer 1 ØB
L Ram Modulation	115V 400 Hz 1Ø	90	-	AC Transfer 1 ØB
Auto Pressure Controller - AC	115V 400 Hz 1Ø	75	-	AC Transfer 1 ØC
L Auto Temp Control	115V 400 Hz 1Ø	57	-	AC Transfer 1 ØC
L 35°F Temp Control	115V 400 Hz 1Ø	50	-	AC Transfer 1 ØC
Cabin Air Recirc Fan	115V 400 Hz 3Ø	4,159	3,119	AC Main 2
Equipment Cooling Blower - Alt	115V 400 Hz 3Ø	810	392	AC Main 2
Outflow Valve Heater Gskt	115V 400 Hz 1Ø	200	-	AC Main 2 ØB
Main Press Control - AC	115V 400 Hz 1Ø	65	-	AC Transfer 2 ØA
Stby Press Control AC	115V 400 Hz 1Ø	65	-	AC Transfer 2 ØA
R Auto Temp Control	115V 400 Hz 1Ø	57	-	AC Transfer 2 ØB
R Ram Modulation	115V 400 Hz 1Ø	90	-	AC Transfer 2 ØB
R 35°F Temp Control	115V 400 Hz 1Ø	50	-	AC Transfer 2 ØB

TABLE 3-12. BOEING 737-300 DC ELECTRICAL ENERGY REQUIREMENTS (REF 11)

EQUIPMENT	POWER REQD	LOAD	SOURCE
Auto Press Control - DC	28 VDC	2.75 A	DC Bus 1
L Turbofan Valve	28 VDC	1.00 A	DC Bus 1
A/C Air Temp Indication	28 VDC	.25 A	DC Bus 1
Manual Press Control - DC	28 VDC	.71 A	DC Stby Bus
Recirc Fan Control	28 VDC	.50 A	DC Bus 2
Stby Press Control - DC	28 VDC	1.00 A	DC Bus 2
Equip Cooling Control	28 VDC	.35 A	DC Bus 2
R Turbofan Valve	28 VDC	1.00 A	DC Bus 2
A/C Mix Valve Position Ind	28 VDC	.25 A	DC Bus 2
Pressure Warning Latch	28 VDC	1.00 A	Battery Bus
L Pack Valve	28 VDC	.60 A	Battery Bus
R Pack Valve	28 VDC	.60 A	Battery Bus
A/C Overhead	28 VDC	1.00 A	Battery Bus
Ram Modulation Control	28 VDC	.30 A	Battery Bus

BOEING 737-100,-200

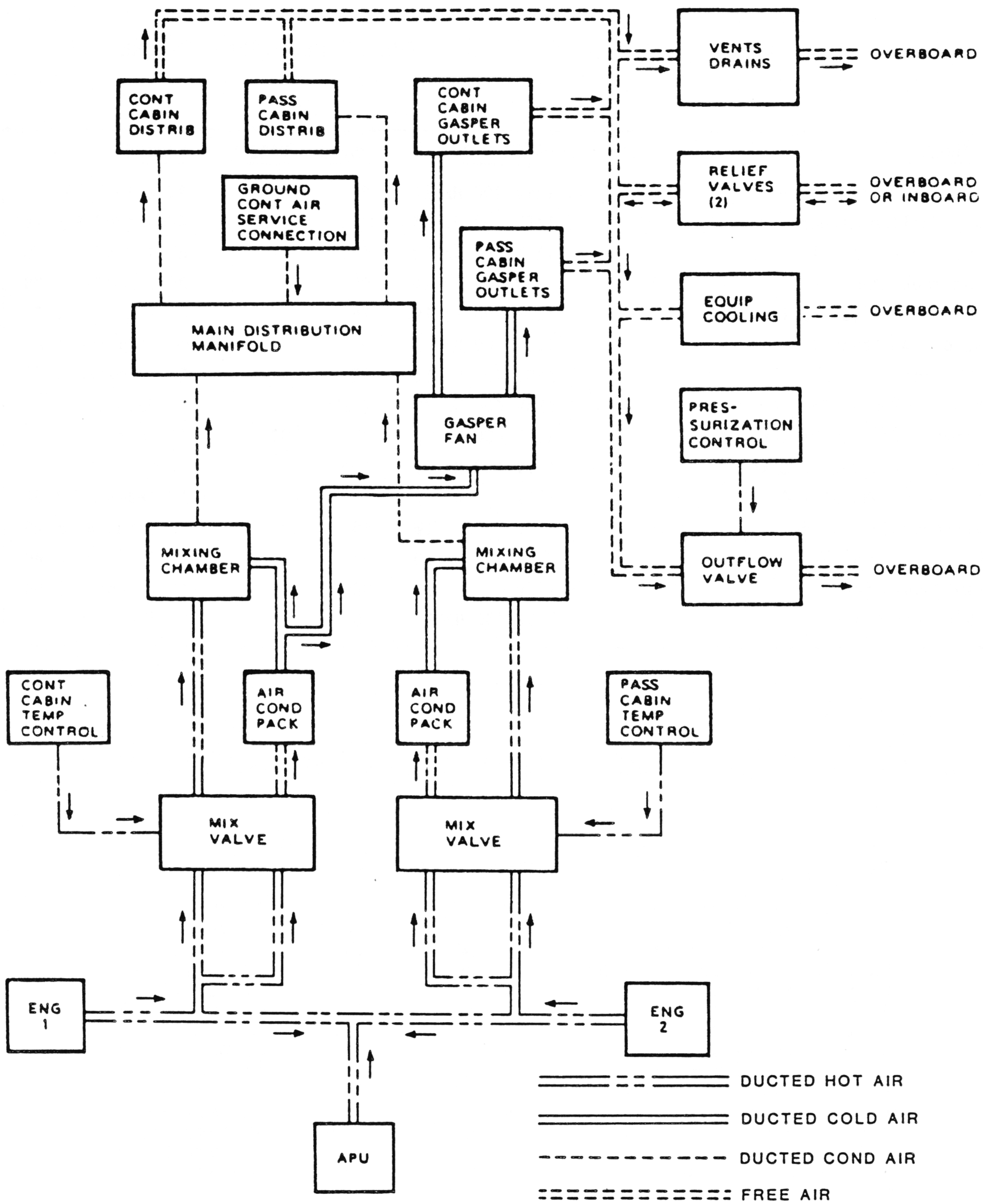


FIGURE 3-1. BOEING 737-100,-200 AIR CONDITIONING AND PRESSURIZATION CONTROL BLOCK DIAGRAM

BOEING 737-300

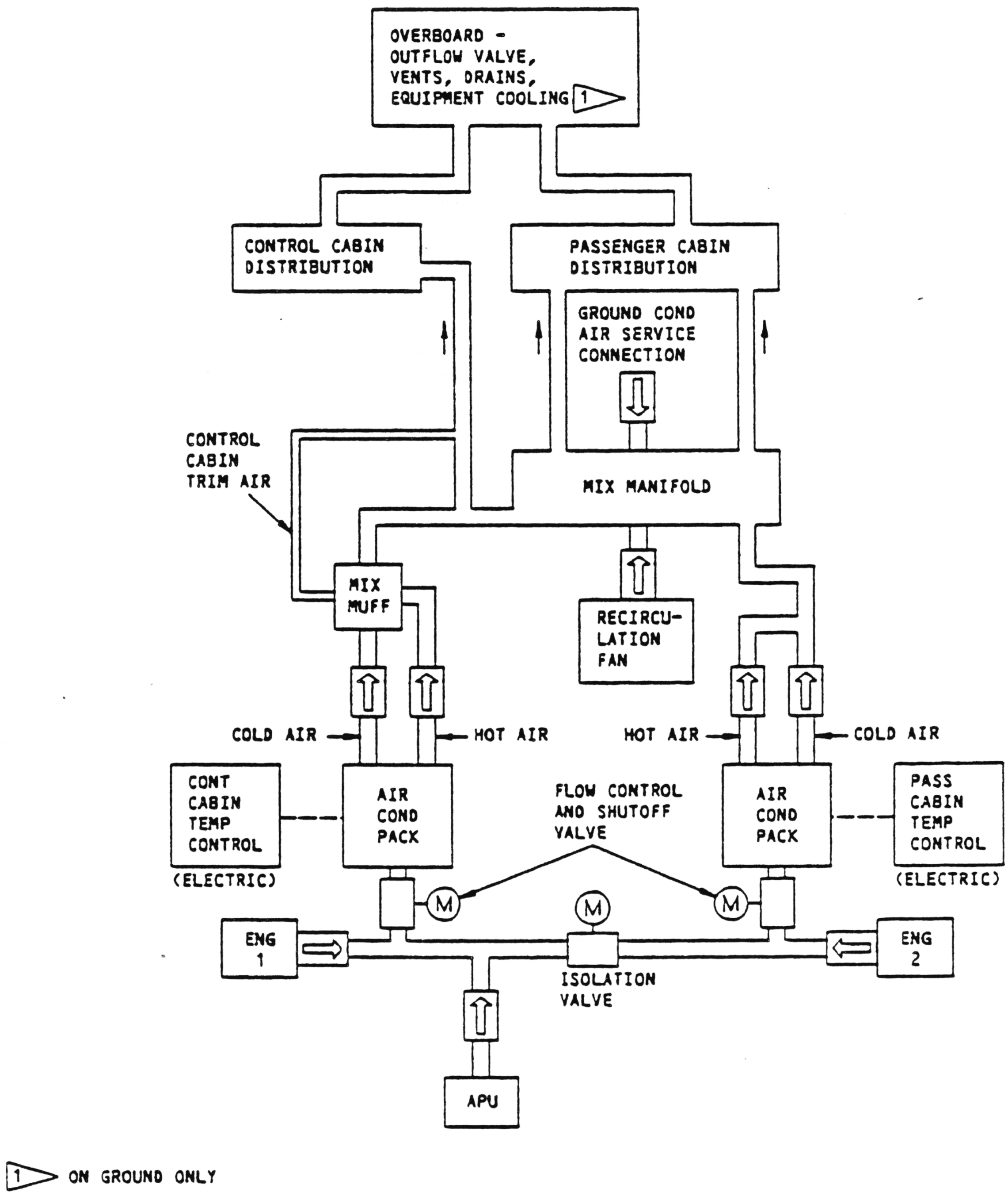


FIGURE 3-2. BOEING 737-300 AIR CONDITIONING AND
PRESSURIZATION CONTROL BLOCK DIAGRAM

BOEING 737-100,-200

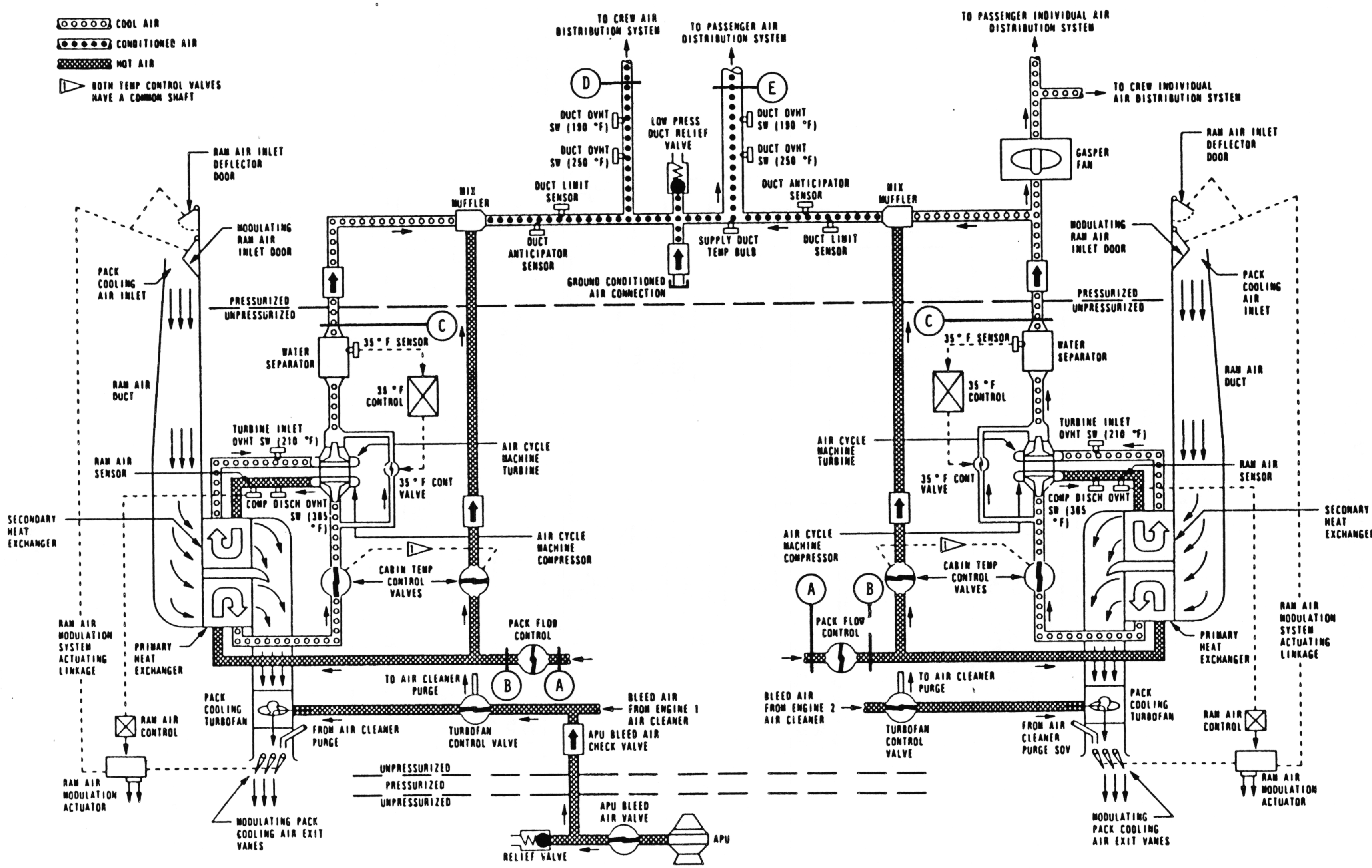


FIGURE 3-3. BOEING 737-100,-200 AIR CONDITIONING PACK SCHEMATIC

BOEING 737-300

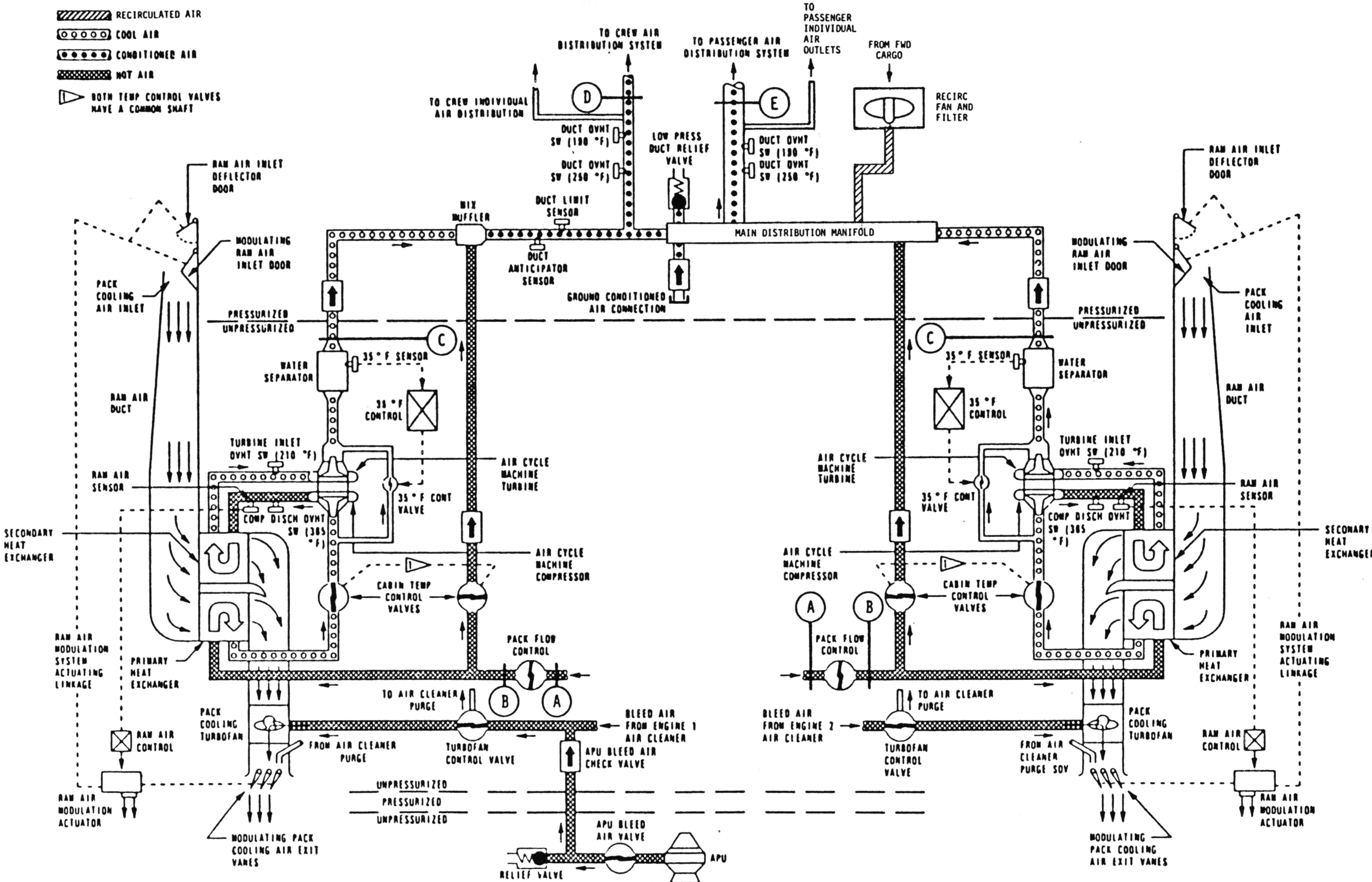


FIGURE 3-4. BOEING 737-300 AIR CONDITIONING PACK SCHEMATIC

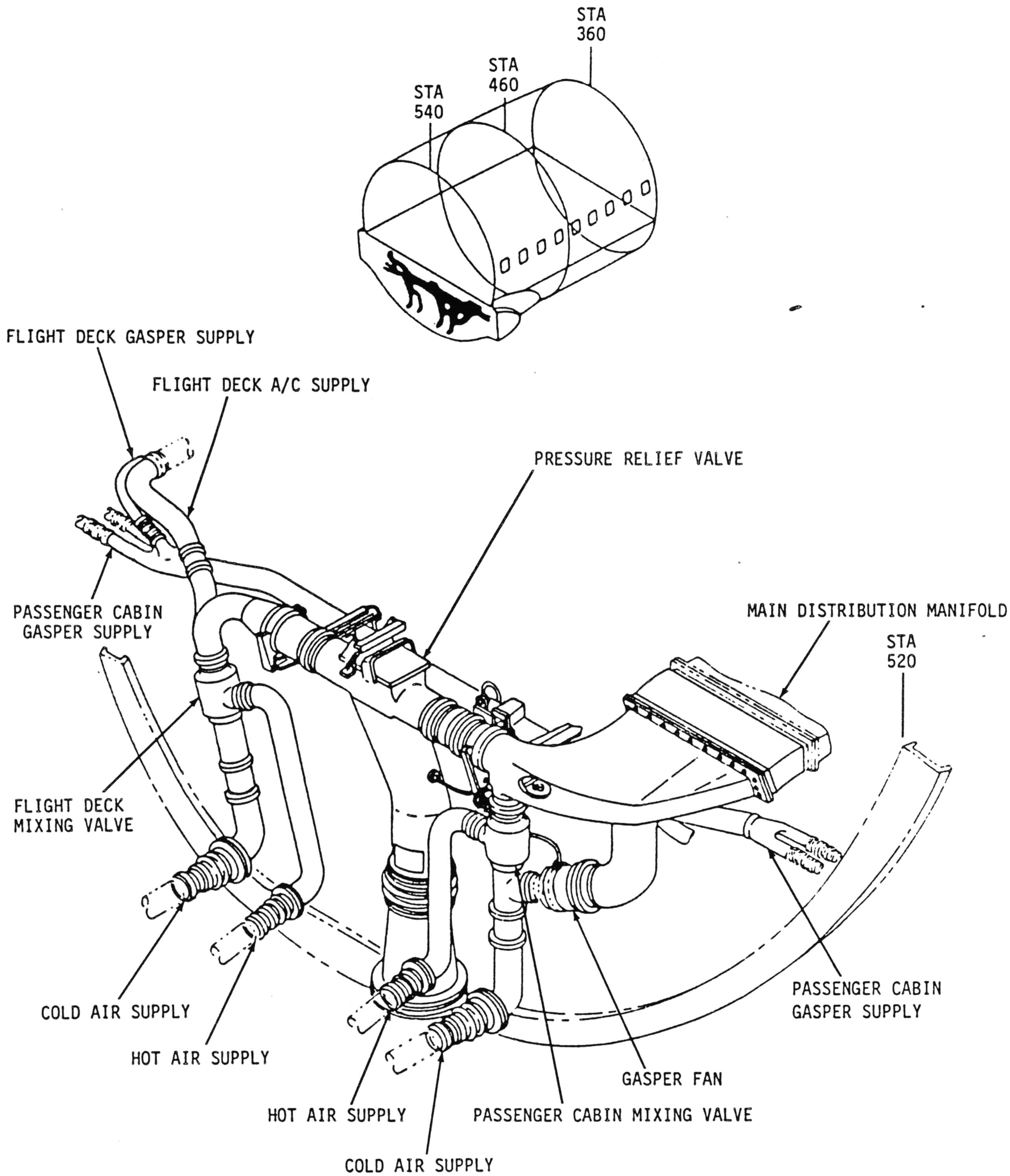


FIGURE 3-5. BOEING 737-100,-200 MIXING AND DISTRIBUTION MANIFOLD

BOEING 737-300

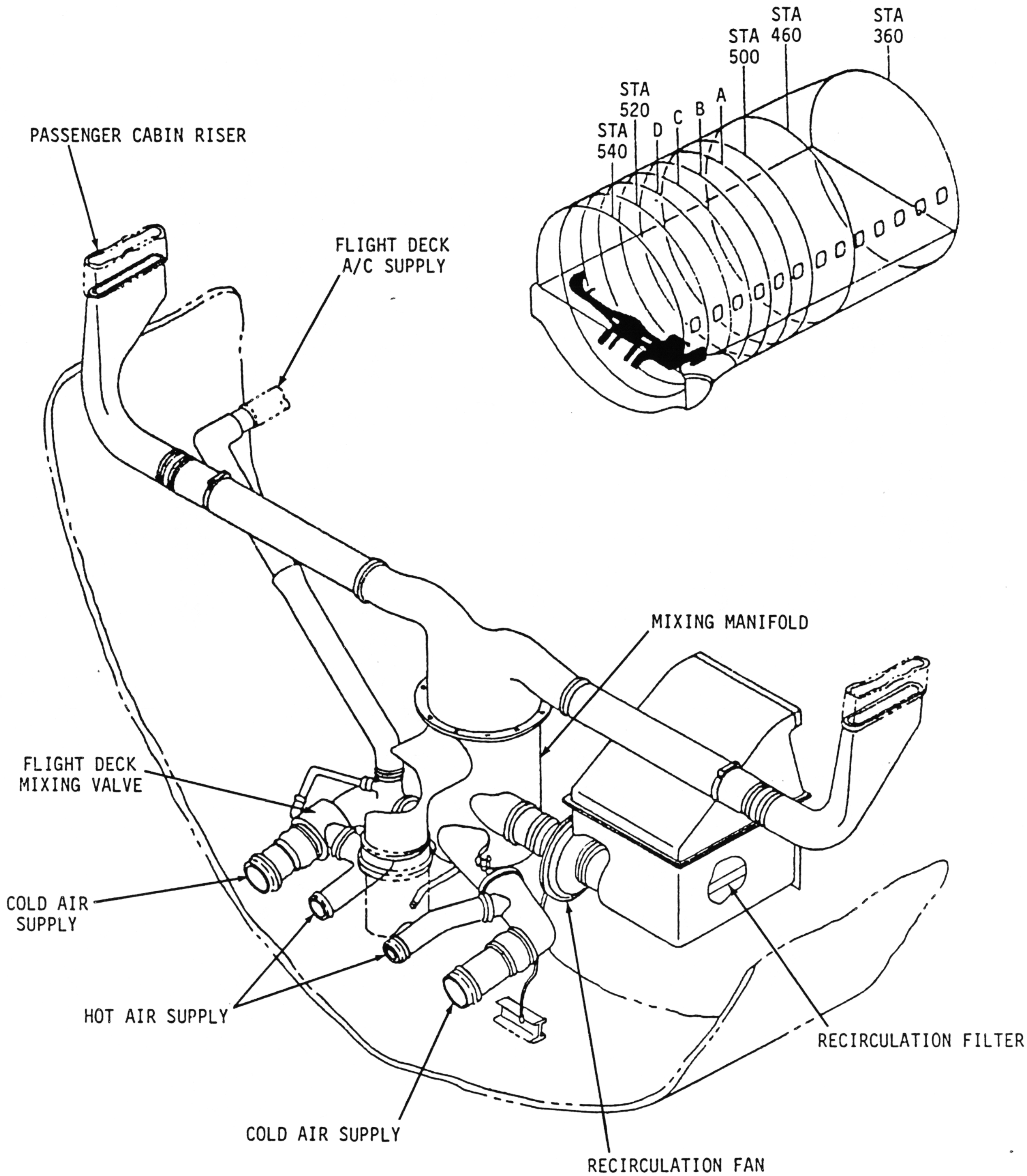


FIGURE 3-6. BOEING 737-300 MIXING AND DISTRIBUTION MANIFOLD

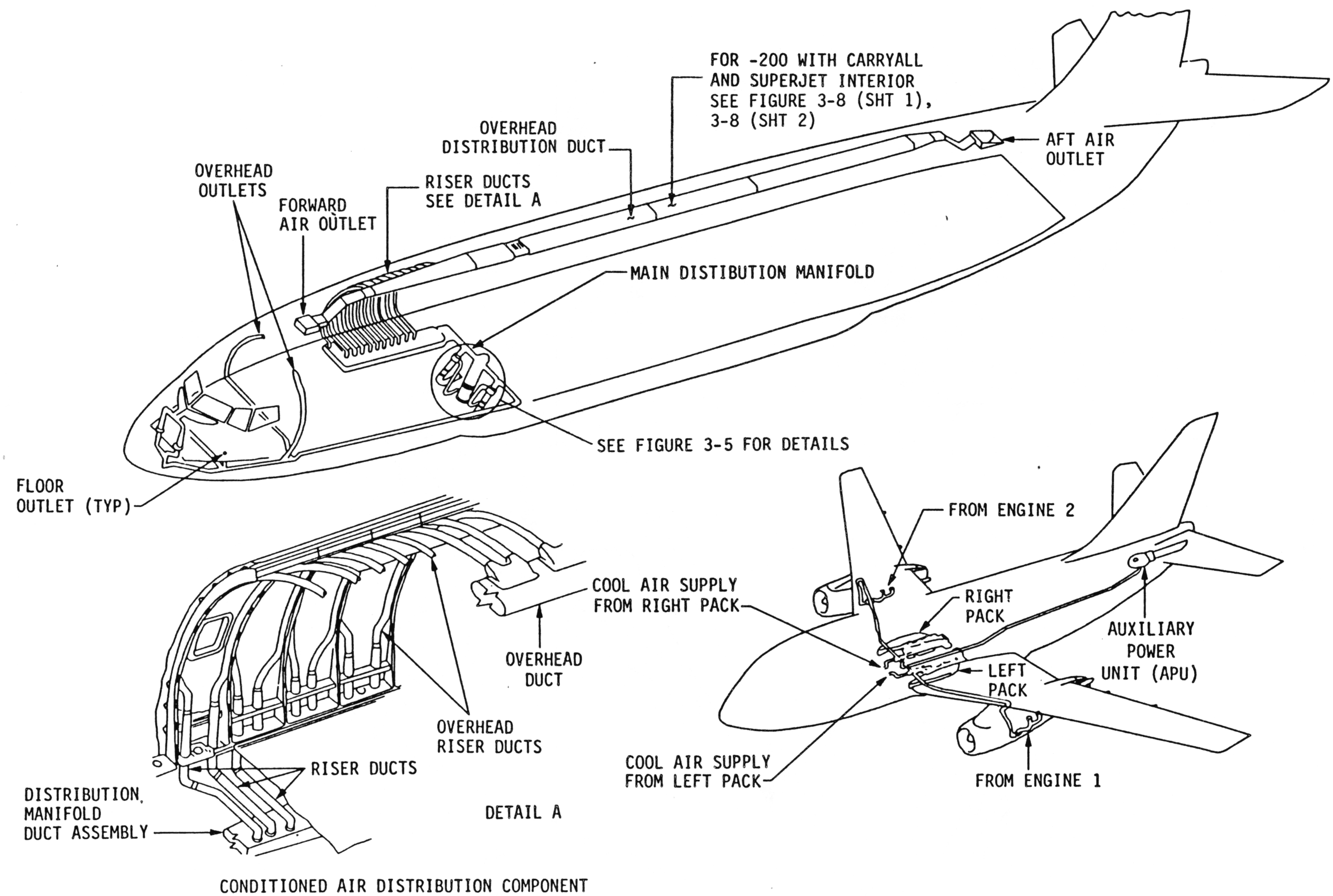


FIGURE 3-7. BOEING 737-100,-200 PASSENGER CABIN AIR DISTRIBUTION

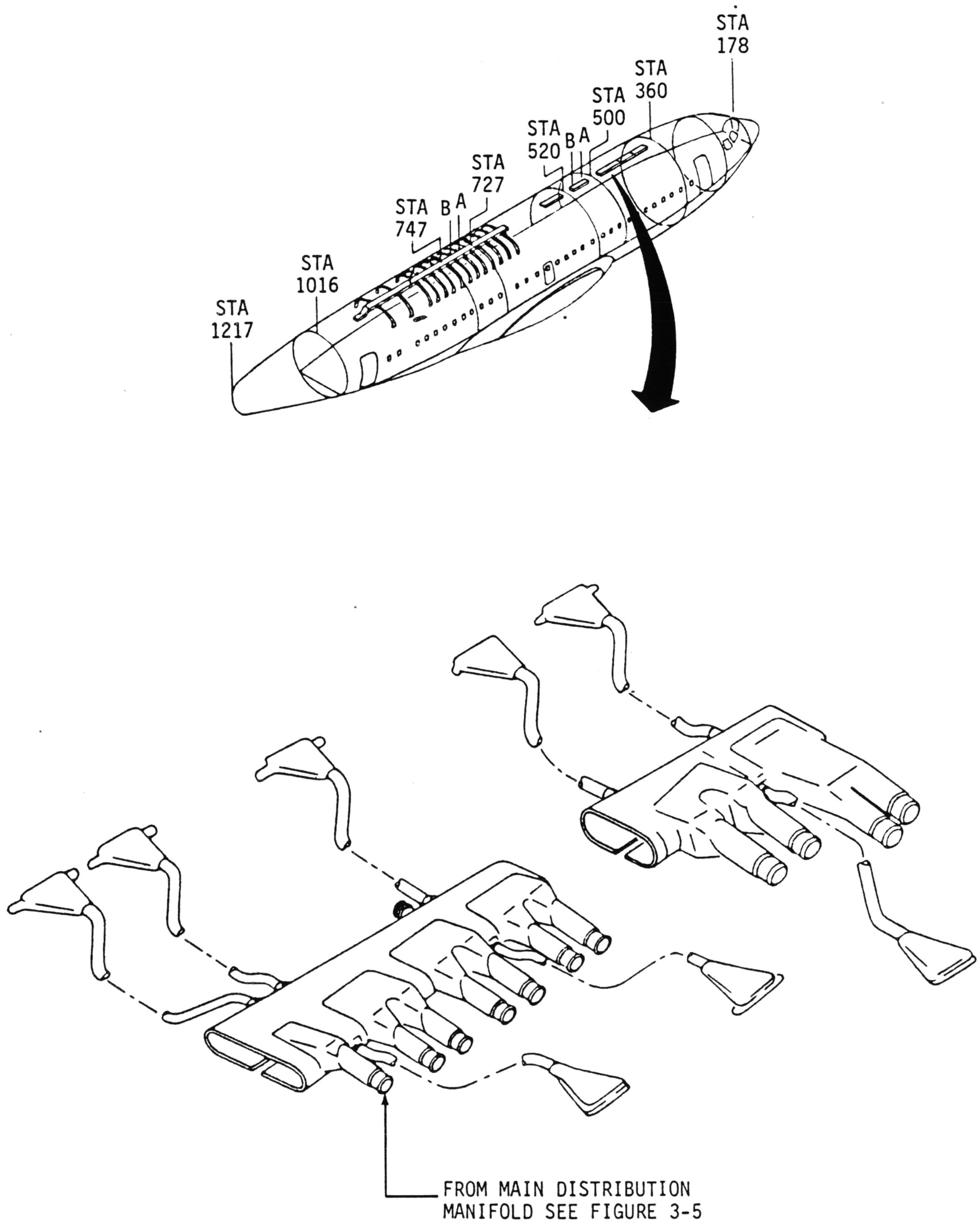


FIGURE 3-8. BOEING 737-200 PASSENGER CABIN AIR DISTRIBUTION, SUPERJET AND CARRYALL INTERIORS (SHEET 1 OF 2)

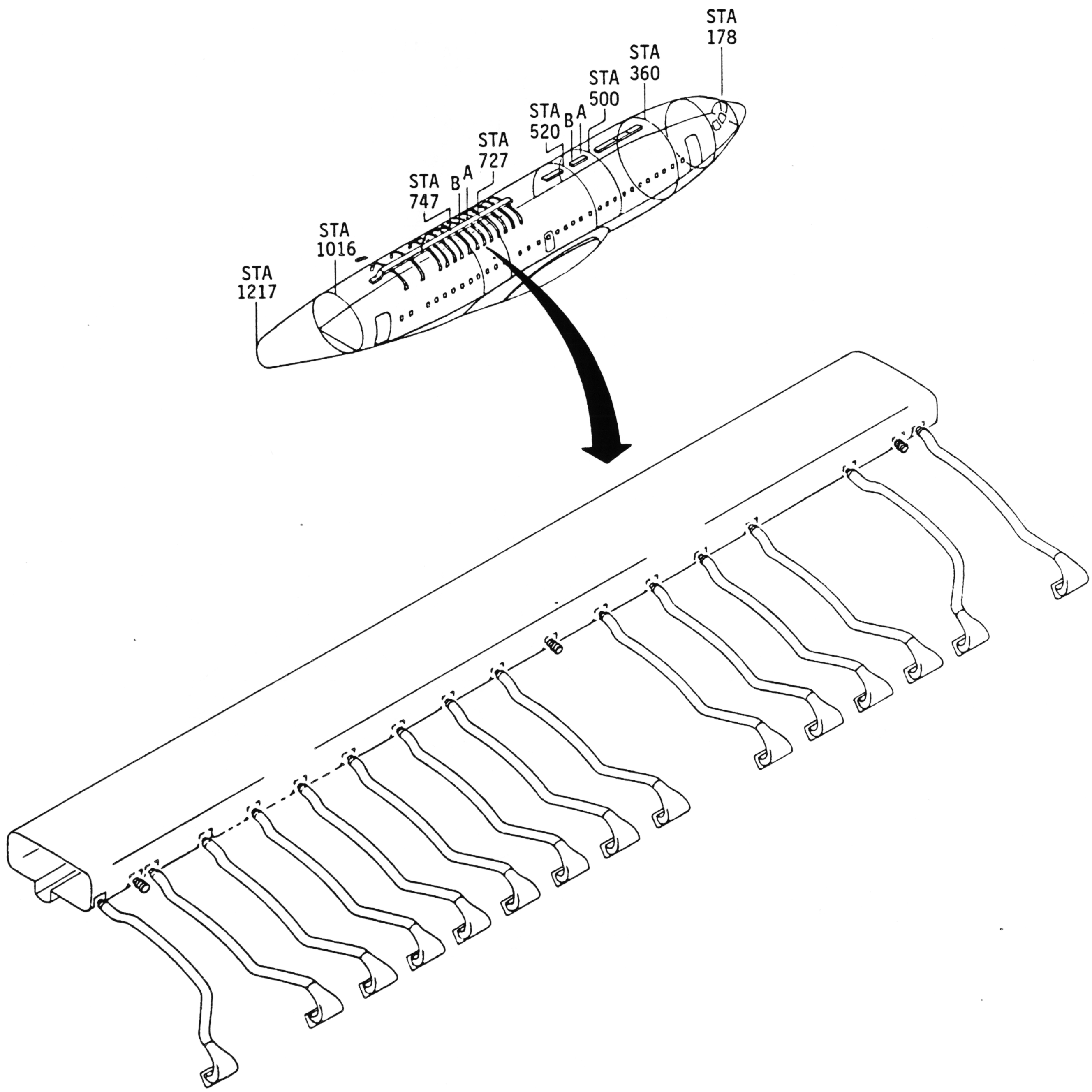


FIGURE 3-8, BOEING 737-200 PASSENGER CABIN AIR DISTRIBUTION, SUPERJET AND CARRYALL INTERIORS (SHEET 2 OF 2)

BOEING 737-300

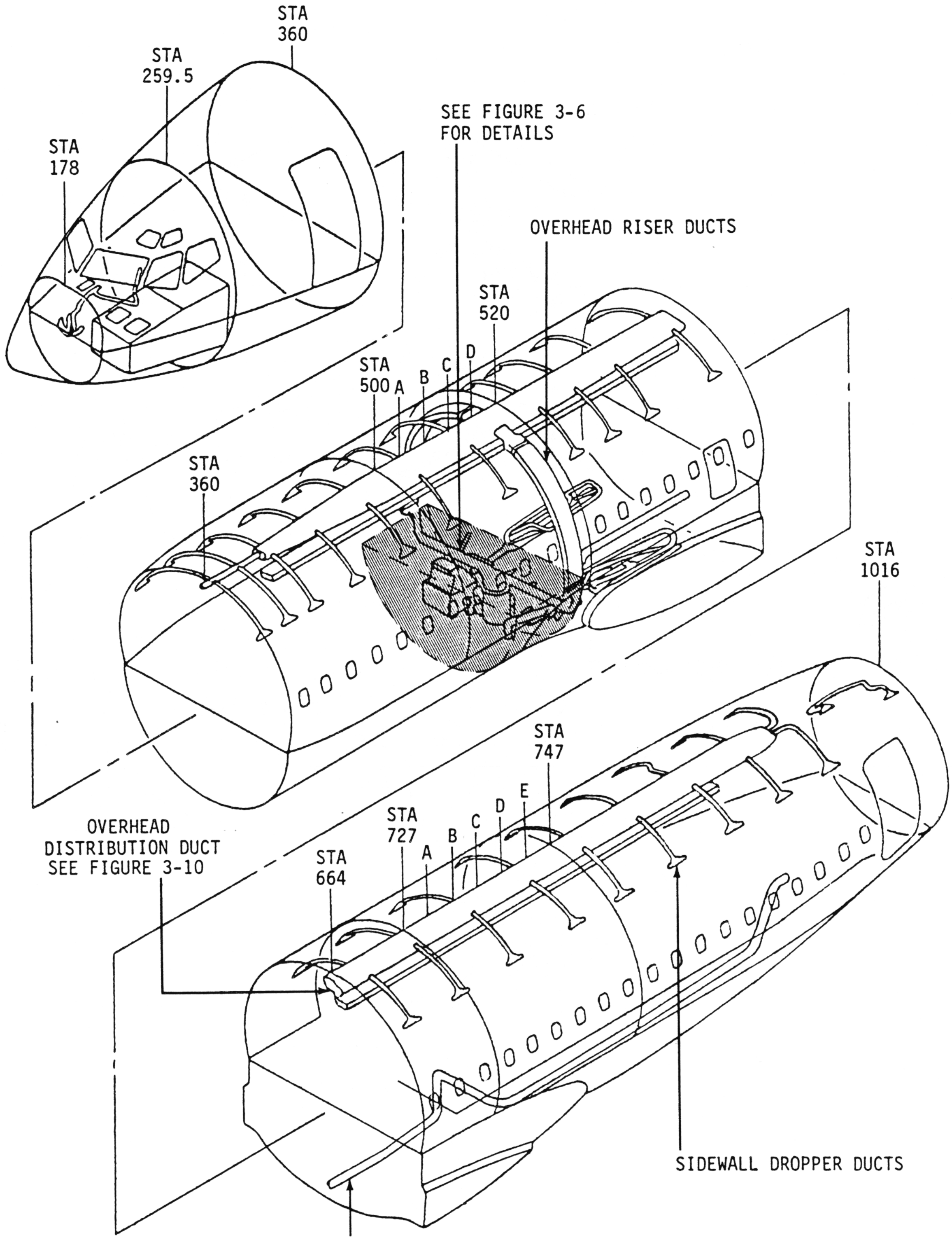
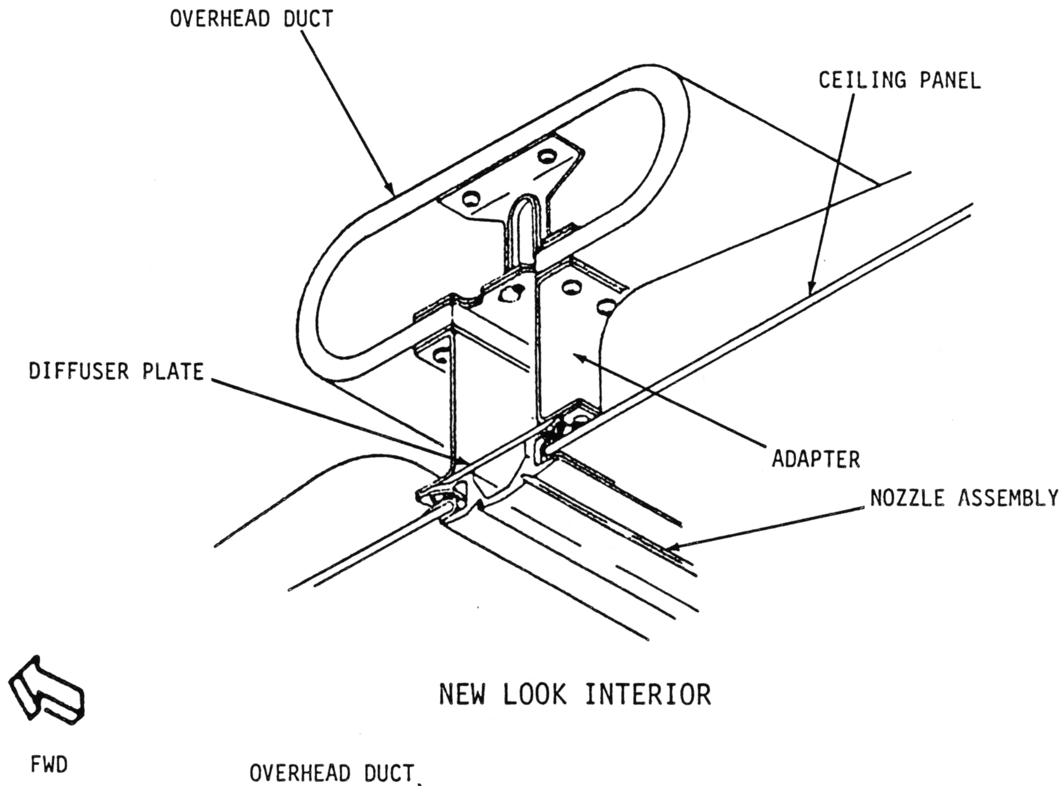
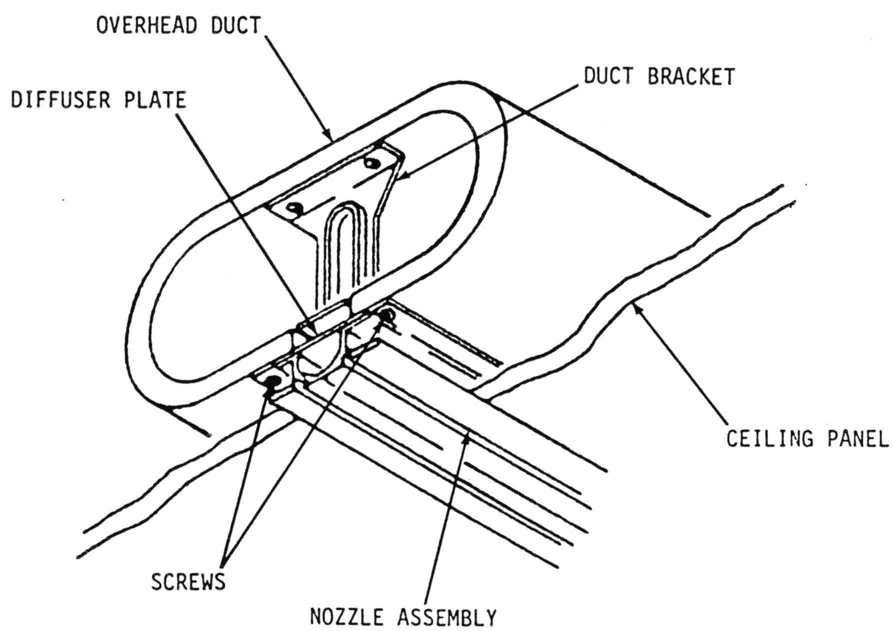


FIGURE 3-9. BOEING 737-300 PASSENGER CABIN AIR DISTRIBUTION

BOEING 737



NEW LOOK INTERIOR



ORIGINAL INTERIOR

FIGURE 3-10. BOEING 737 CEILING OUTLETS

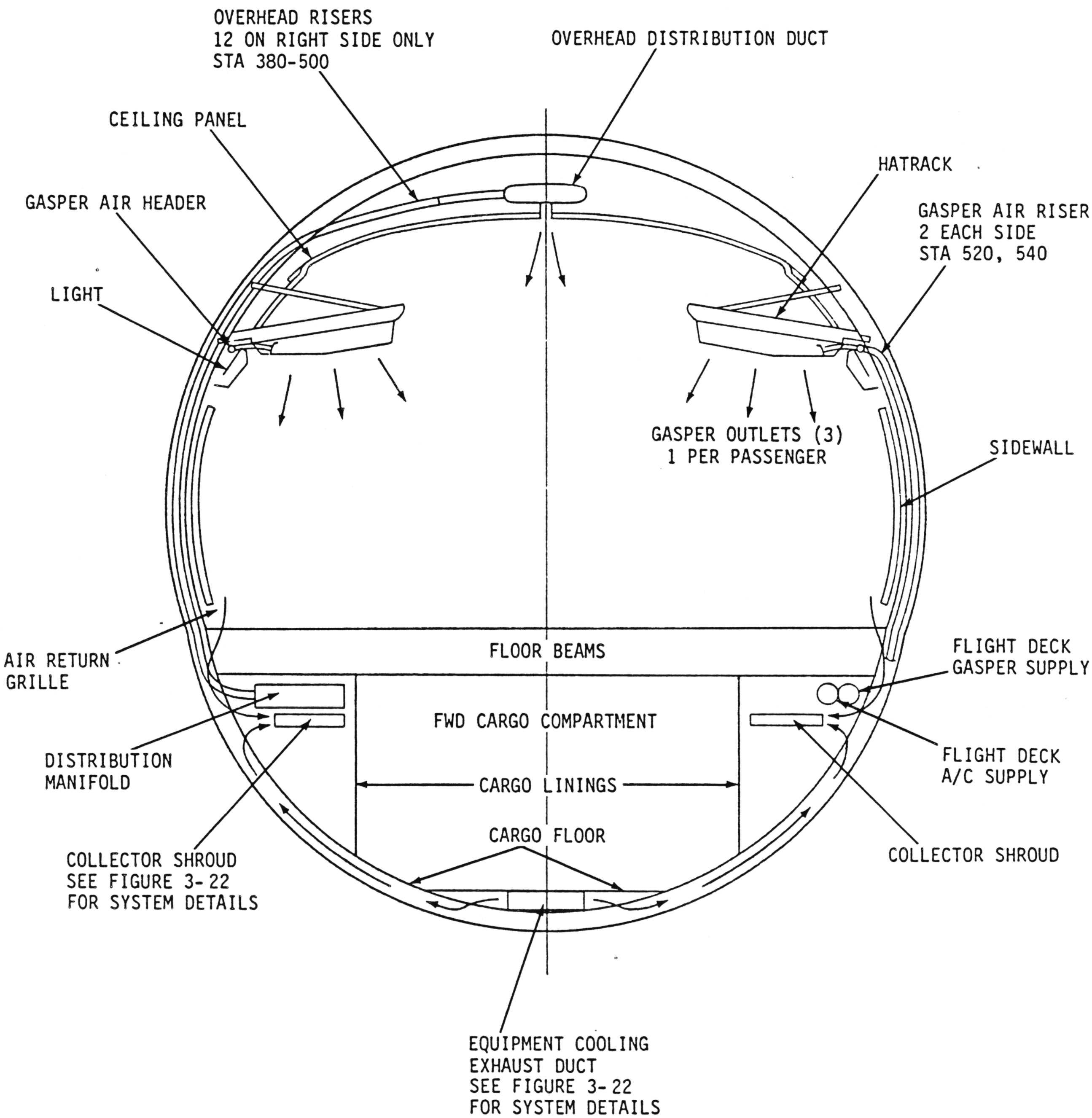


FIGURE 3-11. BOEING 737-100,-200 PASSENGER CABIN CROSS SECTION, HATRACK INTERIOR

BOEING 737-200

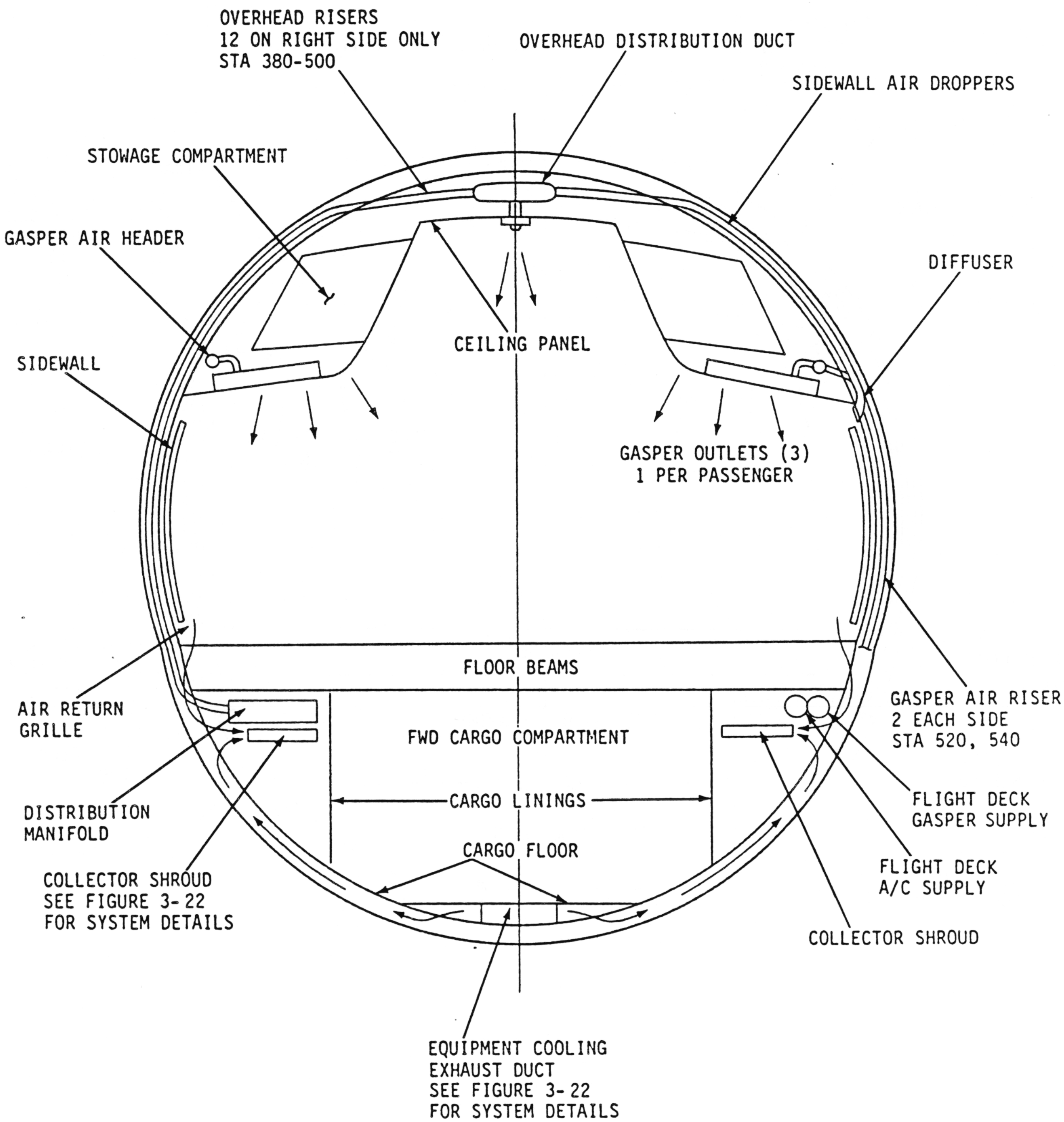


FIGURE 3-12. BOEING 737-200 PASSENGER CABIN CROSS SECTION, SUPERJET (SHOWN) AND CARRYALL INTERIORS

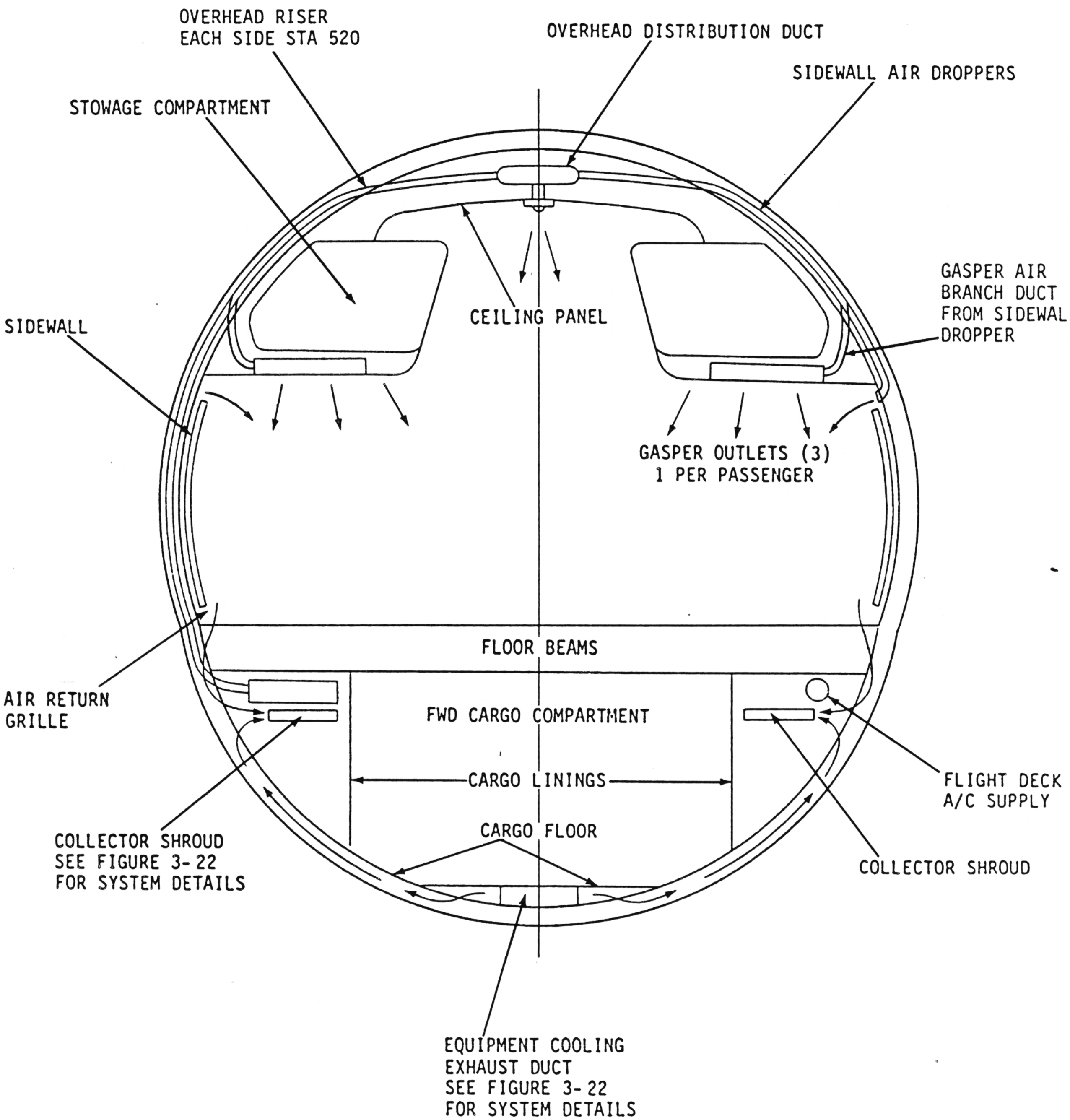
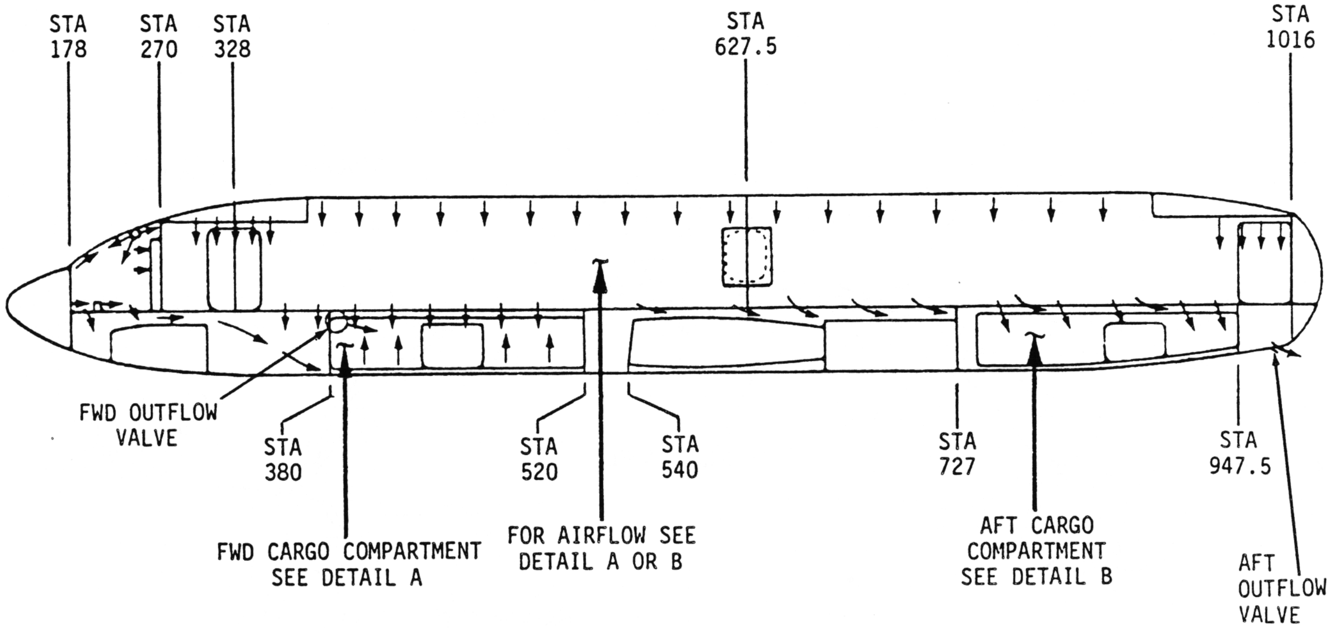
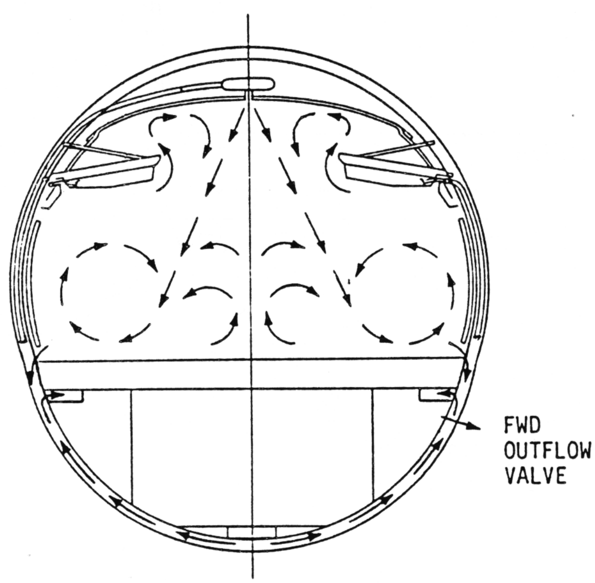


FIGURE 3-13. BOEING 737-300 PASSENGER CABIN CROSS SECTION

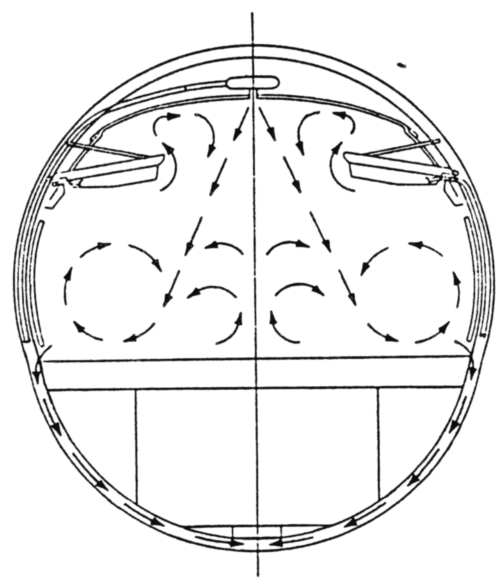
BOEING 737





DETAIL A

OVERHEAD OUTLETS
AND FWD CARGO
COMPARTMENT
AIR FLOW



DETAIL B

OVERHEAD OUTLETS
AND AFT CARGO
COMPARTMENT
AIRFLOW

FIGURE 3-14. BOEING 737 PASSENGER CABIN AIRFLOW PATTERNS

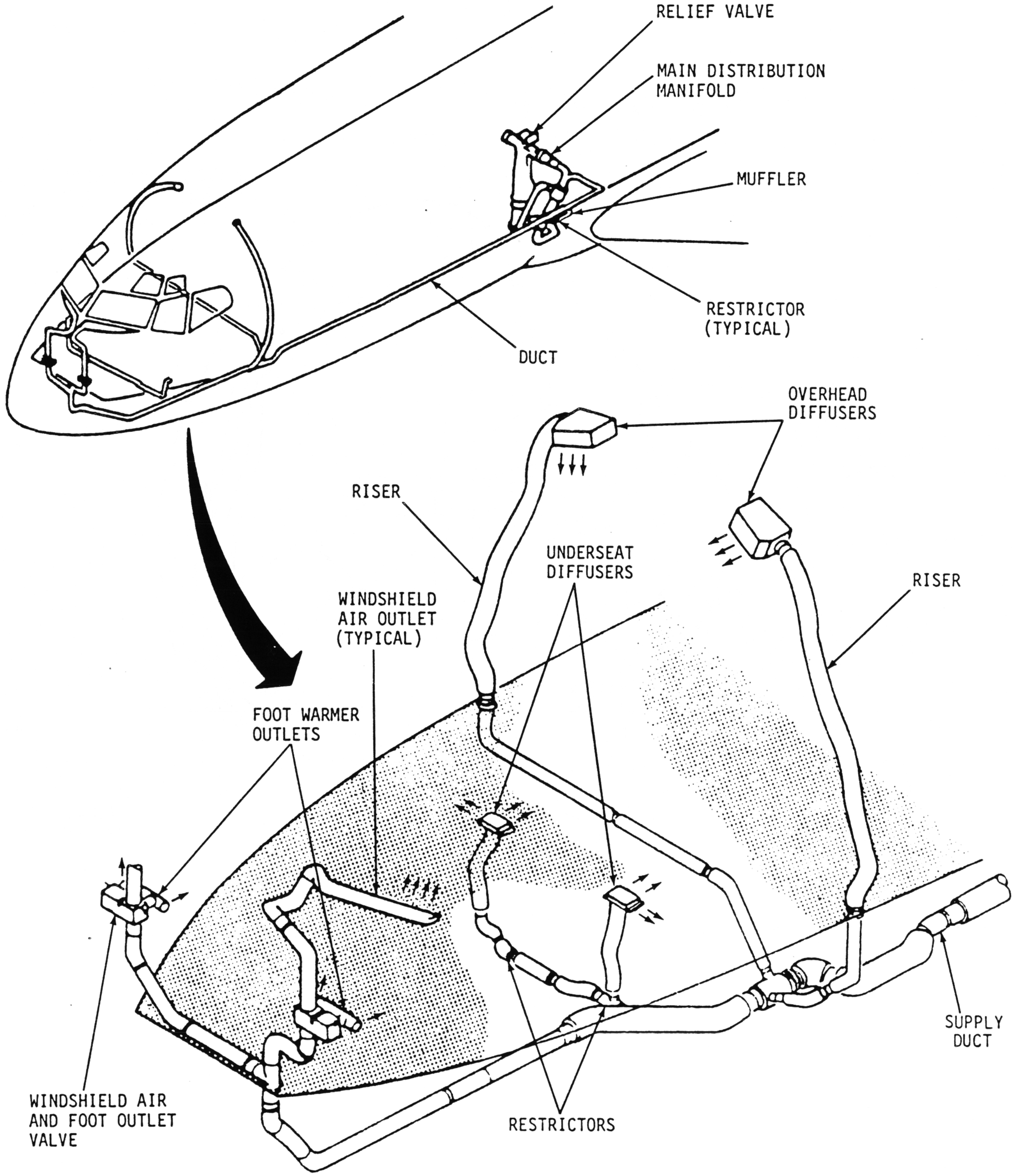


FIGURE 3-15. BOEING 737-100,-200 FLIGHT DECK AIR DISTRIBUTION

BOEING 737-300

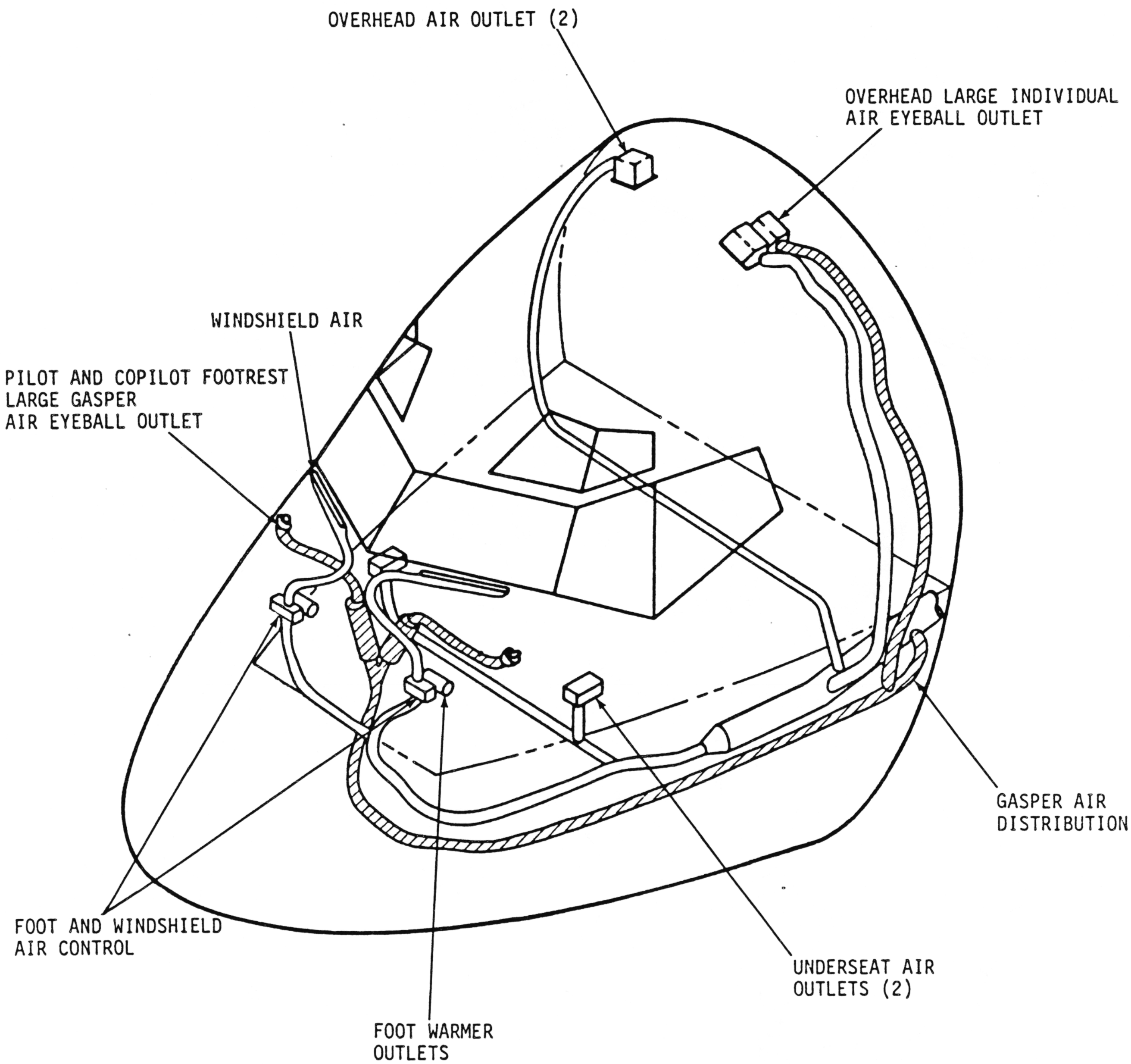


FIGURE 3-16. BOEING 737-300 FLIGHT DECK AIR DISTRIBUTION

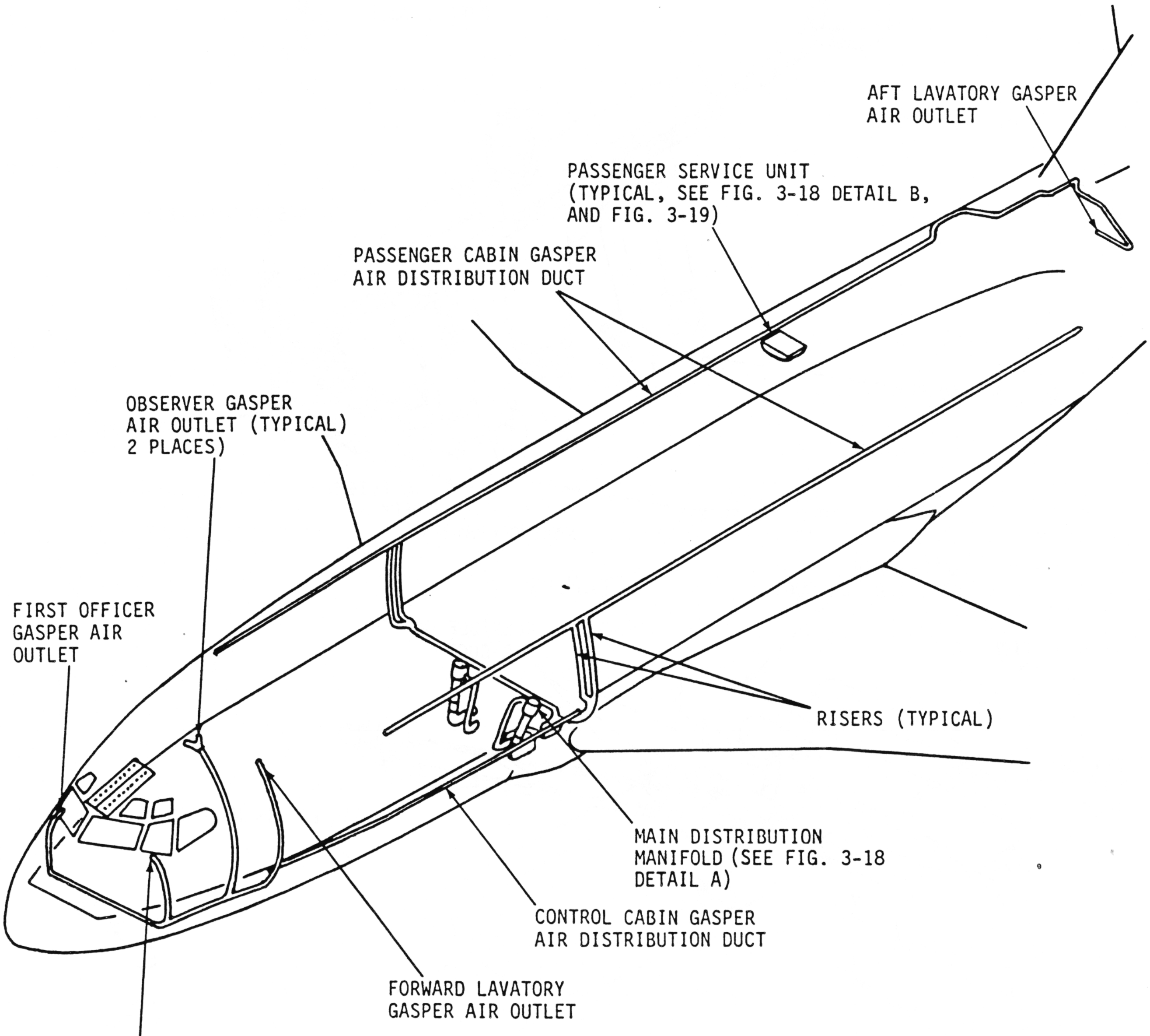
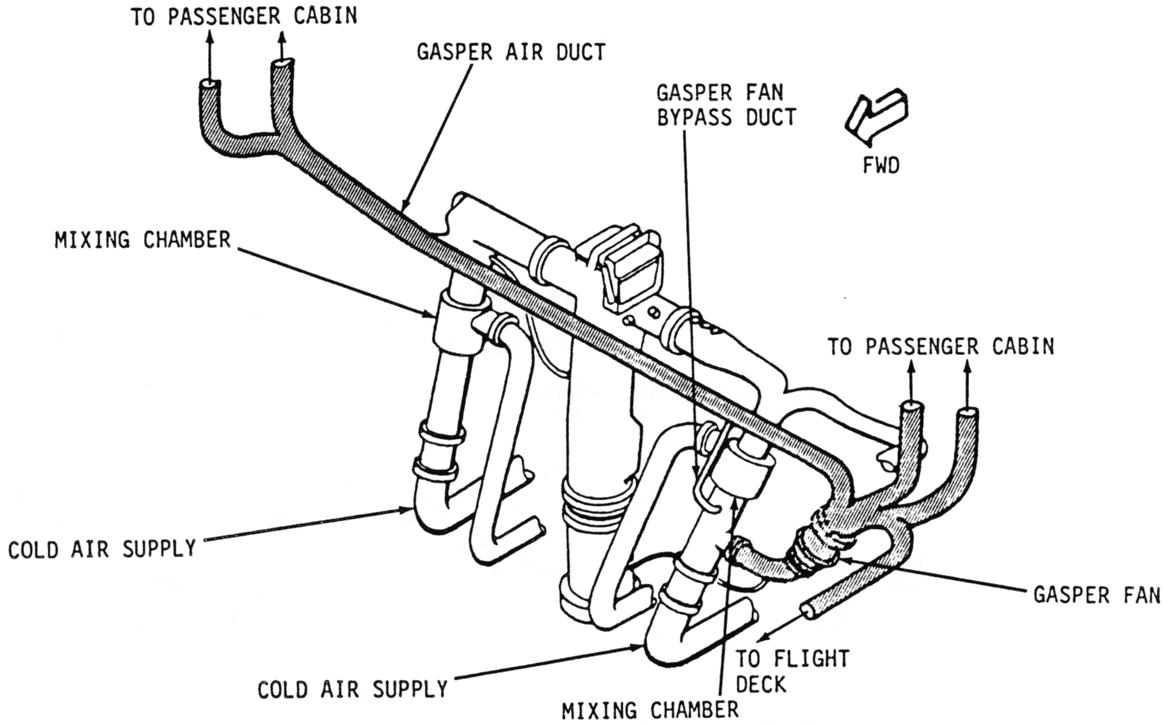
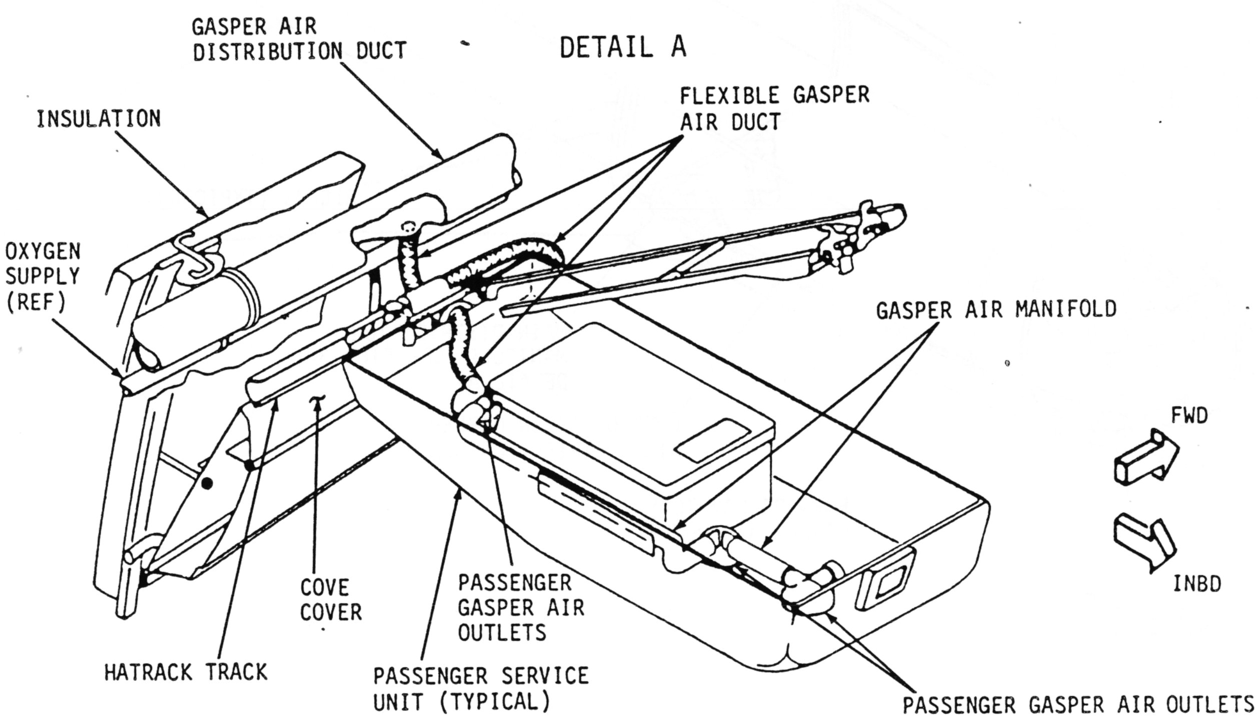


FIGURE 3-17. BOEING 737-100,-200 GASPER AIR
SYSTEM EQUIPMENT LOCATION



DETAIL A



DETAIL B

HATRACK INTERIORS

FIGURE 3-18. BOEING 737-100,-200 GASPER AIR DISTRIBUTION SYSTEM CABIN OUTLETS

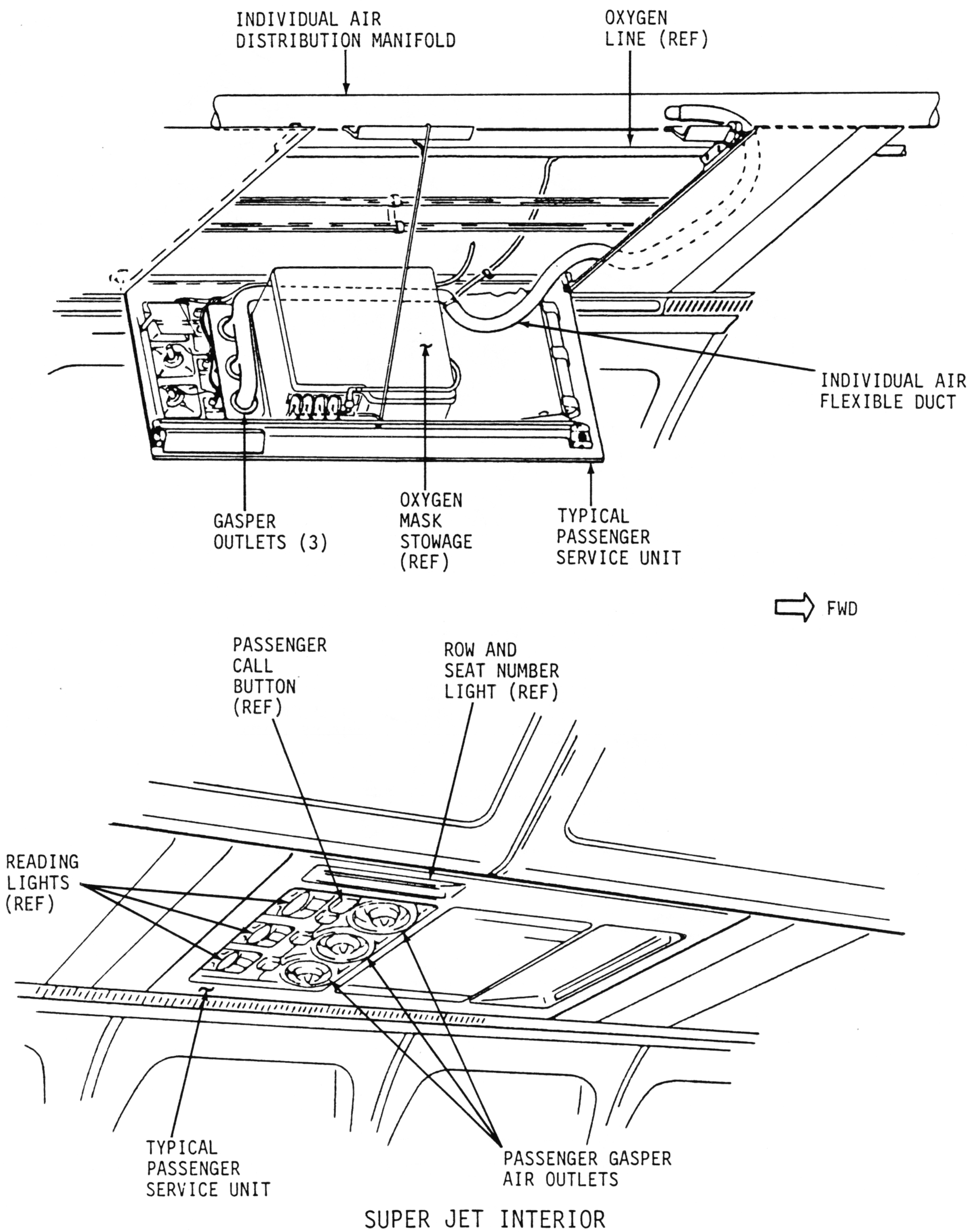
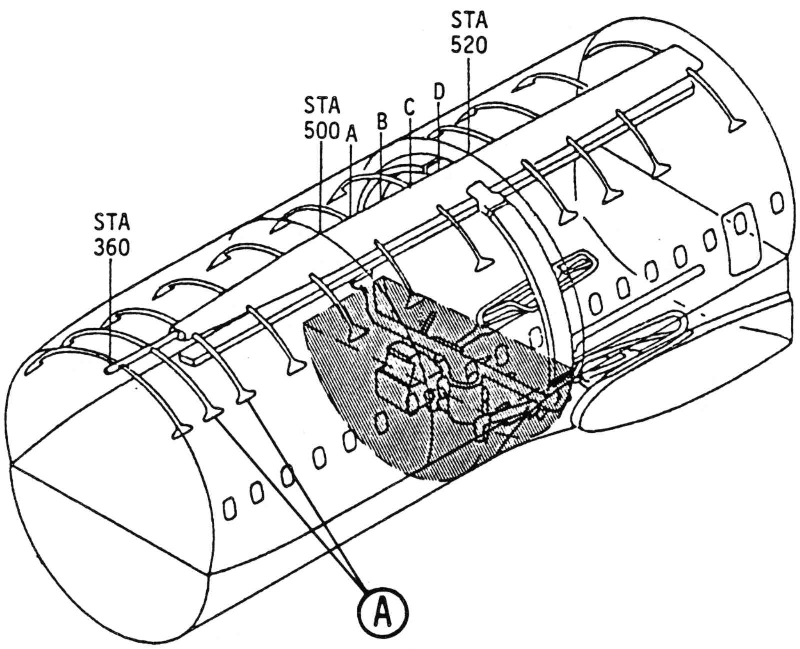


FIGURE 3-19. BOEING 737-200 GASPER AIR SYSTEM CABIN OUTLETS



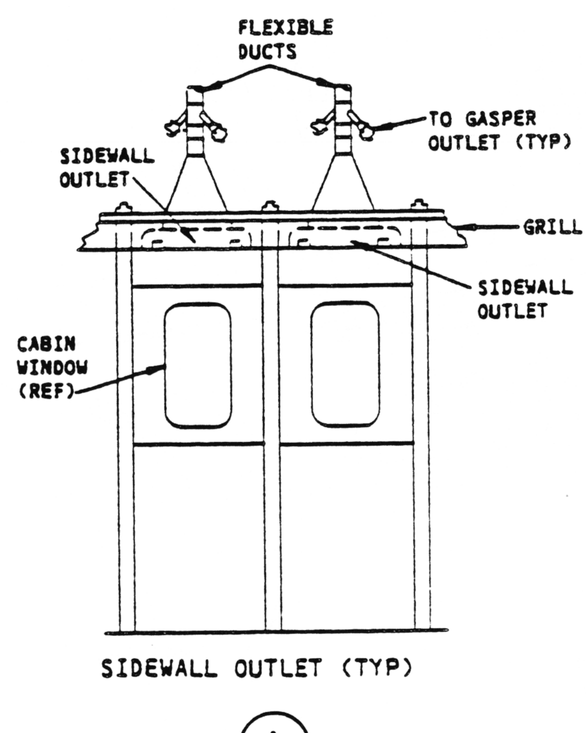
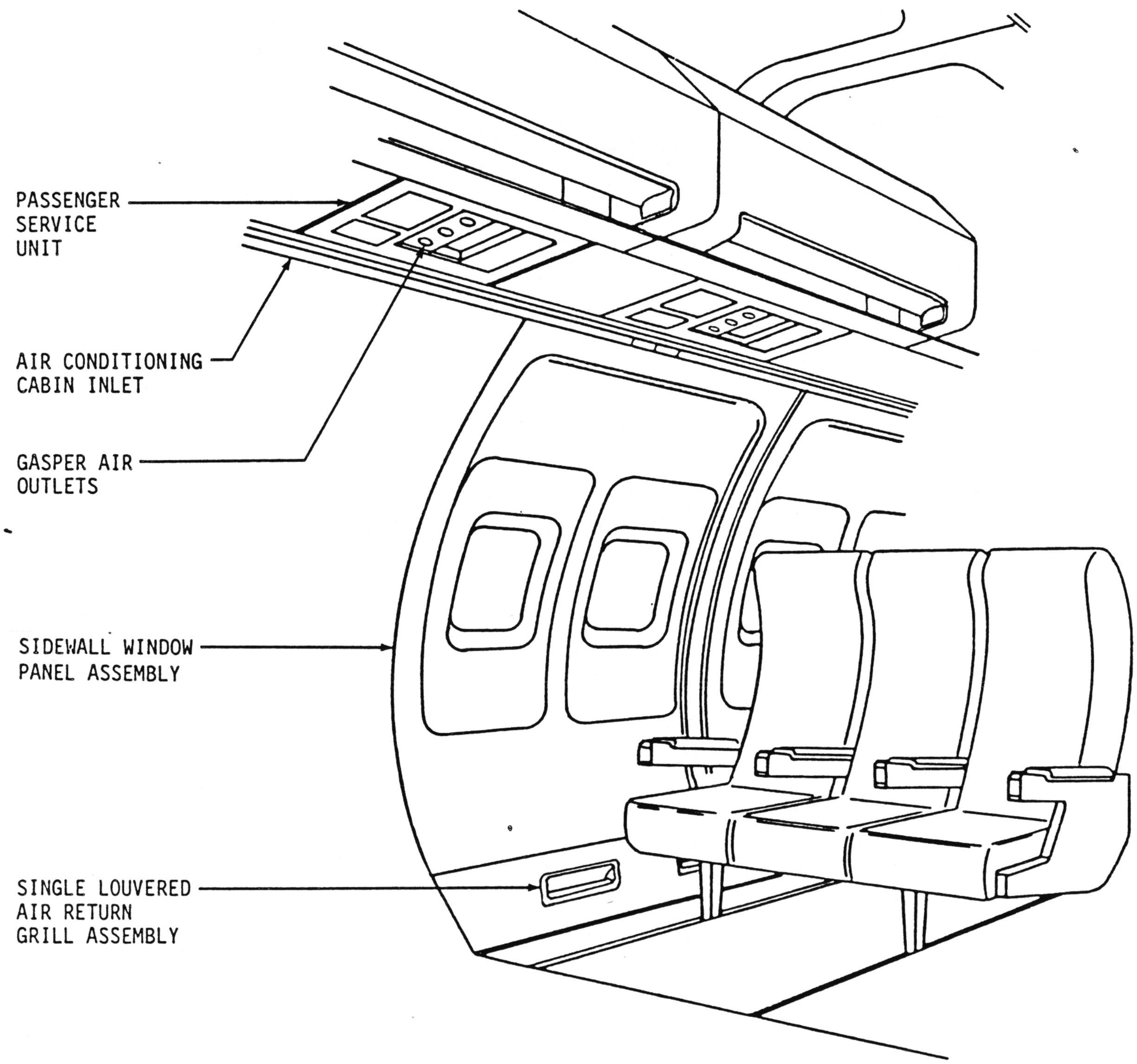


FIGURE 3-20. BOEING 737-300 PASSENGER CABIN GASPER DUCTING



CARRYALL INTERIOR

FIGURE 3-21. BOEING 737-200,-300 GASPER AIR DISTRIBUTION SYSTEM CABIN OUTLETS

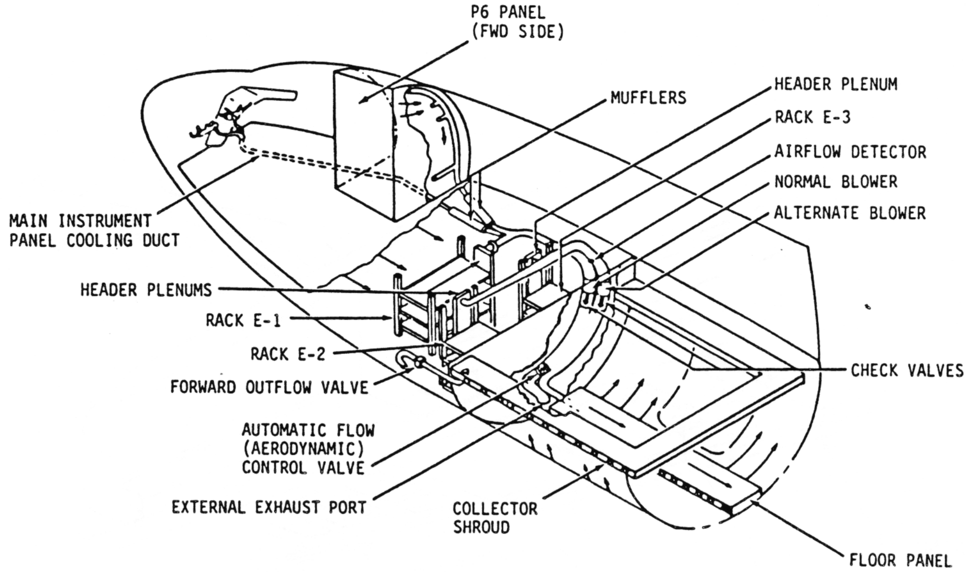


FIGURE 3-22. BOEING 737-100,-200 EQUIPMENT COOLING SYSTEM AND FORWARD CARGO HEATING

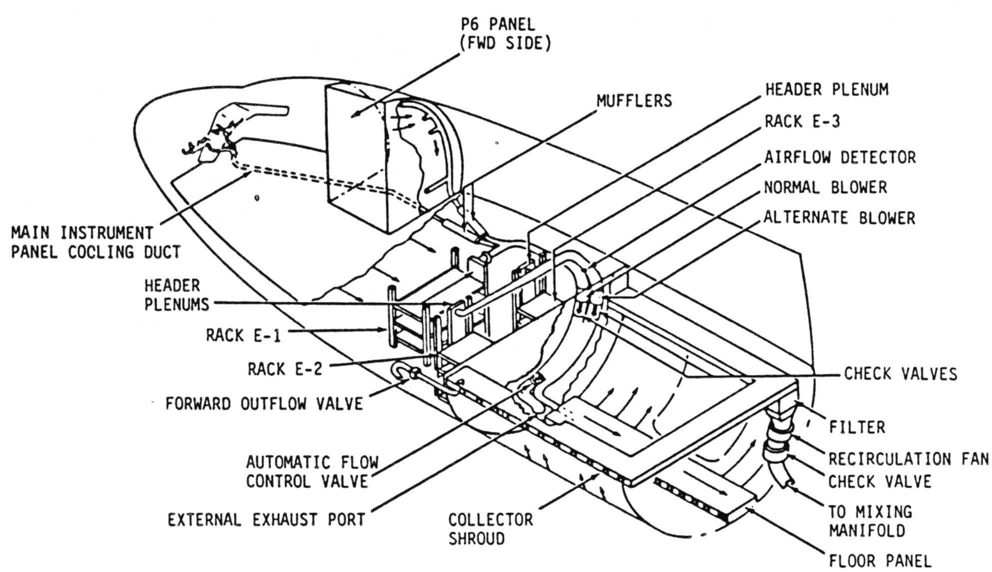


FIGURE 3-23. BOEING 737-300 EQUIPMENT COOLING AND RECIRCULATION SYSTEM COMPONENT LOCATION

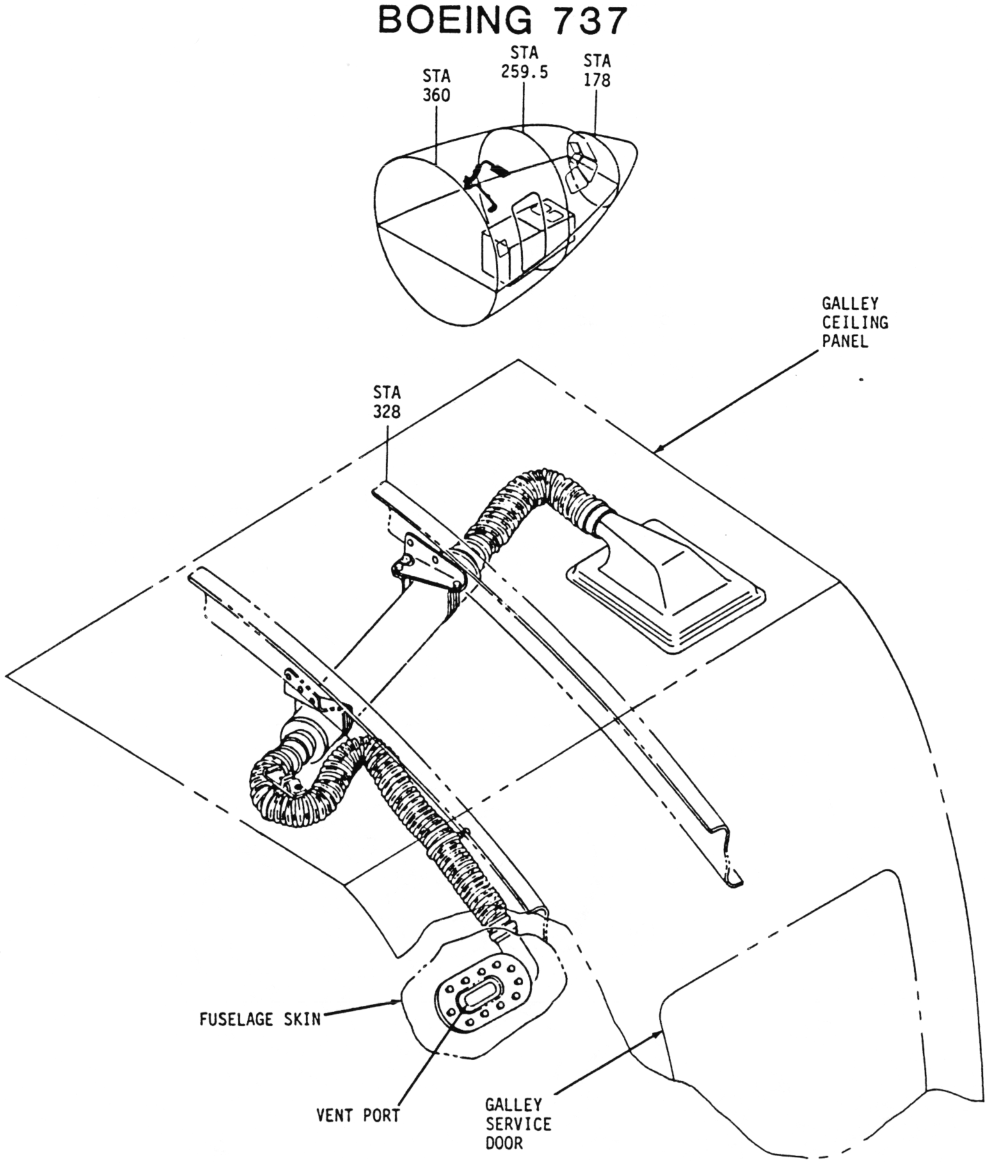


FIGURE 3-24. BOEING 737 TYPICAL GALLEY VENT SYSTEM

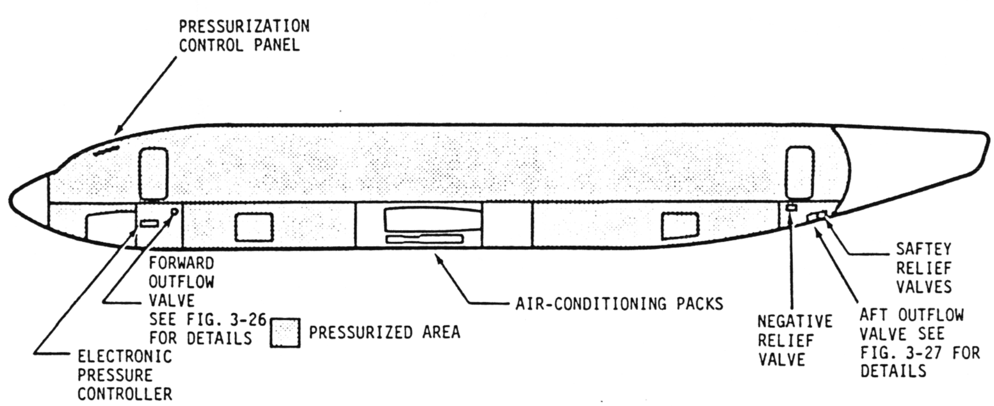


FIGURE 3-25. BOEING 737 PRESSURIZATION OUTFLOW POINTS

BOEING 737

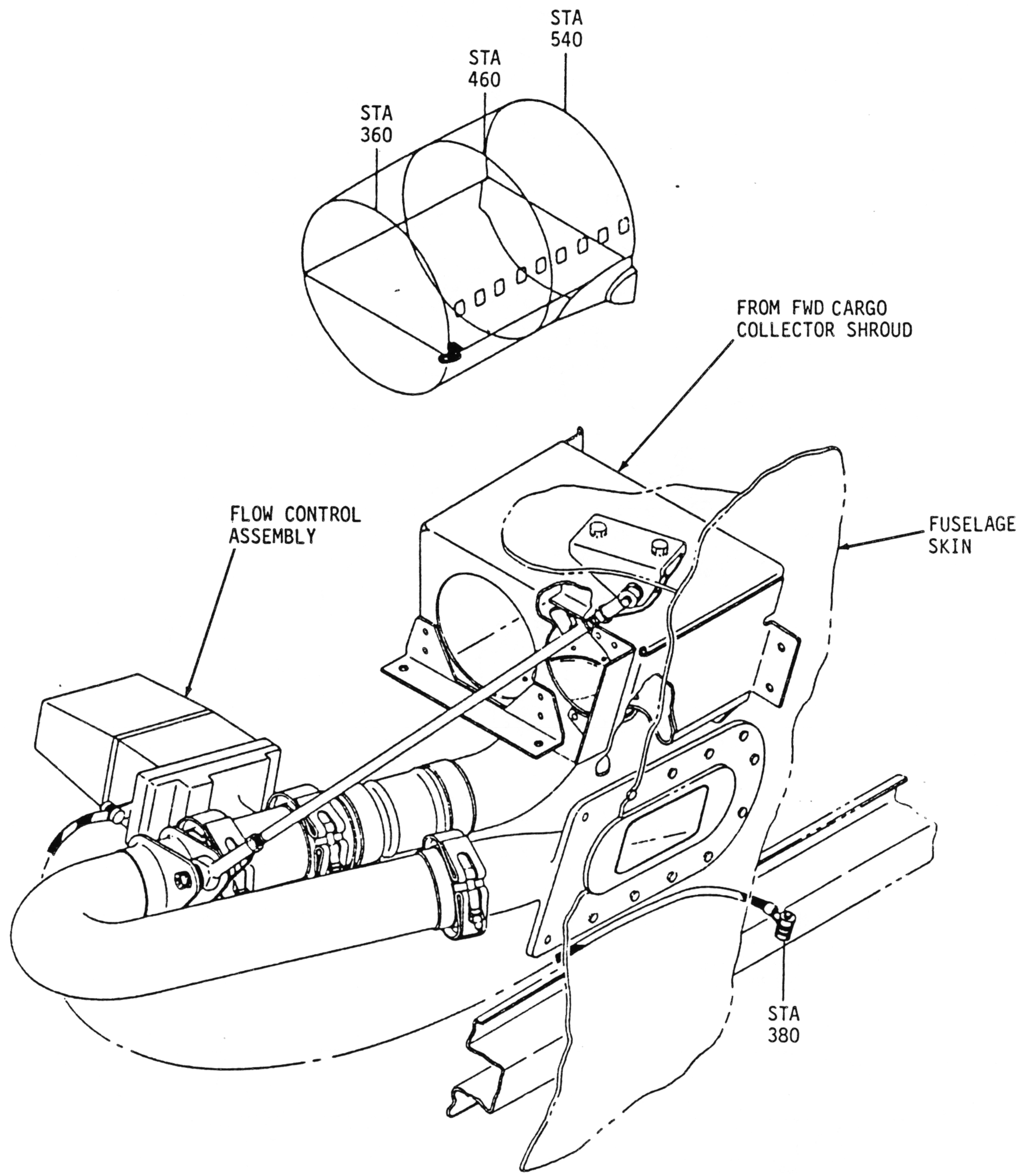


FIGURE 3-26. BOEING 737 FORWARD OUTFLOW VALVE

BOEING 737

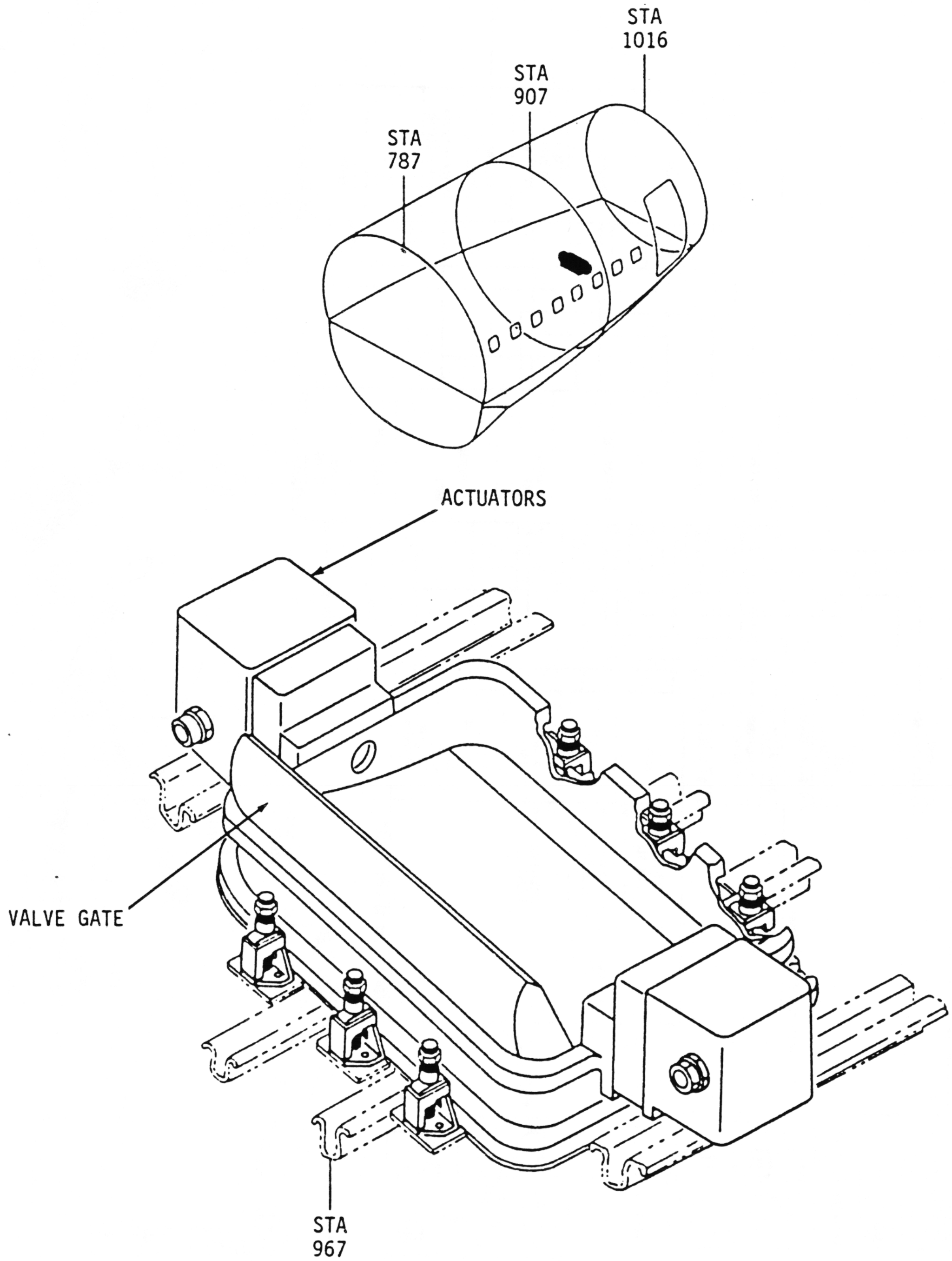


FIGURE 3-27. BOEING 737 AFT OUTFLOW VALVE

BOEING 737

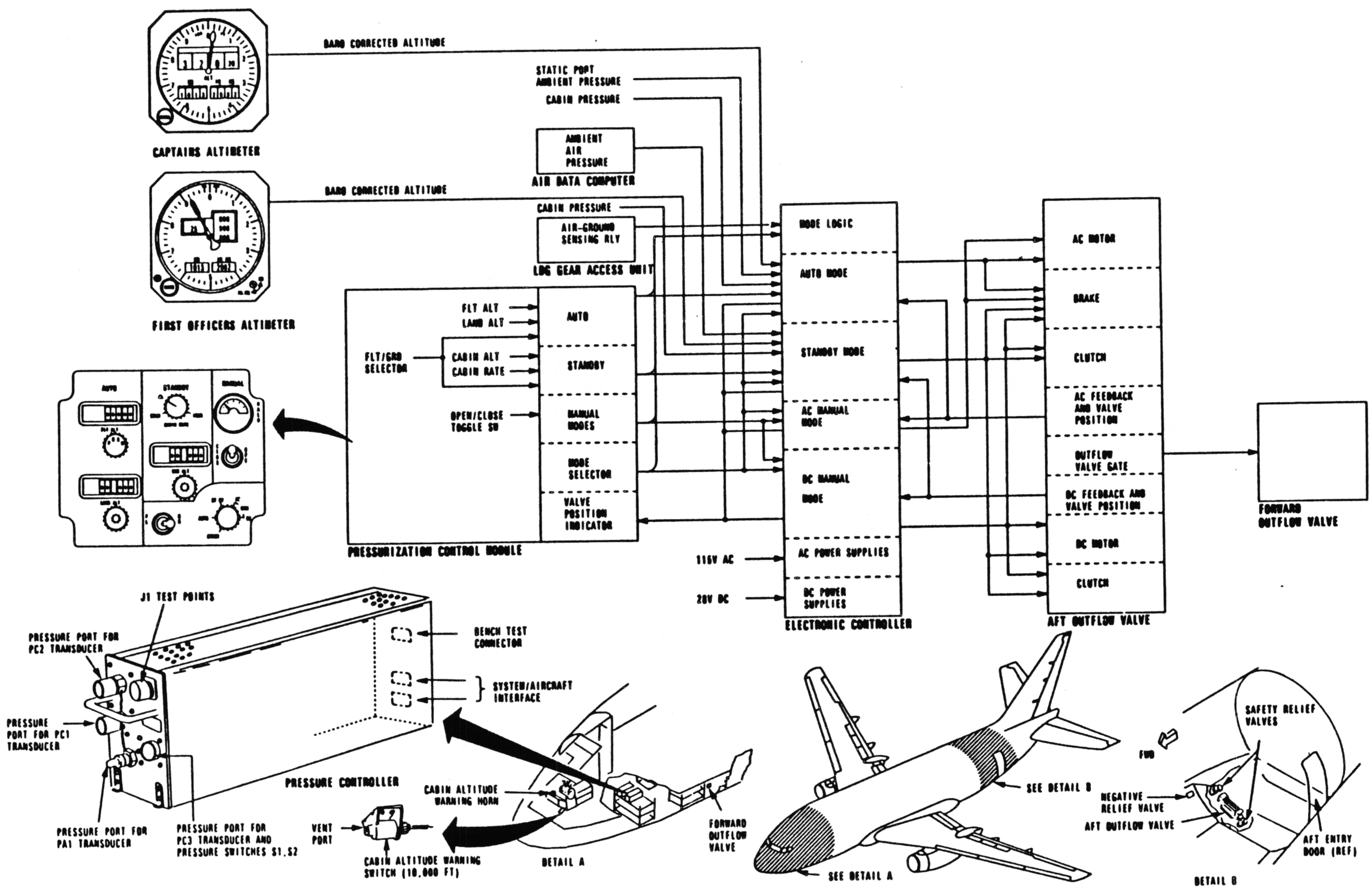
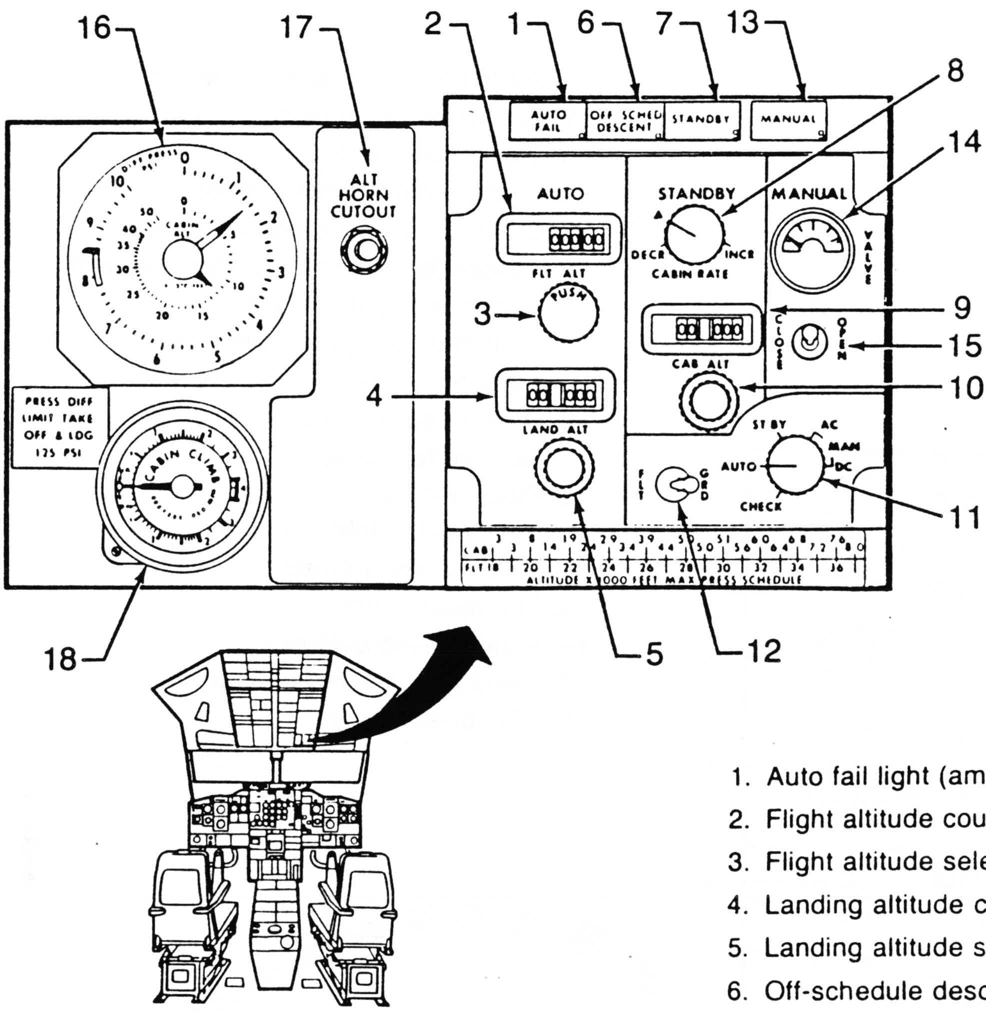


FIGURE 3-28. BOEING 737 PRESSURIZATION CONTROL SCHEMATIC

BOEING 737

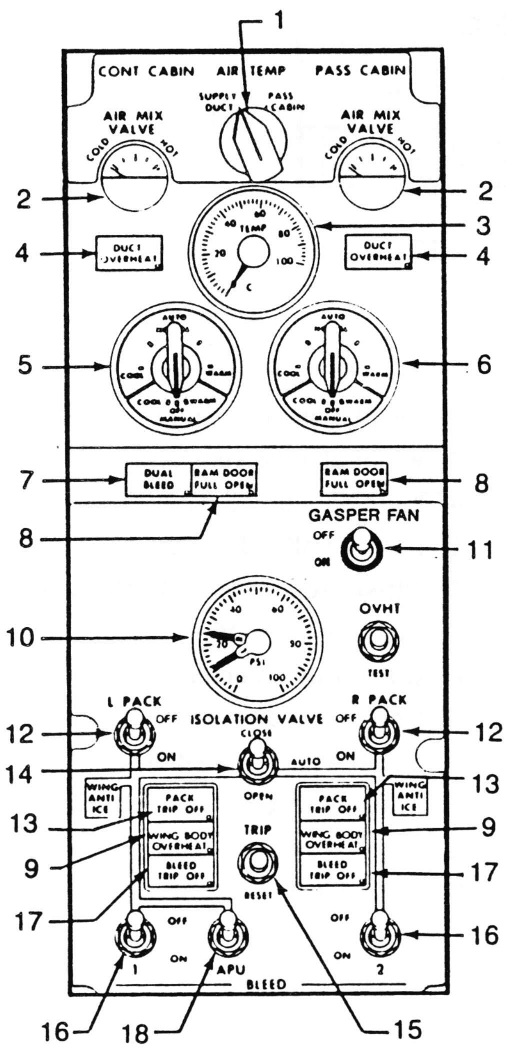


1. Auto fail light (amber)
2. Flight altitude counter
3. Flight altitude selector
4. Landing altitude counter
5. Landing altitude selector
6. Off-schedule descent light (amber)
7. Standby light (green)
8. Cabin rate selector
9. Cabin altitude counter
10. Cabin altitude selector
11. Pressurization mode selector
12. Flight/ground switch
13. Manual light (green)
14. Outflow valve indicator
15. Outflow valve switch
16. Cabin altimeter
17. Altitude horn cutout switch
18. Cabin rate of climb indicator

FIGURE 3-29. BOEING 737 PRESSURIZATION SYSTEM CONTROLS

BOEING 737-100,-200

1. Air temperature source selector
2. Air mix valve indicators
3. Temperature indicator
4. Duct overheat lights (amber)
5. Control cabin temperature selector
6. Passenger cabin temperature selector
7. Dual bleed light (amber)
8. Ram door full open lights (blue)
9. Wing-body overheat light (amber)
10. Duct pressure indicator
11. Gasper fan switch
12. Pack switches
13. Pack trip-off lights (amber)
14. Isolation valve switch
15. Trip reset switch
16. Engine bleed switches
17. Bleed trip-off lights (amber)
18. APU bleed switch



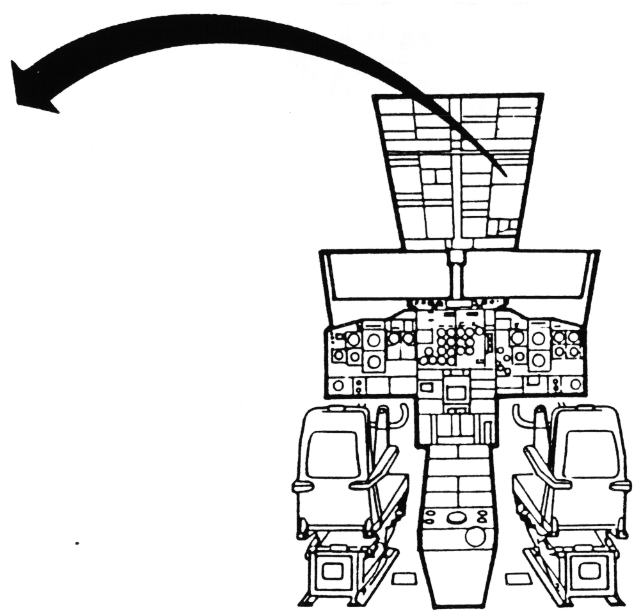


FIGURE 3-30. BOEING 737-100,-200 AIR CONDITIONING CONTROLS

BOEING 737-300

1. Air temperature source selector
2. Air mix valve indicators
3. Temperature indicator
4. Duct overheat lights (amber)
5. Control cabin temperature selector
6. Passenger cabin temperature selector
7. Dual bleed light (amber)
8. Ram door full open lights (blue)
9. Wing-body overheat light (amber)
10. Duct pressure indicator
11. Recirculation fan switch
12. Pack switches
13. Pack trip-off lights (amber)
14. Isolation valve switch
15. Trip reset switch
16. Engine bleed switches
17. Bleed trip-off lights (amber)
18. APU bleed switch

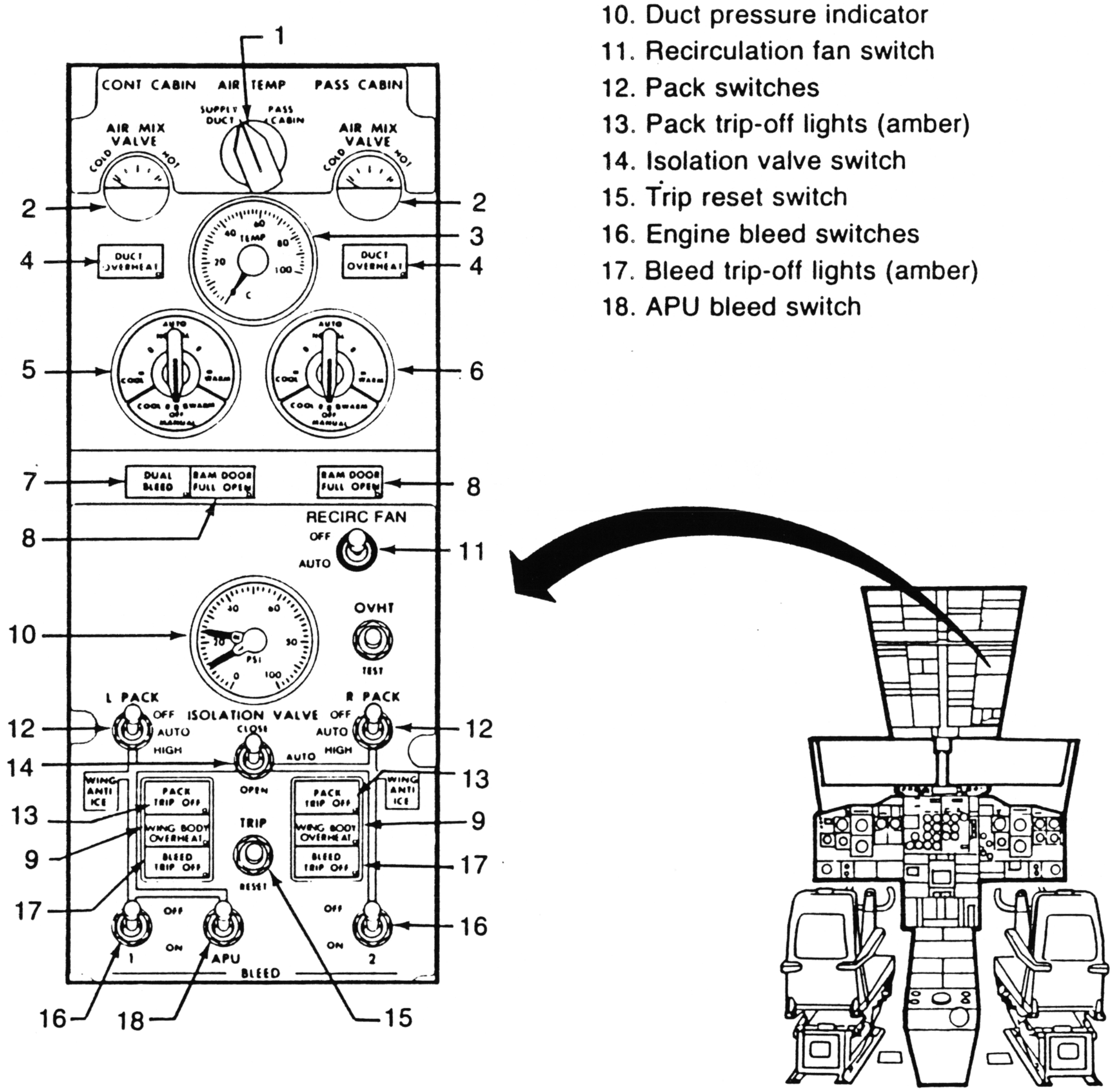


FIGURE 3-31. BOEING 737-300 AIR CONDITIONING CONTROLS

SECTION 4

BOEING 747

Model Variation

The 747 was developed in the early 1960's. The program was launched in 1966 with Pan Am's order for 23 aircraft and the first deliveries began in December of 1969.

The 747 has been produced in eight models, with a variety of engines, cargo door configurations, gross weights and ranges. A summary of the models, certification dates, and approximate number produced is shown in Table 4-1. The letter designator after the model number indicates the type of service that each model is tailored for; SR means short range, C means convertible passenger/freight, F means freight only, and SP means special performance.

747 Environmental Control System

See Table 4-2 for ventilation parameters. The 747 ECS is a three pack air cycle system that uses engine bleed-air as the air source. The packs are located below the wing in an unpressurized area of the fuselage just forward of the wheel well. Block diagrams of the system are shown in Figures 4-1 through 4-3. The air conditioning packs use engine bleed-air from the 8th and 15th engine compressor stages as an air source. During ground operations, a pneumatic ground cart or the APU can be used as an air source. A schematic of the cooling pack is shown in Figure 4-4.

Hot bleed-air temperature and pressure are regulated by the pneumatic system before being routed to the pack flow-control valve. The 747 has used two different flow-control valves. The original valve has no provisions for varying the pack flow rate. The later model valve has two settings, full flow schedule and half flow schedule. The mode is controlled by switches on the flight engineer's panel.

When the packs are operating, the flow-control valve attempts to maintain a constant volumetric flow rate in response to variation of bleed-air conditions. Air leaving the flow-control valve is routed to the primary heat exchanger and trim air system on all three packs. The primary heat exchanger uses ram air to cool the bleed-air before routing to the compressor and compressor bypass check valve. The trim air system adds a controlled amount of hot air to the pack discharge air to allow for different cooling needs in the various cabin zones. The amount of trim air diverted, and the pack discharge temperature, are controlled by the zone temperature and pack temperature controllers.

Air leaving the primary heat exchanger is routed to the air cycle machine (ACM) compressor and compressor bypass check valve. The ACM compressor compresses the air to higher temperature and pressure, and routes it to the secondary heat exchanger. The bypass check valve allows supply air to bypass the compressor when the cooling demands are low and the ACM is rotating slowly. When demand is high, the compressor discharge pressure holds the valve closed.

The secondary heat exchanger uses ram air to cool the compressor discharge air, then routes it to the turbine and turbine bypass valve. The turbine bypass valve controls the amount of cooling provided by controlling the amount of air that is expanded in the ACM turbine. Air leaving the turbine and turbine bypass valve is routed to the water separator, and then to the conditioned air plenums. Pressures and temperatures at Points A through E on Figure 4-4 are listed in Table 4-2. Flow rates for full flow and half-flow are shown in Tables 4-3 and 4-4 respectively.

Passenger Area Distribution

Conditioned air leaving the water separator is routed to the conditioned air plenums. The conditioned air plenums are shown in Figures 4-5, 4-6 and 4-7.

The 747 was equipped with two styles of plenums. On early models the plenums were formed by blocking a section between the floor beams and using the structure as the plenum walls. Later models had separate manifolds nestled between the floor beams. The conditioned air plenums supply air to the cabin risers that divide and route the air to the distribution systems.

The 747 cabin is divided into four environmental zones (three on -SP models), plus the upper deck. Schematics of the distribution of trim and conditioned air for the three passenger models (-100/200, -300 and -SP) are shown in Figures 4-8, 4-9 and 4-10.

On the 747-100 and -200 models, the cabin is divided into three main-deck distribution zones (forward zone, mid zone and aft zone), the upper deck zone, and the flight deck zone. The forward zone extends from the forward pressure bulkhead to the galley complex at door two. The mid zone extends from door two to door four and the aft zone extends from door four to the aft pressure bulkhead. Air is supplied to the zone distribution system by three risers located behind the sidewalls on both sides of the cabin just over the wing. The forward risers on both sides supply air to the forward distribution system. The right-hand forward riser also supplies air to the upper deck distribution system. The mid risers supply air to the mid distribution system and the aft risers supply air to the aft distribution system. The aft riser on the left also supplies air to flight deck distribution system. Schematics of the distribution system are shown in Figures 4-11, 4-12 and 4-13. The main supply ducting is shown in Figures 4-14 and 4-15.

The forward passenger cabin distribution ducting (see Figure 4-16) is supplied from the forward risers on both sides of the cabin. The risers join above the ceiling, and form a large circular duct that runs forward to the rear of the upper deck. The duct then splits into two branches that continue forward above the main deck ceiling. The branch ducts have dropper ducts along their length that supply air to a plenum located below the stowage compartment. The plenum exhausts air into the passenger compartments through a slot in the bottom of the duct that runs the length of the passenger seating zone.

The mid cabin distribution system (see Figures 4-17 and 4-18) is supplied from the middle risers. The mid risers join above the ceiling to form a circular duct that runs aft to just beyond the wing. The duct branches off to feed air to two header ducts located above the ceilings on both sides of the cabin. The header ducts route air through dropper ducts to the plenum below the stowage compartments. The plenum exhausts air into the passenger area through a slot in the bottom of the duct that runs the length of the passenger zone.

The aft cabin distribution (See Figure 4-19) is supplied from the aft risers. The risers join above the ceiling to form a circular duct that runs aft to approximately door four. The duct branches to form two headers located above the ceiling on both sides of the cabin. The headers feed plenums located below the stowage compartments. The plenums exhaust air into the passenger cabin through a slot in the bottom of the duct. A typical dropper duct and plenum arrangement is shown in Figures 4-20 and 4-21.

The upper deck distribution system (see Figure 4-22) is supplied from the forward right-hand riser. The riser branches into the upper deck supply duct and zone two supply duct. The upper deck supply duct runs forward above the ceiling to the back of the upper deck. The duct splits into two branches that run forward below the outboard floor. The branch ducts supply air to upper deck ceiling outlets through risers located behind the sidewalls.

On some -100 and -200 models, the upper deck air temperature is adjusted by the use of electrical resistance heating elements located in the outboard branches of the supply ducts. The heaters are controlled from the flight engineer's panels. A schematic of the upper deck electric heating system is shown in Figure 4-23.

On -300 models the cabin is divided into the same zones as the -100 and -200 models, the larger upper deck zone being the primary difference. The increase in volume requires a higher airflow to the upper deck and, therefore, the riser and supply ducting has been revised. The risers are located as on -100 and -200 models, but areas that each supply air to have been changed. The risers and main supply ducting are shown in Figure 4-14.

The forward riser on the right-hand side supplies air to the upper deck and crew rest area. The riser branches into two branch ducts that run forward at floor level along both sides of the upper deck. The branch ducts supply air to risers that exhaust air into the upper deck through ceiling outlets.

The forward riser on the left-hand side supplies air to the aft cabin distribution system. The distribution ducting is the same as -100 and -200 models. (See Figures 4-16, 4-17 and 4-18). This riser also supplies air to the flight deck distribution system.

The mid risers on both sides supply air to the mid cabin distribution system. Distribution ducting is the same as the -100 and -200 models.

The aft risers supply air to the forward cabin distribution system. Distribution ducting is the same as -100 and -200 models. The aft riser on the left side also supplies air to the aft cabin distribution system.

On SP models the cabin is divided into two zones plus the flight deck and upper deck. The main deck forward zone extends from the forward pressure bulkhead aft to the end of the upper deck (approximately Sta 1000). The aft zone extends from this point to the aft pressure bulkhead.

Air is supplied to the zone distribution ducts by risers as in -100, -200 and -300 models. The main supply ducting is shown in Figure 4-15.

The forward two risers on both sides of the cabin supply air to the aft cabin distribution system. The four risers join to form a common duct that runs aft above the ceiling. The duct then branches into two ducts that run outboard, these ducts further branch into distribution ducts that run forward and aft. The distribution ducts exhaust conditioned air into the cabin through outlets in the ceiling panels.

The aft risers on both sides of the cabin supply air to the forward cabin distribution system. The risers join above the ceiling to form a circular duct that runs forward to the aft end of the upper deck. The duct splits into two branches that run forward on both sides of the cabin. The branch ducts exhaust air into the cabin through outlets in the ceiling panels.

The upper deck distribution system is supplied from the forward riser on the right-hand side. The riser branches above the ceiling, supplying air to the aft cabin system and upper deck. The upper deck supply runs forward to the aft end of the upper deck then branches to form two supply ducts that run forward at the upper deck floor level. The branch ducts supply air to risers that exhaust air into the cabin through outlets in the ceiling.

The forward riser on the left side also supplies air to the flight deck.

Airflow rates entering the various compartments are listed in Tables 4-4 and 4-5 for half and full flow schedules. Air change rates for all fresh and fresh and recirculated air are shown in Tables 4-6 through 4-11. A cross-section of the passenger cabin showing general airflow patterns is shown in Figure 4-24.

Flight Deck Distribution

The flight deck distribution system is shown in Figures 4-25 and 4-26. The distribution system is the same for all models, differing only in the air source. All models supply air to the flight deck from the forward riser on the left-hand side, the difference being which zone the riser supplies (see passenger cabin section for details on risers). The flight deck system supply duct runs forward below the main deck floor from the riser to approximately Sta 560. The duct then splits to supply the flight deck from both sides. The flight deck distribution system supplies air to windshield outlets, foot outlets, overhead outlets, and forward instrument panels.

The windshield outlets supply air to all six windows. The forward two outlets have manual adjustments located below the instrument panels that allow the crew to vary the airflow.

The two foot outlets exhaust air onto the control pedals. The flow can be adjusted in the same way as the windshield outlets.

Individual (Gasper) Air

The individual air system provides a separate supply of cold fresh air to each passenger seat, lavatory, galley and crew member station. On -SP and -300 models, the passenger gaspers were optional, and are not installed on all airplanes. The crew and lavatory gaspers are installed on all 747's. The gasper system is shown in Figure 4-27.

On -100, -200 and -300 models, the gasper system is supplied with air at the pack discharge temperature from the aft riser on the left side. On some airplanes, a fan is used to boost gasper system pressure. The gasper system consists of three sets of ducting running the length of the airplane. The ducting is cylindrical tubing ranging from two to four inches in diameter, with one-inch diameter dropper hoses routing air to the passenger service units. The ducts are constructed from either aluminum or Lexan polycarbonate materials. The gasper ducting is shown in Figure 4-28.

The gasper air supply ducting is located above the center stowage bins and behind the side stowage bins on both sides of the airplane. On some airplanes the upper deck gaspers are supplied from the main deck gasper supply ducting through small tubes that rise through the upper deck floor to the upper deck ceiling. On other airplanes the upper deck gaspers are supplied from the zone 2 gasper supply ducting. The supply duct feeds a smaller duct that branches into two ducts, one running forward at floor level on both sides of the cabin. Small riser ducts run upward behind the sidewall to outlets located in the ceiling. The upper deck gasper ducting is shown in Figure 4-29.

On -100 and -200 models, the flight deck gaspers are supplied from the left-hand main deck gasper supply duct. The supply duct runs up through the upper deck floor and up to the flight deck ceiling. The duct branches to supply four outlets above the pilot and co-pilot and one at the flight engineer's station.

On -300 and -SP models, the same outlets are retained but the supply air is taken from the flight deck conditioned air supply duct if the passenger cabin gaspers are not installed. If passenger cabin gaspers are installed, the configuration is the same as the -100 and -200 models. The flight deck gasper ducting is shown in Figures 4-30 and 4-31.

On some airplanes, the gasper system supplies cooling air to isolated electrical equipment such as column timer decoders, multiplex systems, etc., and to each lavatory and galley. On airplanes not equipped with main deck gaspers, lavatory and galley outlets are supplied from the zone supply ducting.

Equipment Cooling

The 747 uses draw through cooling to cool the forward instrument panel and flight engineer's panels located on the upper deck, and the electronic equipment racks located on the lower deck, forward of the forward cargo compartment. The system uses two blowers to draw air into the racks, around the equipment, and into the exhaust ducting. The blower exhaust is either dumped overboard or directed below the forward cargo compartment. The equipment cooling system is shown in Figure 4-32.

The upper deck blower operates whenever electrical power is available, and draws air from the flight deck through the forward instrument panel and flight engineer's panel. The blower normally exhausts air under the forward cargo compartment. If smoke is detected, the upper deck overboard dump valve opens, and the flow is exhausted overboard by differential pressure.

The lower deck blower also operates whenever electrical power is available and draws air through the electronics racks. When the airplane is on the ground, the blower exhausts air overboard through the flow-control valve and overboard nozzle. At lift off, the flow-control valve begins to close as differential pressure builds, and is fully closed when the differential pressure reaches 2.5 psi. The flow is then directed under the forward cargo compartment to provide heat. If smoke is detected down stream of the blower, the cargo heat valve closes, the flow-control valve opens, and the cooling air is exhausted overboard.

Cargo Heating

The 747 cargo compartments are certified as FAR Class C compartments. As such, they are required to have fire detection and extinguishing systems, adequate means to control ventilation and drafts within the compartment, and prevent hazardous quantities of smoke from entering the occupied areas of the airplane.

The 747 has three cargo compartments designated forward, aft, and bulk. Only the aft and bulk compartments have supplemental heating systems. In addition some models have provisions for ventilating the aft and bulk compartments with conditioned air.

The forward cargo compartment is heated by exhausting air from the passenger cabin between the cargo lining and fuselage skin, and by exhausting air from the equipment cooling system below the compartment floor. The air warms the compartment as it passes over the lining and moves aft to be exhausted through the pressurization outflow valves. The forward cargo heating system is shown in Figure 4-33.

The aft and bulk cargo compartments are heated by exhausting air from the passenger cabin between the cargo lining and fuselage skin, and by a supplemental heat system that exhausts hot air from the pneumatic system below the compartment floor. Flow of pneumatic air is regulated by a control thermostat and overheat thermostat that modulate the positions of the flow-control valve and overheat shut-off valve. The aft cargo heating ducting is shown in Figures 4-34, 4-35 and 4-36.

The control thermostat modulates the pneumatic flow-control valve to maintain compartment temperature within a preset range. Different thermostats available allow the range to be set at 30-38 °F, 65-87 °F or 60-68 °F. A switch located in the cargo compartment allows the selection of one of two control thermostats available.

The overheat thermostat will close the overheat shut-off valve if the limits of the overheat thermostat are exceeded. Overheat thermostats are available with a range of 80-110 °F and 102-110 °F.

Some models have provisions for admitting conditioned air directly into the aft and bulk compartments. Air from the number three pack discharge duct is routed to the left side of the cargo compartments and aft along the left wall. Four branch ducts extend inboard to outlets located in the compartment ceiling, (see Figure 4-34). Hot air from the pneumatic system is added to the supply duct to adjust the temperature of the pack discharge air. Temperature of the compartment can be controlled automatically or manually to a constant temperature from the flight engineer's panel. Selection of the aft cargo air conditioning locks out operation of the aft cargo heating system.

<u>Recirculation Systems</u>

The 747 recirculation system consists of independently controllable fans that draw air from the four zones and exhaust air back into the respective zone ducting. The recirculation fan systems are shown in Figures 4-37 and 4-38.

The zone 1 fan is located below the main deck floor on the left-hand side just forward of the wing. The fan draws air from behind the forward cargo compartment and exhausts air into the flight deck supply duct. The zone 1 fan is normally operated only when the packs are off.

The zone 2 fan is located above the main deck ceiling aft of the upper deck. The fan draws air from above the mid cabin ceiling and from the area aft of the upper deck and exhausts into the zone 2 (forward cabin) main supply duct.

The zone 3 fan is located above the ceiling over the air conditioning supply risers. The fan draws air from the area above the mid-cabin ceiling, and exhausts into the zone 3 (mid-cabin) main supply duct.

The zone 4 fan is located above the aft cabin ceiling. The fan draws air from above the aft cabin ceiling and exhausts into the zone 4 (aft cabin) main supply duct.

All four fans are rated at a nominal flow of 800 cubic feet per minute per fan and operate on 115 volt three-phase AC power. The fans are independently controllable through four switches located on the flight engineer's panel.

On -SP models, the zone 1 fan is retained below the floor, re-circulating air into the flight deck. The three main deck fans (zones 2, 3 and 4) are replaced by two fans mounted above the ceiling in the aft cabin zone (See Figure 4-38). The two fans draw air from above the aft cabin ceiling and exhaust air into the aft-cabin main supply duct and forward-cabin main supply duct.

Ventilation

Air is vented overboard at all times by the lavatory and galley ventilation system and pressurization outflow valves. Under certain conditions, the equipment cooling system also vents air overboard, see equipment cooling system for details.

The lavatory and galley ventilation systems use a fan when on the ground and differential pressure while in flight to exhaust air from the lavatories and galleys. The vent system has variations from model to model to account for different placement of lavatories and galleys. A typical system is shown in Figures 4-39 and 4-40.

The system draws air from the ceiling area of the galleys, and from the lavatory toilet tanks into a system of ducts located above the ceiling. The air flows aft through the ducts, and is exhausted through a flow limiting nozzle. On some airplanes, the ducting passes down below the floor behind the right aft cabin sidewalls. The exhaust fan and flow limiting nozzle are located below the floor, the nozzle exhausting directly overboard and the fan exhaust directed to the pressurization outflow valve (see Figure 4-39). On other airplanes, the fan and flow limiting nozzle are mounted above the ceiling on the right side. The ducting is such that the flow is exhausted through the nozzle at times (see Figure 4-40).

SP-model airplanes have an exhaust nozzle located on the left fuselage next to the nose wheel well, and exhaust air from the area forward of the forward cargo compartment. The valve is normally open, and is used to improve circulation and temperature control in the forward cabin. The valve can be closed if cabin pressure cannot be maintained with it open. It is controlled by a switch on the flight engineer's panel marked air conditioning exhaust and cargo equipment cooling. The vent is shown in Figure 4-41.

The pressurization outflow valves are the primary means of venting air overboard. The 747 has two gate type valves located on the underside of the fuselage aft of the bulk cargo compartment. The outflow valves respond to signals generated in the pressure controller to vary the size of the opening to maintain cabin pressure as requested. A typical outflow valve is shown in Figure 4-42.

Pressurization Control

The 747 has an electrically operated and electronically controlled pressurization control system (PCS). The PCS maintains a low cabin altitude during flight, controls the cabin altitude rate of change and limits the differential pressure by modulating the outflow valve openings. The 747 PCS has four operating modes; auto, manual, manual right, and manual left. A block diagram of the system for each mode is shown in Figures 4-43, 4-44 and 4-45. The control panel is shown in Figure 4-46.

To use the auto mode, the crew sets the flight altitude, the desired cabin altitude rate of change and a correction factor for landing field altitude. The pressure controller then monitors the actual cabin conditions, compares these to selected parameters, and makes the necessary corrections. If the actual flight altitude exceeds selected flight altitude, the pressure controller will raise the cabin altitude to maintain differential pressure at the maximum controller limit. The pressure controller also automatically limits the maximum cabin altitude to 10,000 feet.

To use the manual mode, the crew selects MAN. This places both outflow valves under direct control of the switches on the selector panel. The crew then adjusts the valve position through a toggle switch. Gauges are provided to show outflow valve position. The differential pressure, cabin altitude, and altitude rate of change gauges must be monitored to prevent adverse cabin conditions. Over-pressurization is prevented by the safety relief system.

The manual left and manual right modes put the left or right valve under manual control, while retaining automatic pressure control with the other valve.

The cabin pressure controller limits the normal differential pressure to 8.9 ± 0.1 psi maximum. Some airplanes have switches that allow the crew to select lower controller-limited differential pressure. Common settings are 6.9 ± 0.1 psi below 31,300 feet, and 8.5 ± 0.1 psi below 31,300 feet. Limits of the pressurization system are shown in Table 4-3.

ECS Controls

The ECS controls include pack valve switches, zone temperature controls, recirculation fan switches and bleed-air source switches. The ECS controls are shown in Figures 4-47, 4-48 and 4-49.

The pack valve switches are used to open the flow-control valve and set the operating mode (See Figure 4-47). The 747 has used two flow-control valves; one is not adjustable, and the other has provisions for half flow and full flow. On airplanes with half-flow valves, three additional recirculation fans are mounted below the floor near the main distribution manifold (see Figure 4-50). When half flow is selected, the fans begin to operate and add enough air to the pack discharge air to make the flow the same as when full flow is selected. This reduces demands on the bleed-air system, and leads to increased thrust and fuel economy.

The temperature control of the pack can be automatic or manual and is selected on the flight engineer's panel. During auto control, the pack discharge temperature is determined by the zone temperature controllers working in conjunction with the pack temperature controller. The pack controller modulates the turbine bypass valve to regulate the amount of air passing through the ACM turbine, hence the amount of cold air produced. During manual operation, the crew can control the pack discharge temperature by acting directly on the turbine bypass valve. Gauges are provided to indicate turbine bypass valve position, compressor discharge temperature, and pack outlet temperature. Switch lights allow selection of which pack's conditions are to be shown on the gauges.

The temperature control panels are shown in Figures 4-48 and 4-49. Zone temperature controls allow the crew to select and control the compartment temperatures automatically or manually. When the selector dial is positioned in the upper range, the compartment temperature can be thermostatically controlled between 63-85 °F. The zone temperature controller then adjusts the pack discharge temperature and zone trim air valves, thus controlling the passenger cabin supply temperature to maintain the selected temperature. A block diagram of the zone temperature control system is shown in Figure 4-51.

When using manual control (lower portion of the dial), the crew controls the position of the trim air valve directly. The trim air valve and compartment temperature must be monitored on the gauges provided to prevent excessive compartment temperatures.

Electrical energy requirements of the ECS equipment and control systems are shown in Tables 4-12 through 4-15. The loads presented are the connected load from the 747 electrical loads analysis documents. It must be noted that the loads are for when the equipment is operating, and that not all the equipment operates continuously throughout the flight.

TABLE 4-1. BOEING 747 PRODUCTION DATA

MODEL	FIRST FLIGHT (REF 1)	CERTIFICATION (REF 2)	NO. PRODUCED (REF 3)
747-100	2-9-69	1-21-70	168
747-100 SR	9-10-73	9-26-73	26
747-100 B	6-20-79	8-1-79	9
747-200 B	10-11-71	12-23-70	275
747-200 C	3-23-73	4-17-73	11
747-200 F	11-30-71	3-7-72	49
747-300	10-5-82	3-1-83	21
747-SP	7-4-75	3-1-76	44

TABLE 4-2. BOEING 747-100,-200,-300,-SP SYSTEM TEMPERATURES AND PRESSURES (REF 12)

(°F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL	5.9	418	42.3	418	15.2	45.2	14.8	45.2	14.8	45.2	14.8	75	14.7	100
20,000 FT CLIMB	40.4	414	35.1	414	13.6	34	13.2	34	13.2	34	13.2	75	6.8	27.8
25,000 FT CRUISE	DATA NOT AVAILABLE													
30,000 FT CRUISE	29.2	411	28.8	411	13.7	35	13.4	35	13.4	35	13.4	75	4.4	-8
35,000 FT CRUISE	23.6	409	23.2	409	12.7	40.8	12.5	40.8	12.5	40.8	12.5	75	3.5	-26.2
40,000 FT CRUISE	18.2	393	17.7	393	12.0	46.7	11.7	46.7	11.7	46.7	11.7	75	2.7	-44.2
20,000 FT CRUISE	31.2	260	30.9	260	13.7	34.2	13.4	34.2	13.4	34.2	13.4	75	6.8	28
10,000 FT CRUISE	32.4	369	32.1	369	14.3	40.2	14.0	40.2	14.0	40.2	14.0	75	8.3	46

MAXIMUM SUPPLY TEMP 180°F

MINIMUM SUPPLY TEMP 35°F

TABLE 4-3. BOEING 747 VENTILATION PARAMETERS

VOLUMES (CU FT)		747-100/200	747-300	747-SP
TOTAL PRESSURIZED		51,000	57,800	37,000
PASS. CABIN		27,900	29,700	21,600
FLIGHT DECK		920	920	920
FWD CARGO		2,768	2,768	1,730
AFT CARGO		2,422	2,422	1,730
BULK CARGO		1,000	1,000	800
PRESSURIZATION				
MAX ΔP (PSI)				
CONTROLLER LIMITED		6.9 – 8.9*		8.5 – 8.9**
SAFETY VALVE LIMITED		9.25 ± 0.15 – 9.70 ± 0.15***		
CABIN ALTITUDE CHANGE RATES		ASCENT		DESCENT
CONTROLLER SELECTED	MAX	2,490		1,490
CONTROLLER SELECTED	MIN	140		85

*SELECTABLE, 6.9 BELOW 31,300 FT, 8.9 ABOVE
**SELECTABLE, 8.5 BELOW 31,000 FT, 8.9 ABOVE
***BACKUP SAFETY RELIEF AT 9.70 IF 9.25 RELIEF FAILS

TABLE 4-4. BOEING 747-100,-200,-300,-SP VOLUME FLOW (FULL FLOW SCHEDULE) (REF 12)

FLIGHT REGIME	FLOW CONTROL VALVE (lb/min)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (cfm)	% RECIRC	TOTAL (cfm)	% RECIRC
SEA LEVEL	206.6	10,220	23.5	547.9	0
20,000 FT CLIMB	194	10,520	22.8	568.9	0
25,000 FT CRUISE	DATA NOT AVAILABLE				
30,000 FT CRUISE	166.1	9,232	26.0	478.7	0
35,000 FT CRUISE	151.7	9,094	26.4	469.0	0
40,000 FT CRUISE	152.5	9,540	25.1	500.2	0
20,000 FT DESCENT	171.6	9,459	25.3	494.6	0
15,000 FT DESCENT	164.6	8,940	26.8	458.3	0

TABLE 4-5. BOEING 747-100,-200,-300,-SP VOLUME FLOW (HALF FLOW SCHEDULE) (REF 12)

FLIGHT REGIME	FLOW CONTROL VALVE (lb/min)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (cfm)	% RECIRC	TOTAL (cfm)	% RECIRC
SEA LEVEL	103.3	10,220	61.8	547.9	50
20,000 FT CLIMB	97.0	10,520	61.4	568.9	50
25,000 FT CRUISE	DATA NOT AVAILABLE				
30,000 FT CRUISE	83.0	9,232	63.0	478.7	50
35,000 FT CRUISE	75.8	9,094	63.2	469.0	50
40,000 FT CRUISE	76.3	9,540	62.6	500.2	50
20,000 FT DESCENT	85.8	9,459	62.7	494.6	50
15,000 FT DESCENT	82.3	8,940	63.4	458.3	50

TABLE 4-6. BOEING 747-100,-200 AIR CHANGE RATES (CHANGES PER HOUR), FULL-FLOW SCHEDULE

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL CLIMB	16.8	22.0	35.7
20,000 FT CLIMB	17.4	22.6	37.1
25,000 FT CRUISE	N/A*	N/A*	N/A*
30,000 FT CRUISE	14.7	19.9	31.2
35,000 FT CRUISE	14.4	19.6	30.5
40,000 FT CRUISE	15.4	20.5	32.6
20,000 FT DESCENT	15.2	20.3	32.3
15,000 ft DESCENT	14.1	19.2	29.9

TABLE 4-7. BOEING 747-100,-200 AIR CHANGE RATES (CHANGES PER HOUR), HALF-FLOW SCHEDULE

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK (ALL FRESH)	FLIGHT DECK (FRESH & RECIRC)
SEA LEVEL CLIMB	8.4	22.0	17.8	35.7
20,000 FT CLIMB	8.7	22.6	18.6	37.1
25,000 FT CRUISE	N/A*	N/A*	N/A*	N/A*
30,000 FT CRUISE	7.4	19.9	15.6	31.2
35,000 FT CRUISE	7.2	19.6	15.2	30.5
40,000 FT CRUISE	7.7	20.5	16.3	32.6
20,000 FT DESCENT	7.6	20.3	16.2	32.3
15,000 FT DESCENT	7.0	19.2	15.0	29.9

TABLE 4-8. BOEING 747-300 AIR CHANGE RATES (CHANGES PER HOUR), FULL-FLOW SCHEDULE

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL CLIMB	15.8	20.6	35.7
20,000 FT CLIMB	N/A*	N/A*	N/A*
25,000 FT CRUISE	16.4	21.3	37.1
30,000 FT CRUISE	13.8	18.7	31.2
35,000 FT CRUISE	13.5	18.4	30.5
40,000 FT CRUISE	14.5	19.3	32.6
20,000 FT DESCENT	14.3	19.1	32.0
15,000 FT DESCENT	13.2	18.0	29.9

TABLE 4-9. BOEING 747-300 AIR CHANGE RATES (CHANGES PER HOUR), HALF-FLOW SCHEDULE

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK (ALL FRESH)	FLIGHT DECK (FRESH & RECIRC)
SEA LEVEL CLIMB	7.9	20.6	17.8	35.7
20,000 FT CLIMB	8.2	21.3	18.5	37.1
25,000 FT CRUISE	N/A*	N/A*	N/A*	N/A*
30,000 FT CRUISE	6.9	18.7	15.6	31.2
35,000 FT CRUISE	6.8	18.4	15.3	30.5
40,000 FT CRUISE	7.3	19.3	16.3	32.6
20,000 FT DESCENT	7.2	19.1	16.0	32.0
15,000 FT DESCENT	6.6	18.0	15.0	29.9

TABLE 4-10. BOEING 747-SP AIR CHANGE RATES (CHANGES PER HOUR), FULL-FLOW SCHEDULE

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL	21.7	28.4	35.7
20,000 FT CLIMB	22.5	29.2	37.1
25,000 FT CRUISE	N/A*	N/A*	N/A*
30,000 FT CRUISE	18.9	25.6	31.2
35,000 FT CRUISE	18.6	25.3	30.5
40,000 FT CRUISE	19.8	26.5	32.6
20,000 FT DESCENT	19.6	26.3	32.0
15,000 FT DESCENT	18.2	24.8	29.9

*NOT AVAILABLE

TABLE 4-11. BOEING 747-SP AIR CHANGE RATES (CHANGES PER HOUR), HALF-FLOW SCHEDULE

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK (ALL FRESH)	FLIGHT DECK (FRESH & RECIRC)
SEA LEVEL	10.9	28.4	17.8	35.7
20,000 FT CLIMB	11.3	29.3	18.6	37.1
25,000 FT CRUISE	N/A*	N/A*	N/A*	N/A*
30,000 FT CRUISE	9.5	25.6	15.6	31.2
35,000 FT CRUISE	9.3	25.3	15.3	30.5
40,000 FT CRUISE	9.9	26.5	16.3	32.6
20,000 FT DESCENT	9.8	26.3	16.0	32.0
15,000 FT DESCENT	9.1	24.8	15.0	29.9

*NOT AVAILABLE

TABLE 4-12. BOEING 747-100,-200,-300 AC ELECTRICAL ENERGY REQUIREMENTS (REF 13)

EQUIPMENT	POWER REQD	LOAD	SOURCE
A/C Recirculating Fan	115V 400 Hz 3Ø	1.19 KW 2.12 KVAR	AC Bus 1
Gasper Fan	115V 400 Hz 3Ø	1.19 KW 2.12 KVAR	AC Bus 1
Flight Deck Boost Fan	115V 400 Hz 3Ø	1.19 KW 2.12 KVAR	AC Bus 1
A/C Temp Control Zone 1 Auto	115V 400 Hz 1Ø	40 W	AC Bus ØA
Zone 2 Manual	115V 400 Hz 1Ø	30 W	AC Bus ØA
Temp Sensor Fan	115V 400 Hz 1Ø	30 W 20 VAR	AC Bus ØA
Upper Deck Heater - Left	115V 400 Hz 1Ø	1.15 KW	AC Bus ØB
A/C Heater Valve Aft Cargo	115V 400 Hz 1Ø	280 W	AC Bus ØB
Upper Deck Heater Left	115V 400 Hz 1Ø	1.15 Kw	AC Bus ØC
Cabin Pressure Control	115V 400 Hz 1Ø	50 W	AC Bus ØC
A/C Temp Control Zone 2 Auto	115V 400 Hz 1Ø	40 W	AC Bus 2 ØA
Zone 4 Man	115V 400 Hz 1Ø	30 W	AC Bus 2 ØA
A/C Temp Sensor Fan Zone 1 & 3	115V 400 Hz 1Ø	30 W 20 VAR	AC Bus 2 ØC
A/C Recirc Fan Zone 3	115V 400 Hz 3Ø	1.19 KW 2.12 KVAR	AC Bus 3
Upper Deck Equip Cooling Fan	115V 400 Hz 3Ø	2.05 KW 1.56 KVAR	AC Bus 3
A/C Temp Control Pack 3	115V 400 Hz 1Ø	350 W	AC Bus 3 ØA
Pack 2	115V 400 Hz 1Ø		
Zone 3	115V 400 Hz 1Ø	40 W	AC Bus ØA
Zone 1	115V 400 Hz 1Ø	40 W	AC Bus ØB
Upper Deck Heater - Right	115V 400 Hz 1Ø	1.15 KW	AC Bus ØB
- Left	115V 400 Hz 1Ø	1.15 KW	AC Bus ØB
A/C Temp Sensor Fan Zone 2 & 4	115V 400 Hz 1Ø	30 W 20 VAR	AC Bus ØC
A/C Recirc Fan Zone 4	115V 400 Hz 3Ø	1.19 KW 2.12 KVAR	AC Bus 4
Equip Cooling Blower	115V 400 Hz 3Ø	2.05 KW 1.56 KVAR	AC Bus 4
A/C Temp Controller Pack 1	115V 400 Hz 1Ø	350 W	AC Bus ØA
Zone 4	115V 400 Hz 1Ø	30 W	AC Bus ØA
Zone 2	115V 400 Hz 1Ø	30 W	AC Bus ØA
A/C Pressurization System	115V 400 Hz 3Ø	1.40 KW .69 KVAR	AC Essential Bus

TABLE 4-13. BOEING 747-100,-200,-300 DC ELECTRICAL ENERGY REQUIREMENTS (REF 13)

EQUIPMENT	POWER REQD	LOAD	SOURCE
A/C Cargo Heat Controller	28V DC	.20 A	DC Bus 1
A/C Pack 1 Auto/Man Control	28V DC	1.50 A	DC Bus 1
Recirc Fan Control Zone 2	28V DC	.50 A	DC Bus 1
Pack 1 Shut-off Valve	28V DC	.50 A	DC Bus 1
Gasper Fan Control	28V DC	.50 A	DC Bus 1
Turbine Bypass Valve	28V DC	.10 A	DC Bus 1
Zone 1 & Duct Temp Indication	28V DC	.20 A	DC Bus 1
Pressure Flow Selection	28V DC	.60 A	DC Bus 1
Zone 1 Auto/Man Control	28V DC	.10 A	DC Bus 1
Upper Deck Heat Control Left	28V DC	.50 A	DC Bus 1
Pack Re-set	28V DC	.10 A	DC Bus 1
A/C Pack Indication Selector	28V DC	.20 A	DC Bus 2
A/C Pack 2 Auto/Man Control	28V DC	.50 A	DC Bus 2
A/C Pack 2 Shut-off Valve	28V DC	.50 A	DC Bus 2
Zone 2 & Duct Temp Indication	28V DC	.20 A	DC Bus 2
Zone 3 & Duct Temp Indication	28V DC	.20 A	DC Bus 2
Zone 2 Auto/Manual Control	28V DC	.10 A	DC Bus 2
Zone 3 Auto/Manual Control	28V DC	.10 A	DC Bus 2
A/C Pack 3 Auto/Manual Control	28v DC	.50 A	DC Bus 3
Zone 4 Auto/Manual Control	28v DC	.50 A	DC Bus 3
ACM Outlet Temp Indicator	28V DC	.08 A	DC Bus 3
Compressor Discharge Temp Ind	28V DC	.08 A	DC Bus 3
Zone 4 & Duct Temp Indicator	28V DC	.20 A	DC Bus 3
Pack Temp Indicator Selector	28V DC	.20 A	DC Bus 3
Zone Supply Overheat Re-set	28V DC	.10 A	DC Bus 3
Pack 3 Shut-off Valve	28V DC	.50 A	DC Bus 3
Upper Deck Temp Control Right	28V DC	.50 A	DC Bus 3
Cabin Pressurization	28V DC	2.50 A	DC Bus 3
Equipment Cooling Fan Control	28V DC	.50 A	DC Essential
A/C OUtflow Valve R Manual	28V DC	.50 A	Battery Bus
A/C Outflow Valve L Manual	28V DC	.50 A	Battery Bus
Equip Cooling Valve Control	28V DC	2.20 A	Battery Bus

TABLE 4-14. BOEING 747-SP AC ELECTRICAL ENERGY REQUIREMENTS (REF 14)

EQUIPMENT	POWER REQD	LOAD	SOURCE
A/C Recirc Fan, Upper Deck	115V 400 Hz	3Ø 1.216 KW 2.11 KVAR	AC Bus 1
A/C Temp Control Zone 1 Auto	115V 400 Hz	1Ø 40 W	AC Bus 1
A/C Temp Control Zone 3 Manual	115V 400 Hz	1Ø 30 W	AC Bus 1
Aft Cargo Conditioned Air	115V 400 Hz	1Ø .112 KW .084 KVAR	AC Bus 1
A/C Temp Control Zone 2 Auto	115V 400 Hz	1Ø 40 W	AC Bus 2
Upper Deck Temp Sensor Fan	115V 400 Hz	1Ø 16 W 11 VAR	AC Bus 2
Upper Deck Temp Control Manual	115V 400 Hz	1Ø 2 W	AC Bus 2
A/C Temp Controller Pack 3	115V 400 Hz	1Ø .35 KW	AC Bus 3
A/C Temp Controller Pack 2	115V 400 Hz	1Ø .35 KW	AC Bus 3
A/C Temp Controller Zone 3	115V 400 Hz	1Ø 40 W	AC Bus 3
A/C Temp Controller Zone 1	115V 400 Hz	1Ø 40 W	AC Bus 3
Aft Cargo Temp Sensor	115V 400 Hz	1Ø 16 W 11 VAR	AC Bus 3
Equip Cooling Blower	115V 400 Hz	1Ø 2.06 KW 1.55 KVAR	AC Bus 4
A/C Vent Fan	115V 400 Hz	1Ø 1.19 KW 2.12 KVAR	AC Bus 4
A/C Temp Controller Pack 1	115V 400 Hz	1Ø .35 KW	AC Bus 4
A/C Temp Controller Pack 2	115V 400 Hz	1Ø 30 W	AC Bus 4
Aft Cargo Air Cond Temp	115V 400 Hz	1Ø 30 W	AC Bus 4
Pressure Controller - Auto	115V 400 Hz	1Ø 30 W	Essent. A/C

TABLE 4-15. BOEING 747-SP DC ELECTRICAL ENERGY REQUIREMENTS (REF 14)

EQUIPMENT	POWER REQD	LOAD	SOURCE
A/C Cargo Heat Control	28 VDC	.12 A	DC Bus 1
Pack 1 Auto/Man Control	28 VDC	1.50 A	DC Bus 1
Pack 1 Shut-off Valve	28 VDC	.5 A	DC Bus 1
Pack Bypass Valve Ind.	28 VDC	.1 A	DC Bus 1
Zone 1 Temp Indicator	28 VDC	.20 A	DC Bus 1
Pressure/Flow Selector	28 VDC	.70 A	DC Bus 1
Zone 1 Auto/Manual Contr.	28 VDC	.10 A	DC Bus 1
Upper Deck Temp Indicat.	28 VDC	.20 A	DC Bus 1
Pack Indicator Selector	28 VDC	.20 A	DC Bus 2
Pack 2 Auto/Man Control	28 VDC	.50 A	DC Bus 2
Pack 2 Shutoff Valve	28 VDC	.50 A	DC Bus 2
Zone 2 Temp Indication	28 VDC	.20 A	DC Bus 2
Zone 3 Temp Indication	28 VDC	.20 A	DC Bus 2
A/C 2 Auto/Manual Control	28 VDC	.10 A	DC Bus 2
A/C 3 Auto/Manual Control	28 VDC	.10 A	DC Bus 2
Vent Fan Control	28 VDC	1.50 A	DC Bus 2
Pack 3 Auto/Man Control	28 VDC	.50 A	DC Bus 3
ACM Outlet Temp Indicat.	28 VDC	.08 A	DC Bus 3
ACM Compressor Discharge Temp Indication	28 VDC	.08 A	DC Bus 3
Pack Temp Indicator Selector	28 VDC	.20 A	DC Bus 3
Pack 3 Shutoff Valve	28 VDC	.50 A	DC Bus 3
Trim Air Control	28 VDC	.50 A	DC Bus 3
Cabin Press Control	28 VDC	1.50 A	DC Bus 3
Aft Cabin Conditioned Air Control	28 VDC	.20 A	DC Bus 3
Aft Cargo Temp Indication	28 VDC	.18 A	DC Bus 3
Upper Deck Temp Control	28 VDC	.12 A	DC Bus 3
R Cabin Pressure Control	28 VDC	.05 A	Battery Bus
L Cabin Pressure Control	28 VDC	.05 A	Battery Bus
Equipment Cooling Dump Valve	28 VDC	2.20 A	Battery Bus
Equipment Cooling Cargo Valve	28 VDC	1.00 A	Battery Bus

BOEING 747-100,-200

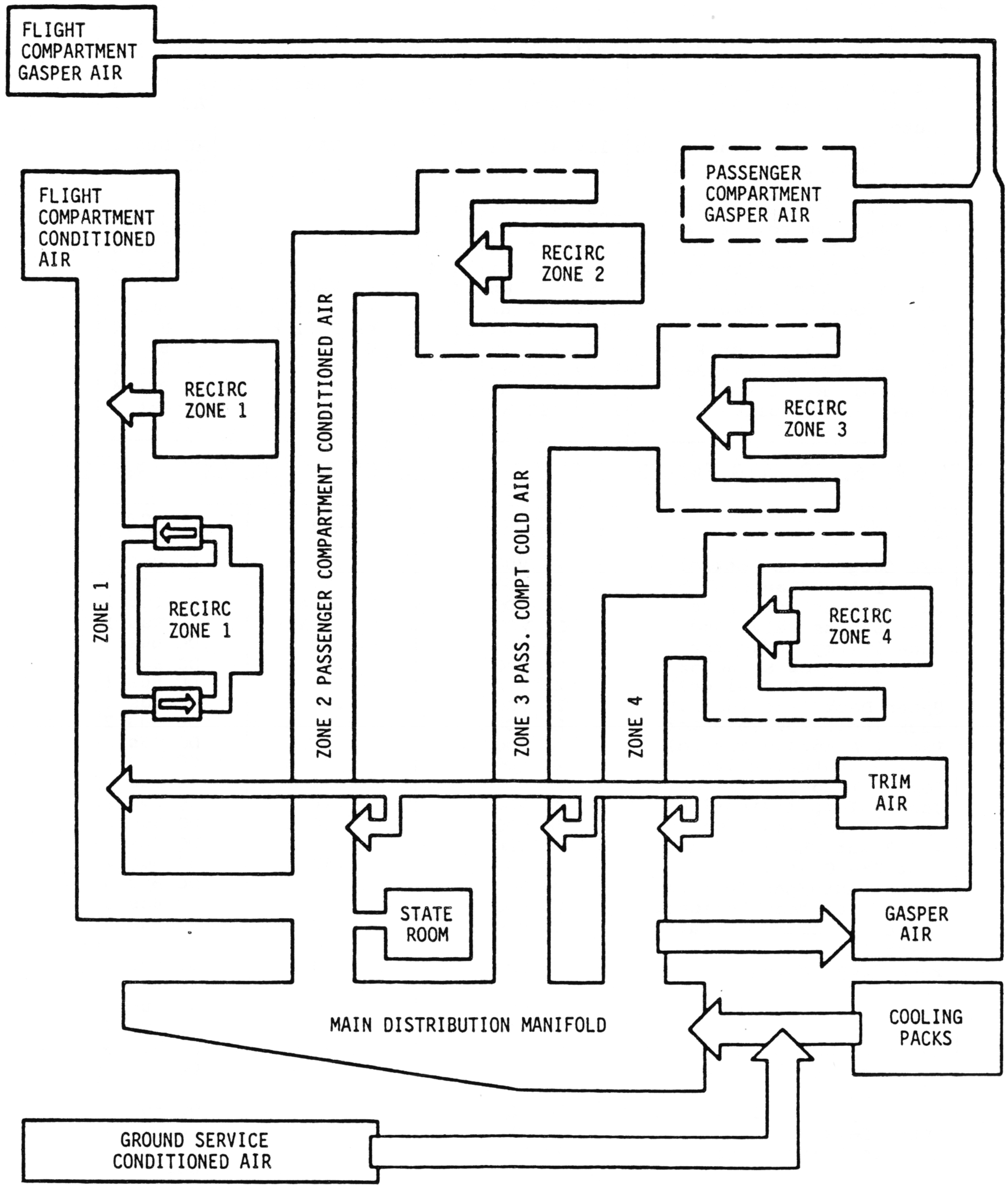


FIGURE 4-1. BOEING 747-100,-200 AIR CONDITIONING DISTRIBUTION BLOCK DIAGRAM

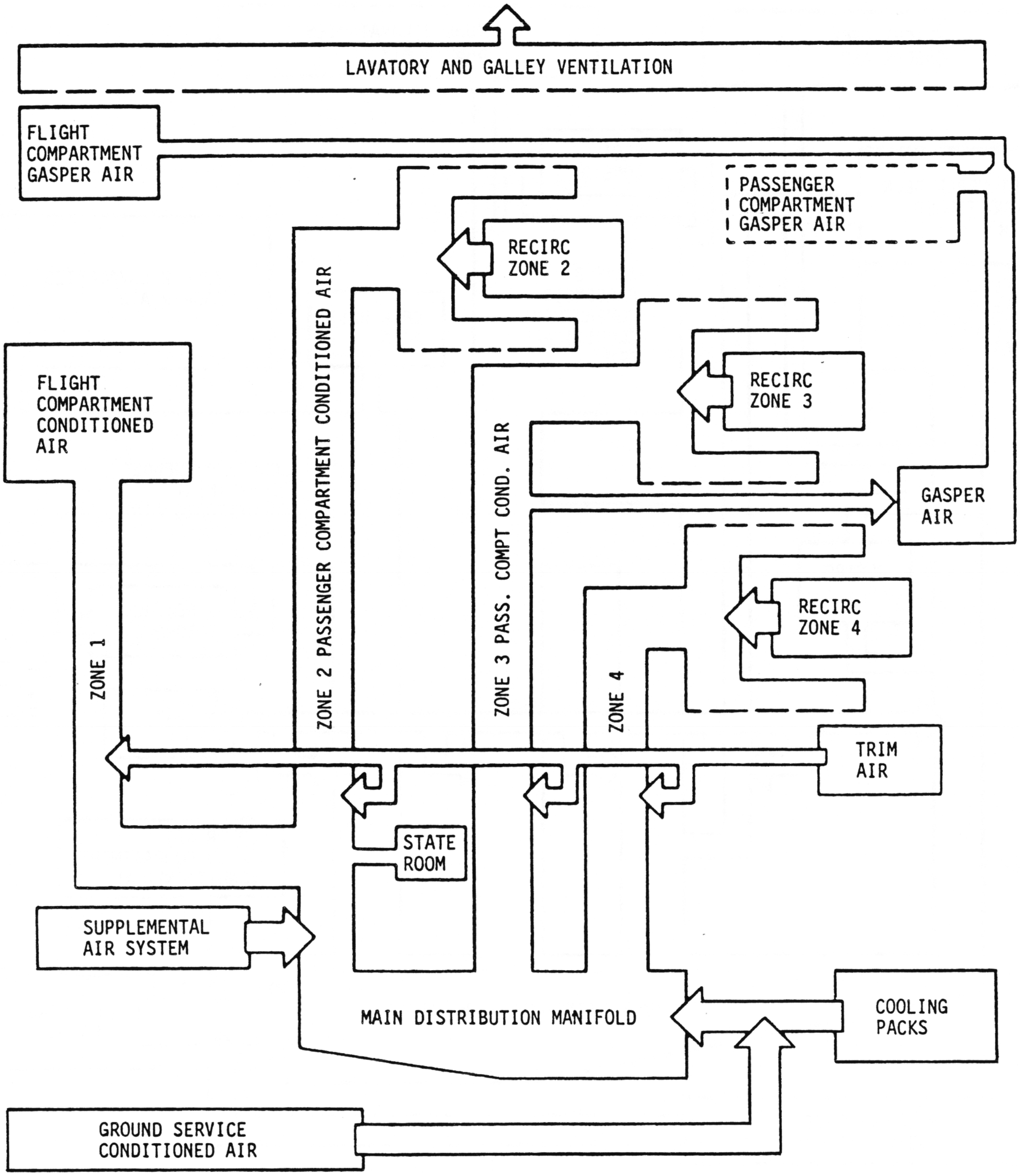


FIGURE 4-2. BOEING 747-300 AIR CONDITIONING DISTRIBUTION BLOCK DIAGRAM

BOEING 747-SP

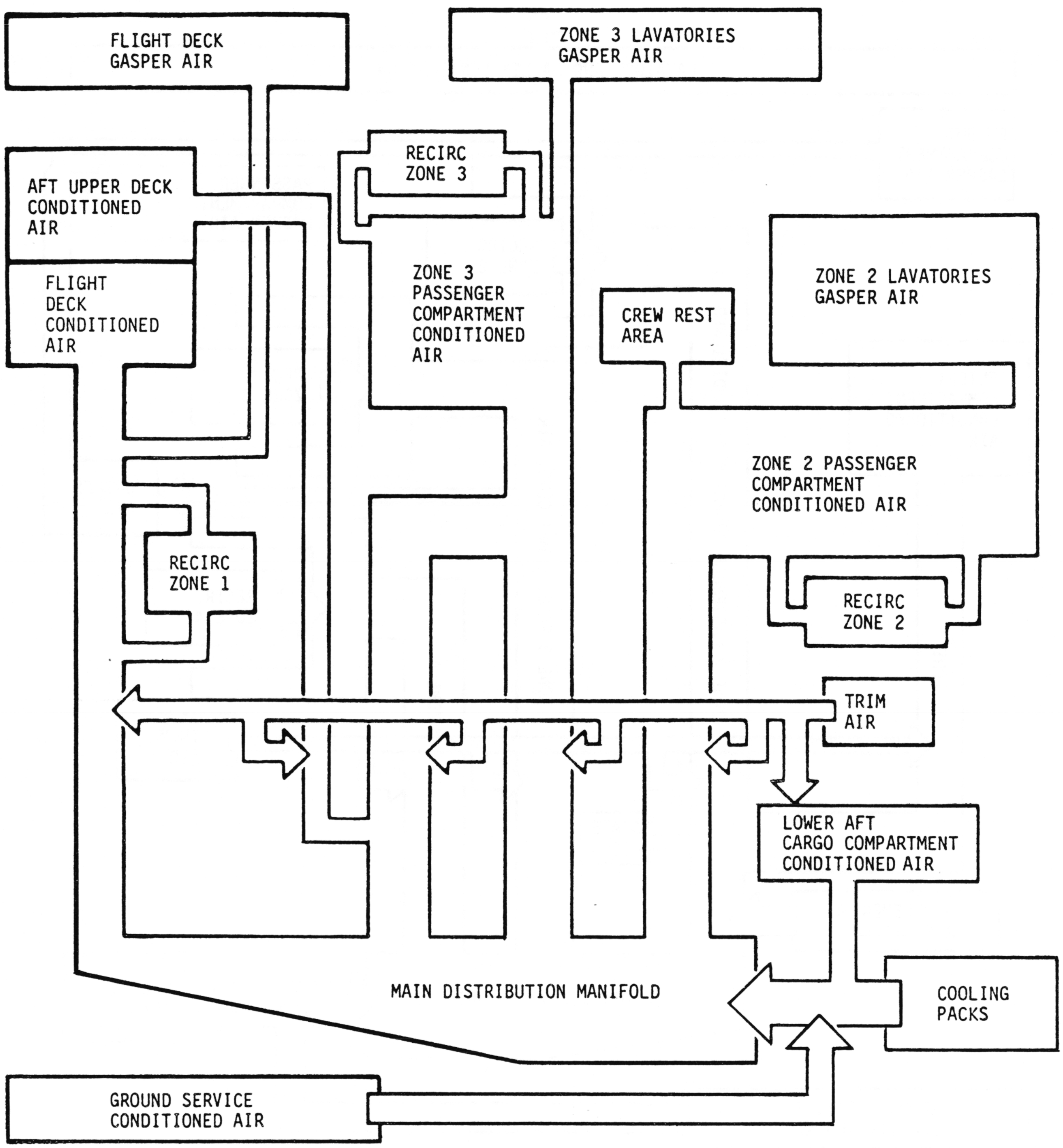


FIGURE 4-3. BOEING 747-SP AIR CONDITIONING
DISTRIBUTION BLOCK DIAGRAM

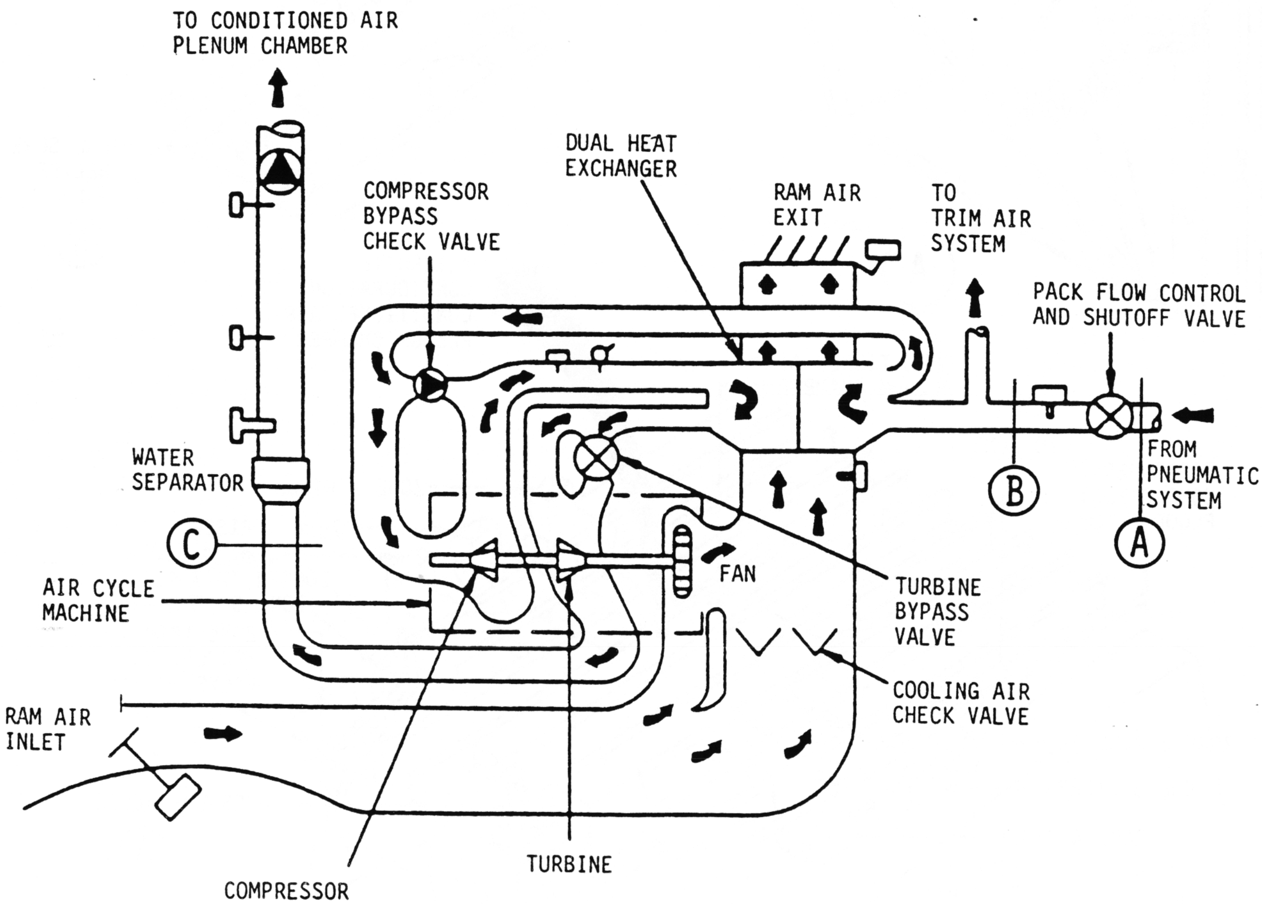


FIGURE 4-4. BOEING 747 AIR CONDITIONING PACK SCHEMATIC

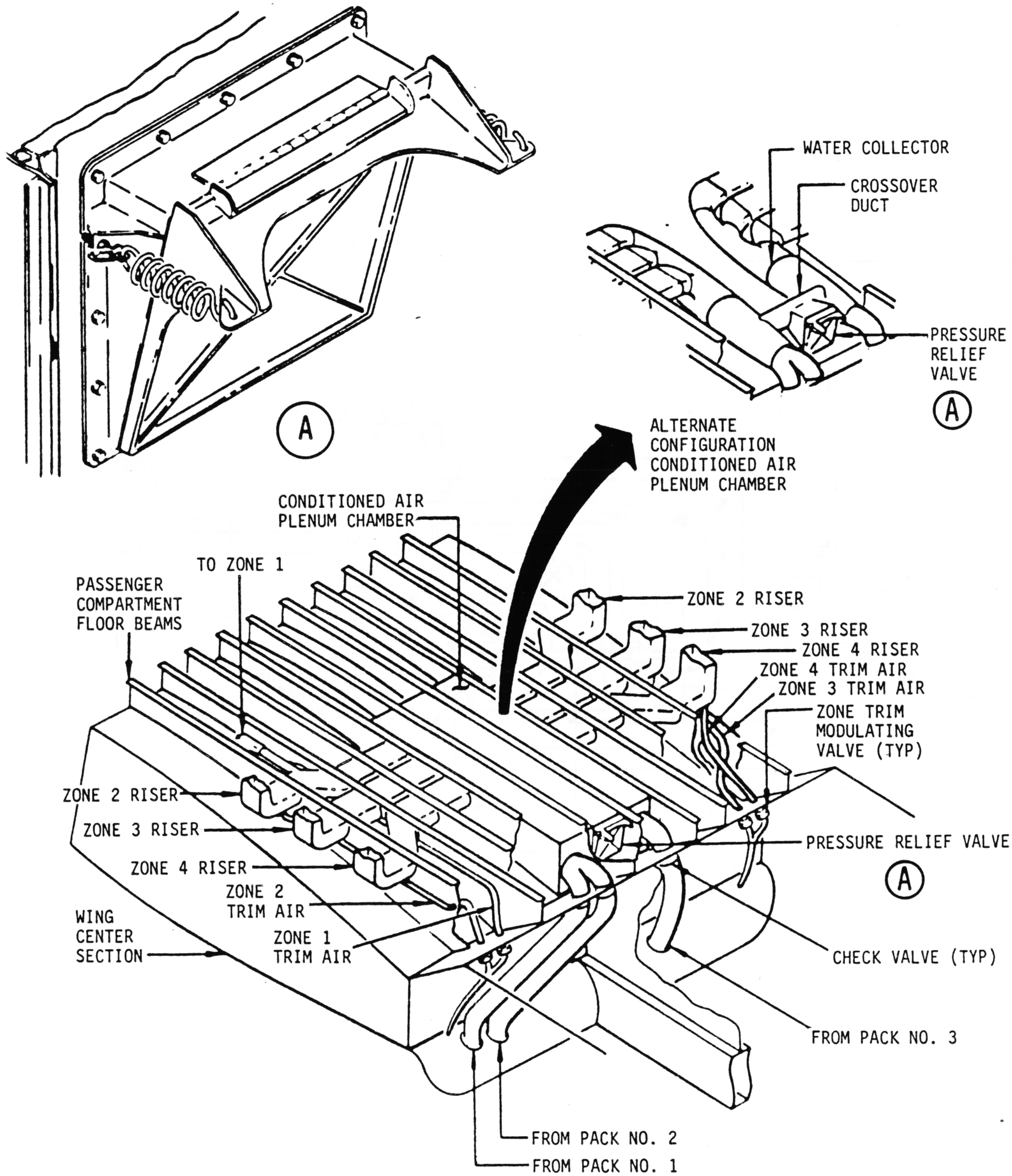


FIGURE 4-5. BOEING 747-100,-200 MAIN DISTRIBUTION MANIFOLD

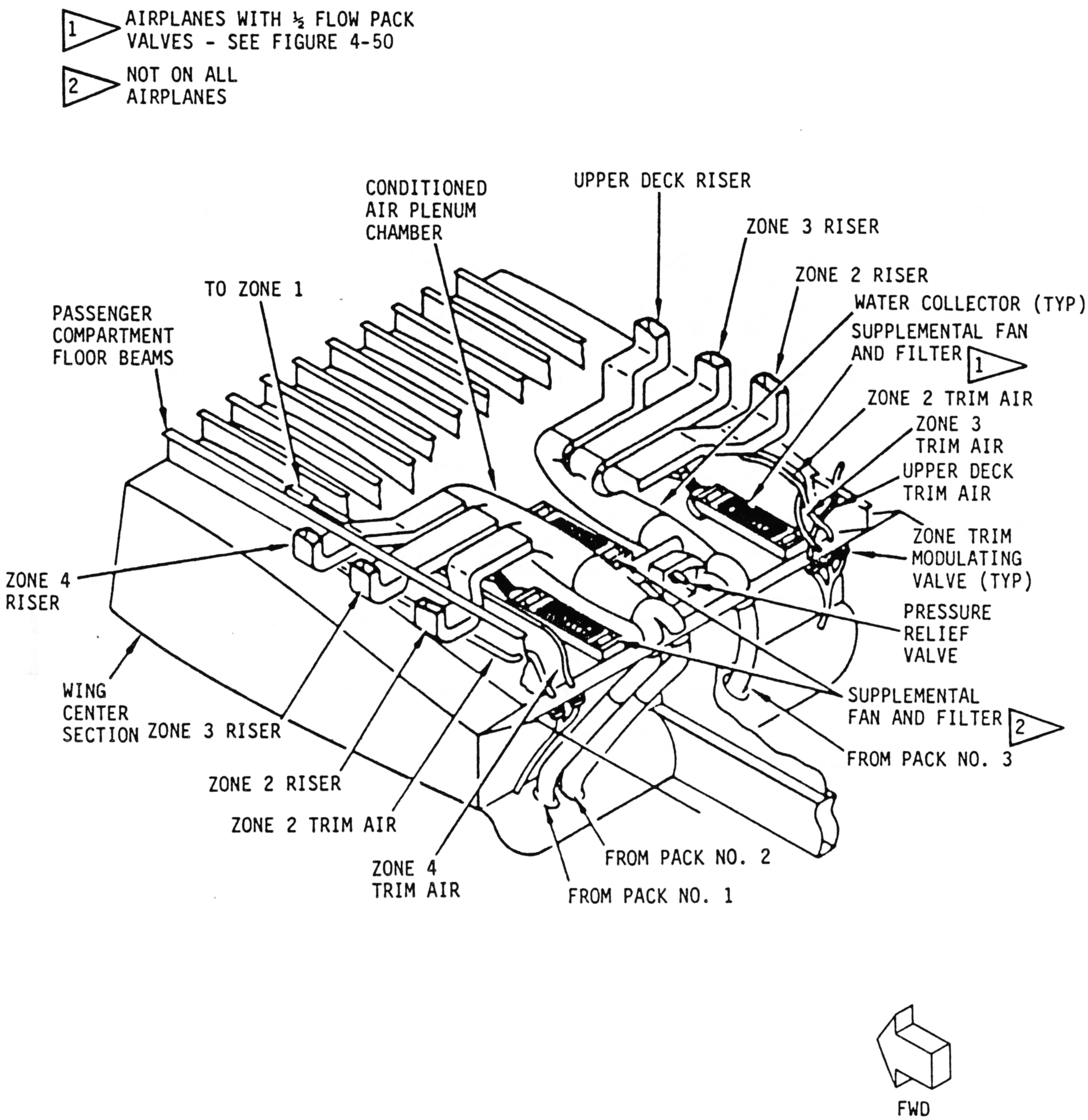


FIGURE 4-6. BOEING 747-300 MAIN DISTRIBUTION MANIFOLD

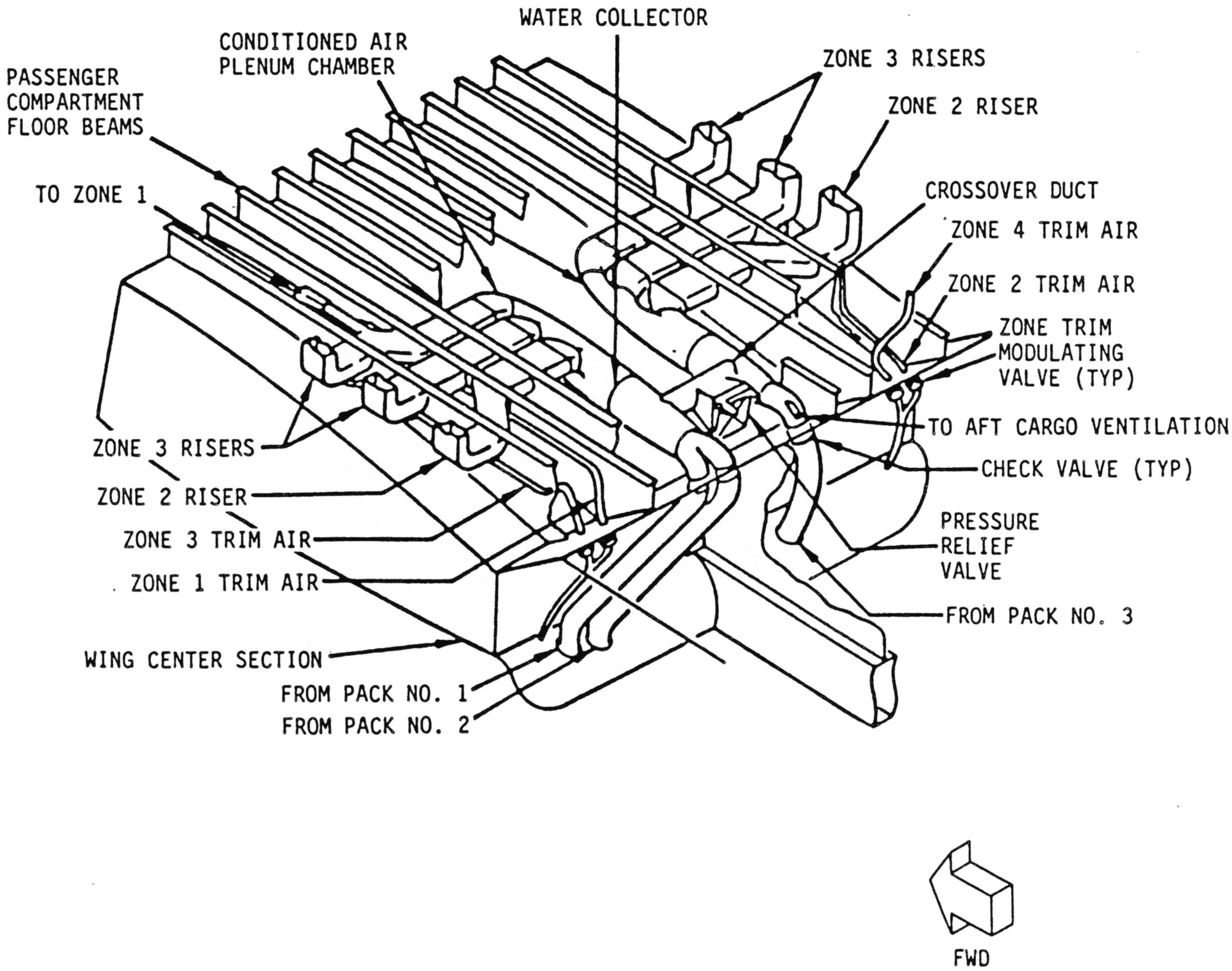


FIGURE 4-7. BOEING 747-SP MAIN DISTRIBUTION MANIFOLD

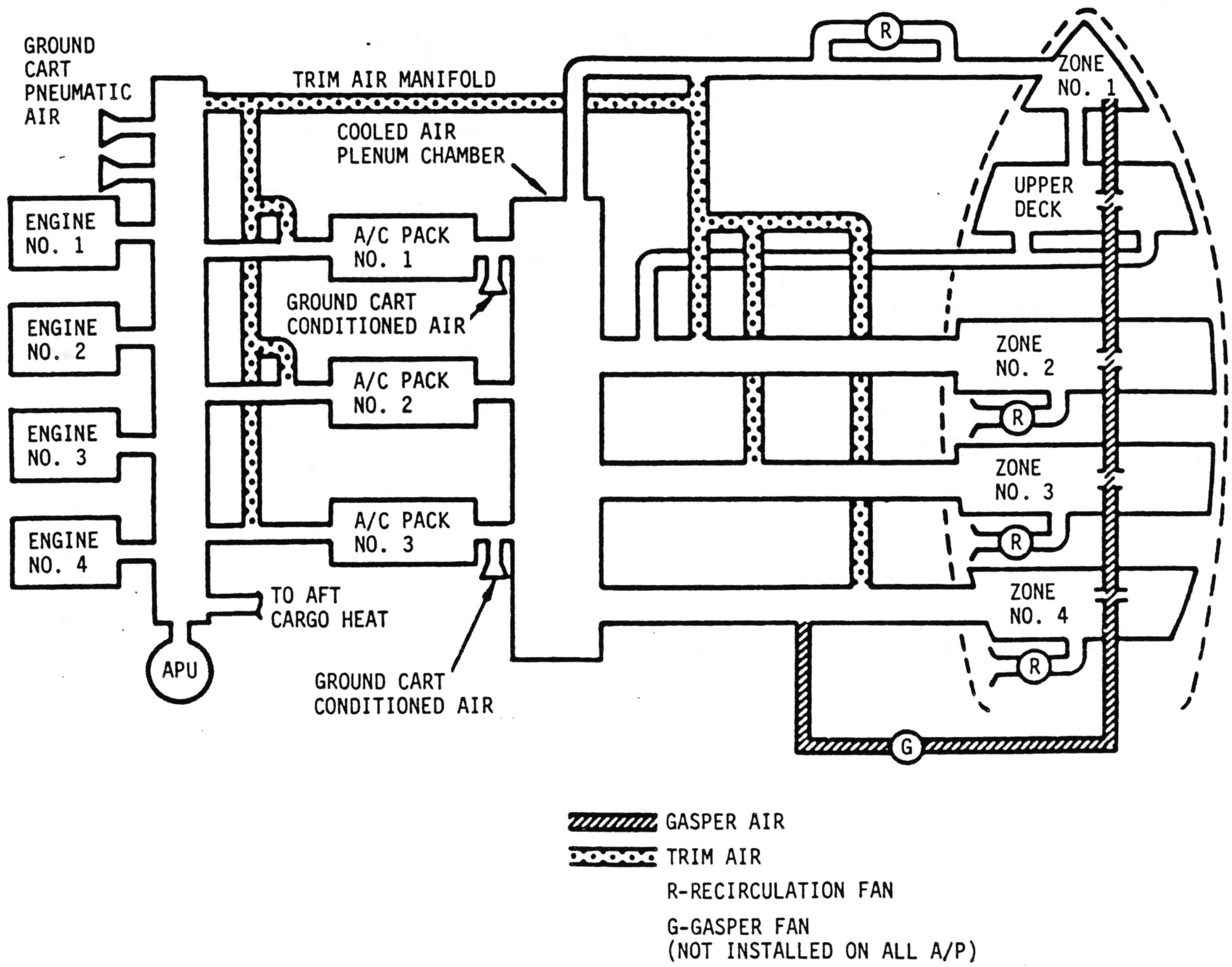


FIGURE 4-8. BOEING 747-100,-200 ZONE DISTRIBUTION SCHEMATIC

BOEING 747-300

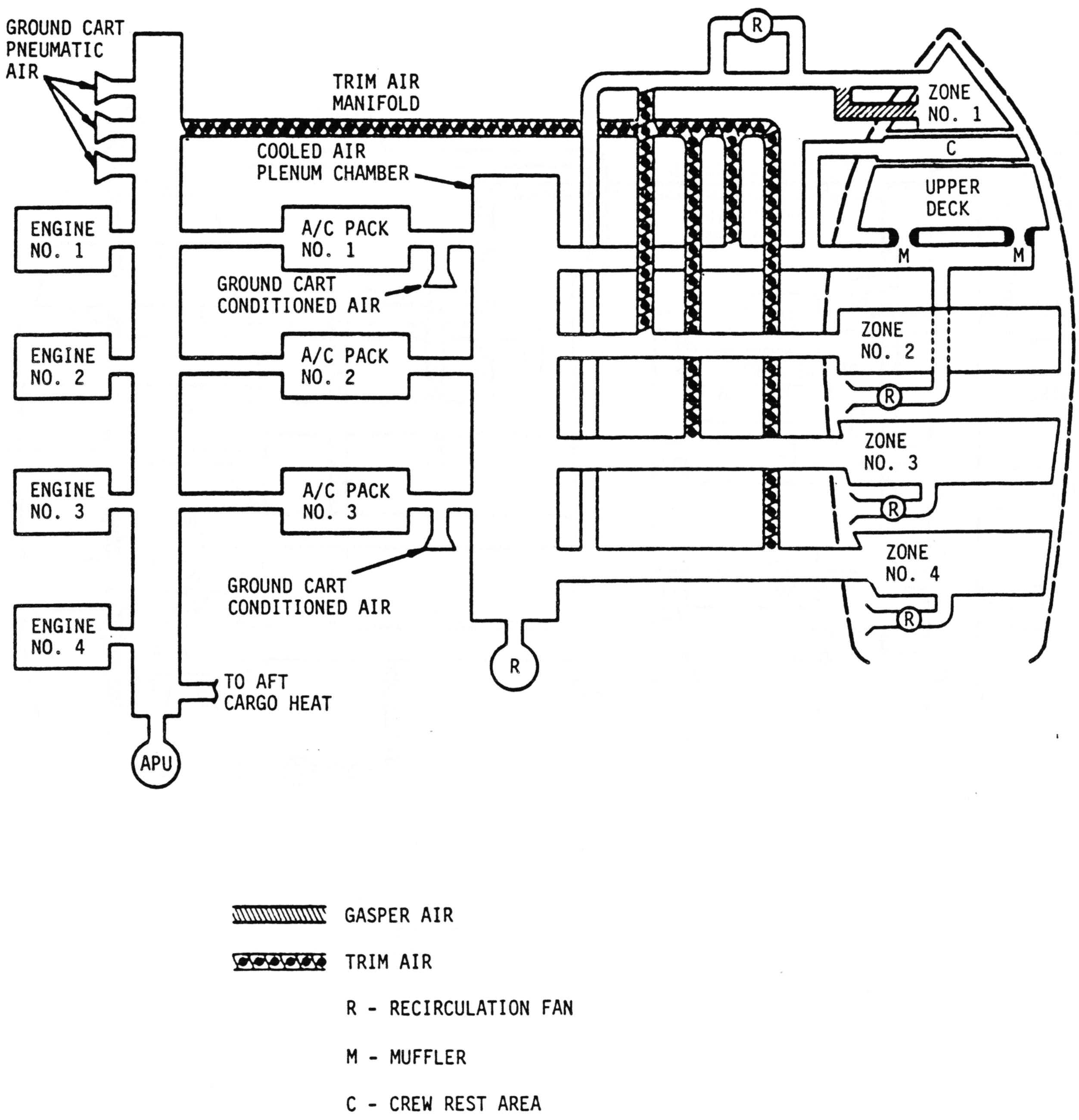


FIGURE 4-9. BOEING 747-300 ZONE DISTRIBUTION SCHEMATIC

BOEING 747-SP

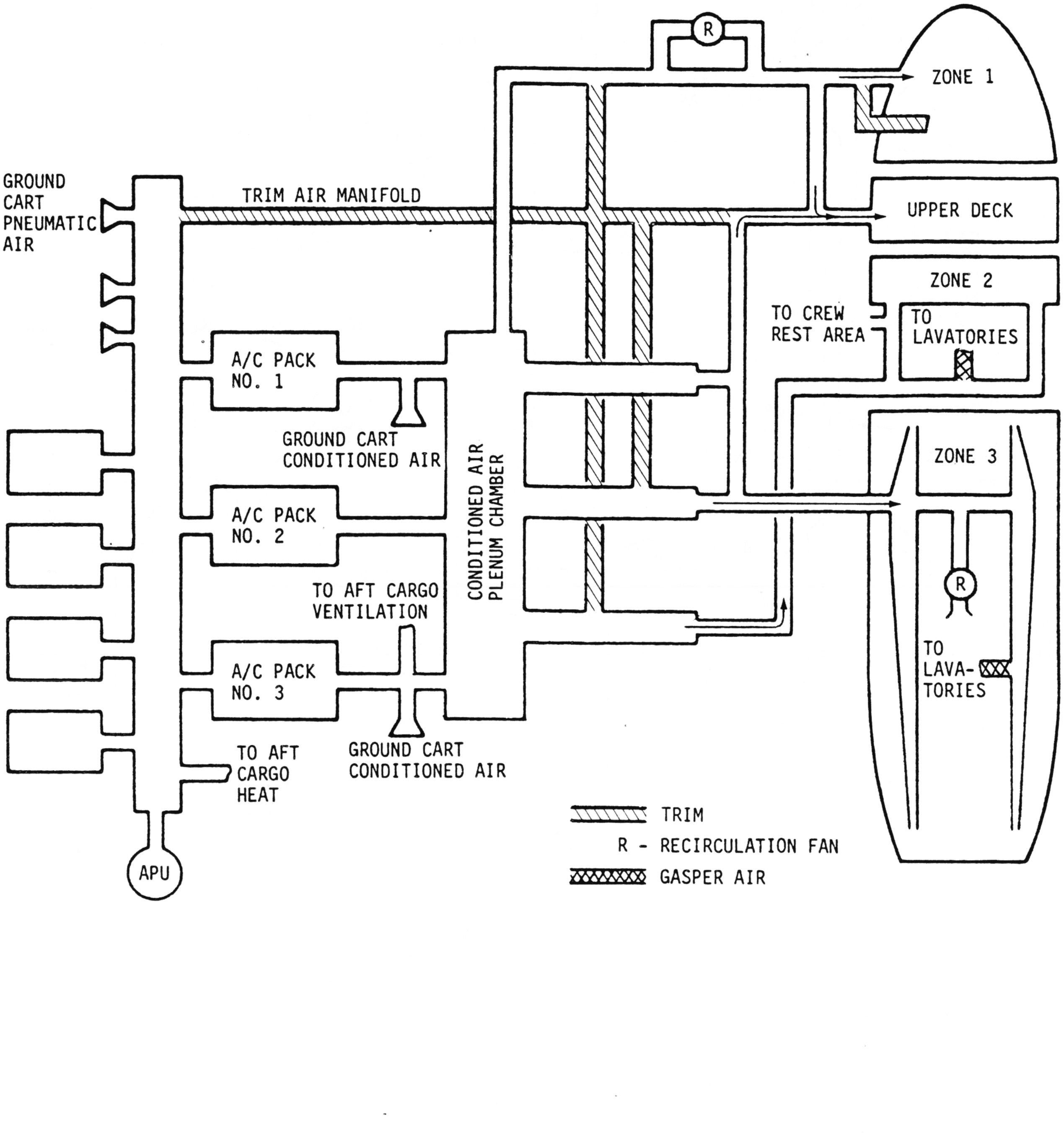


FIGURE 4-10. BOEING 747-SP ZONE DISTRIBUTION SCHEMATIC

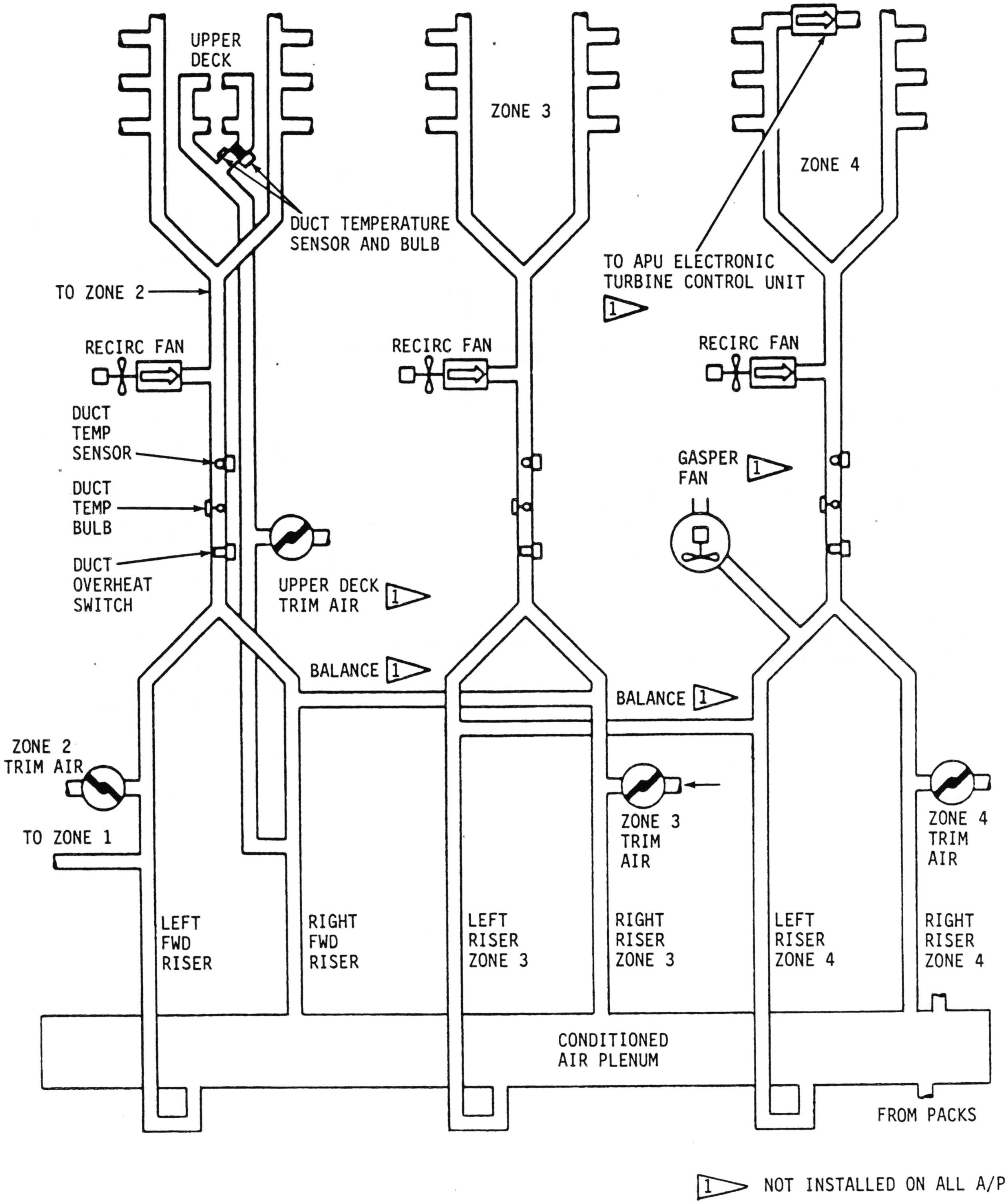


FIGURE 4-11. BOEING 747-100,-200 PASSENGER CABIN DISTRIBUTION SCHEMATIC

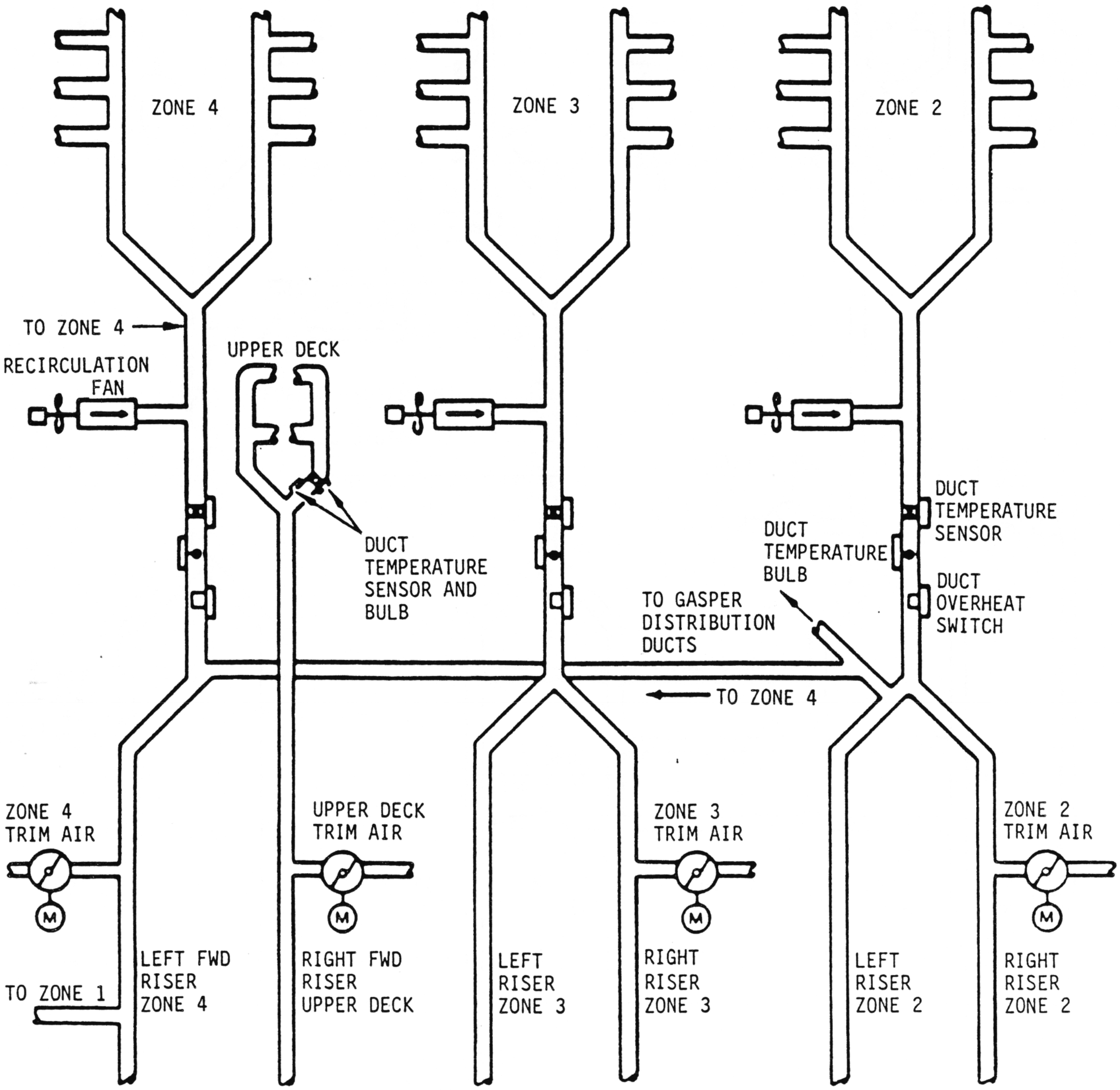


FIGURE 4-12. BOEING 747-300 PASSENGER CABIN DISTRIBUTION SCHEMATIC

BOEING 747-SP

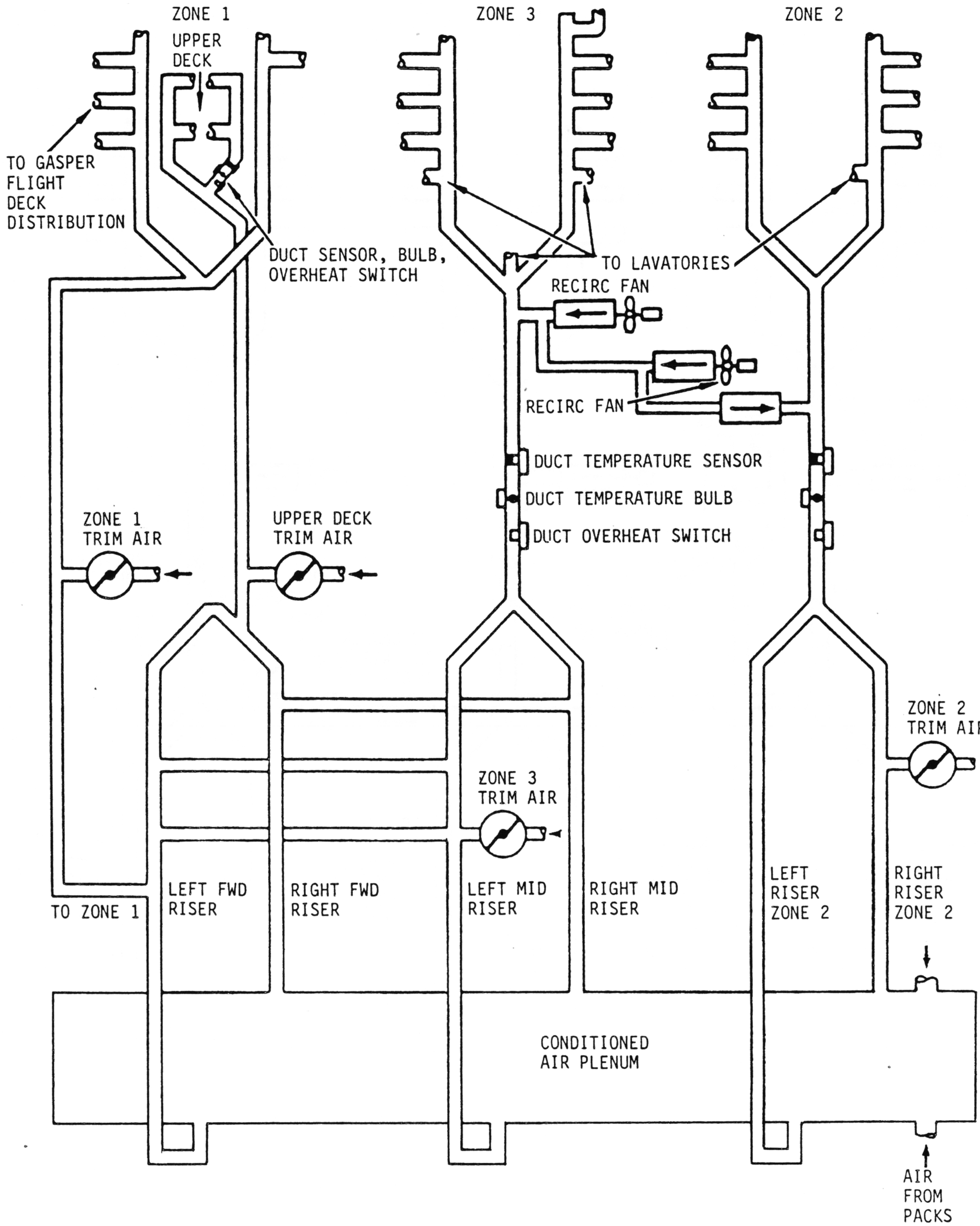
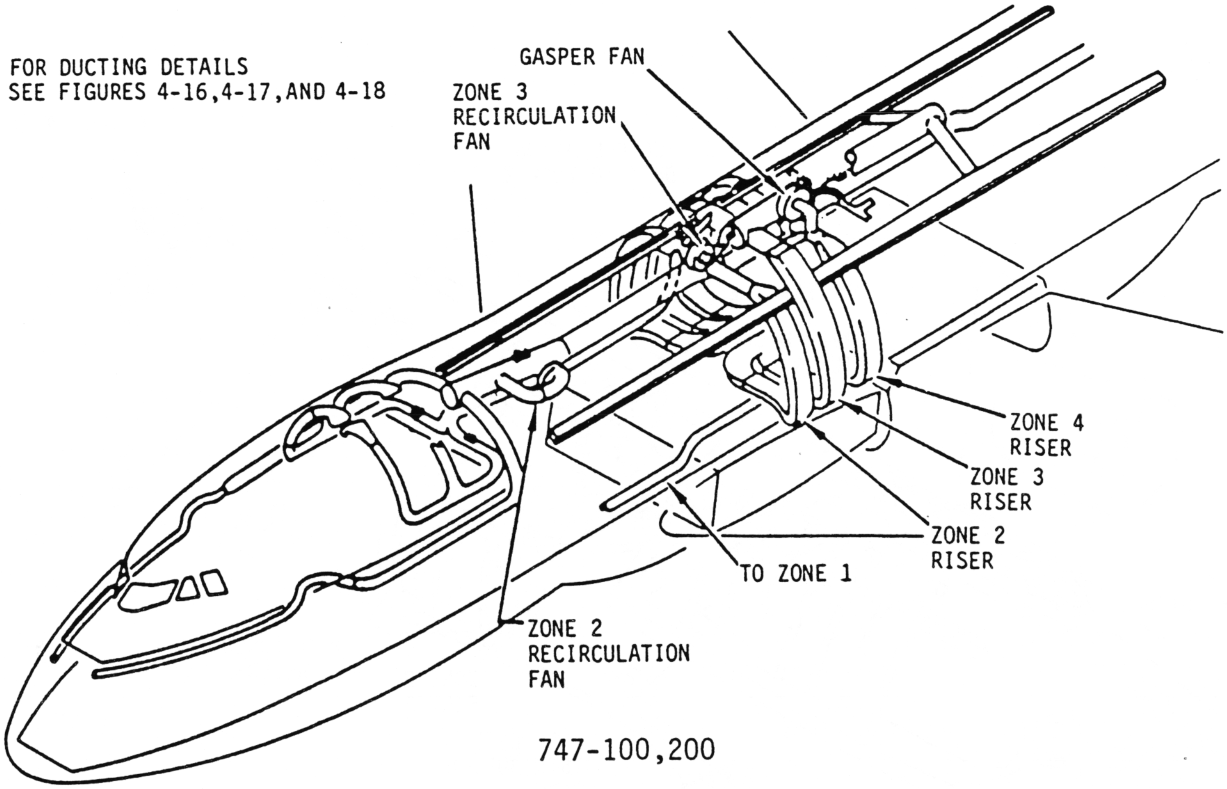
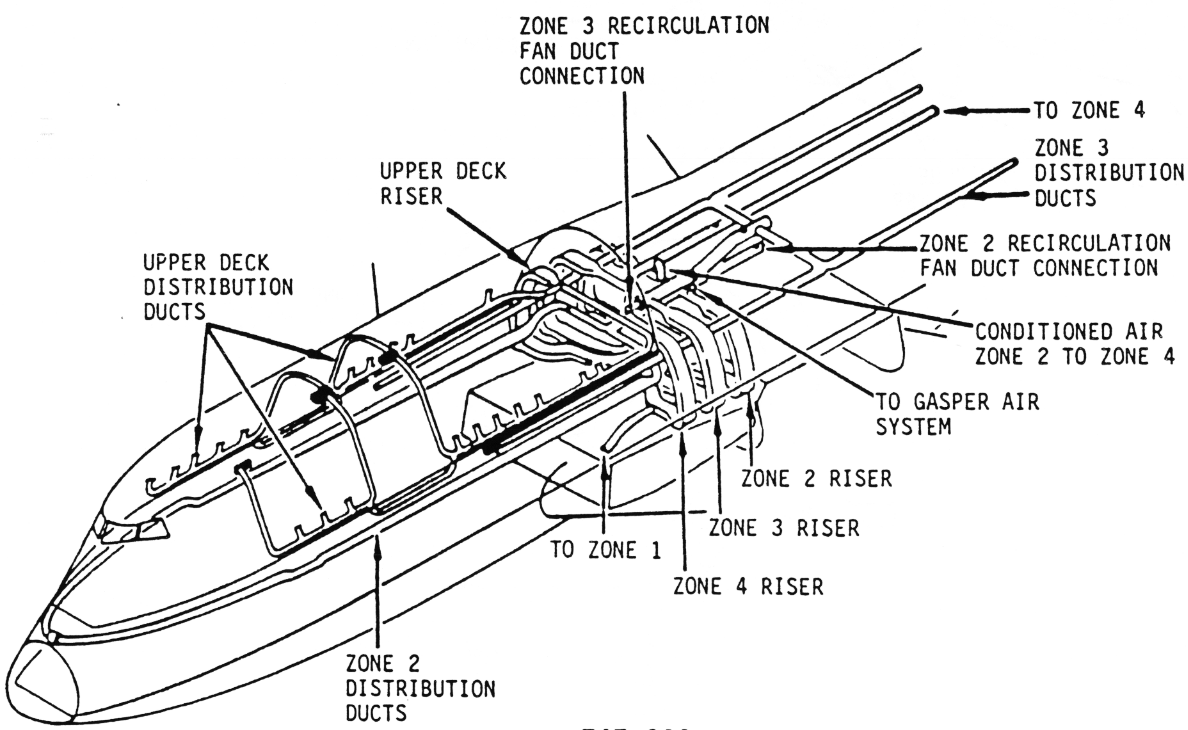


FIGURE 4-13. BOEING 747-SP PASSENGER CABIN DISTRIBUTION SCHEMATIC

BOEING 747-100,-200,-300



747-100,200



747-300

FIGURE 4-14. BOEING 747-100,-200,-300 PASSENGER CABIN MAIN SUPPLY DUCTING

BOEING 747-SP

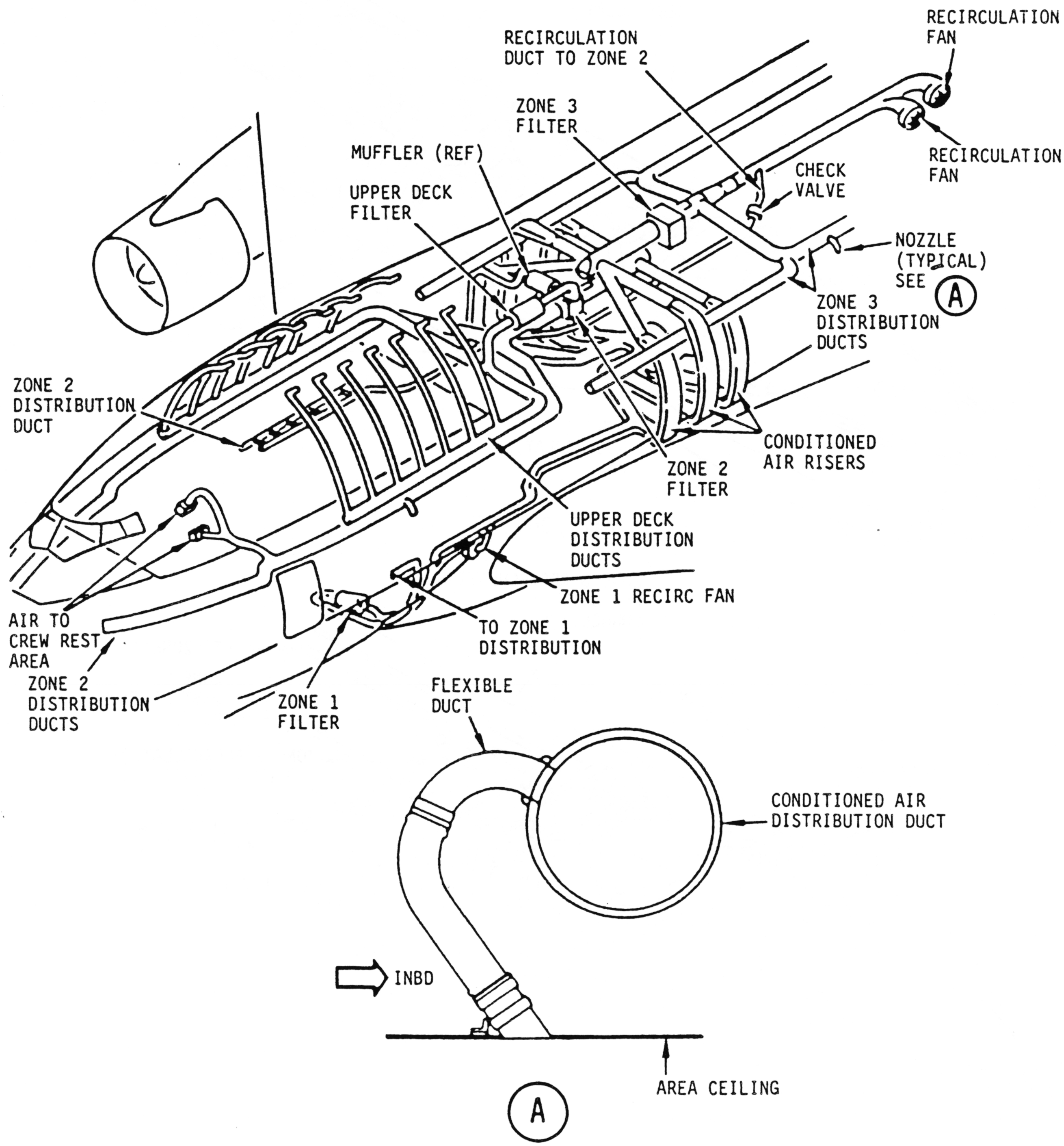


FIGURE 4-15. BOEING 747-SP MAIN SUPPLY DUCTING

BOEING 747-100,-200,-300

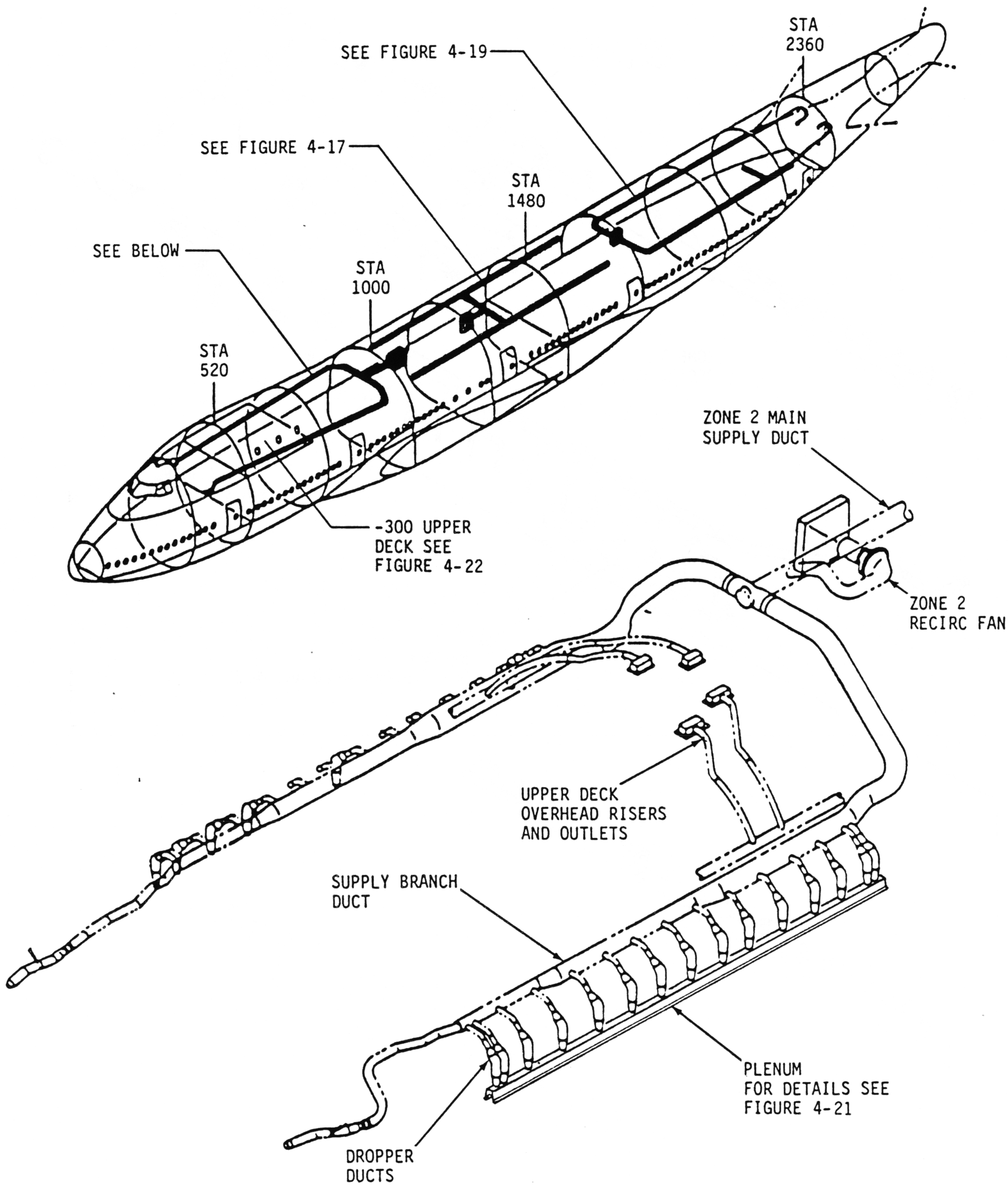


FIGURE 4-16. BOEING 747-100,-200,-300 FORWARD PASSENGER CABIN DISTRIBUTION DUCTING

BOEING 747-100,-200,-300

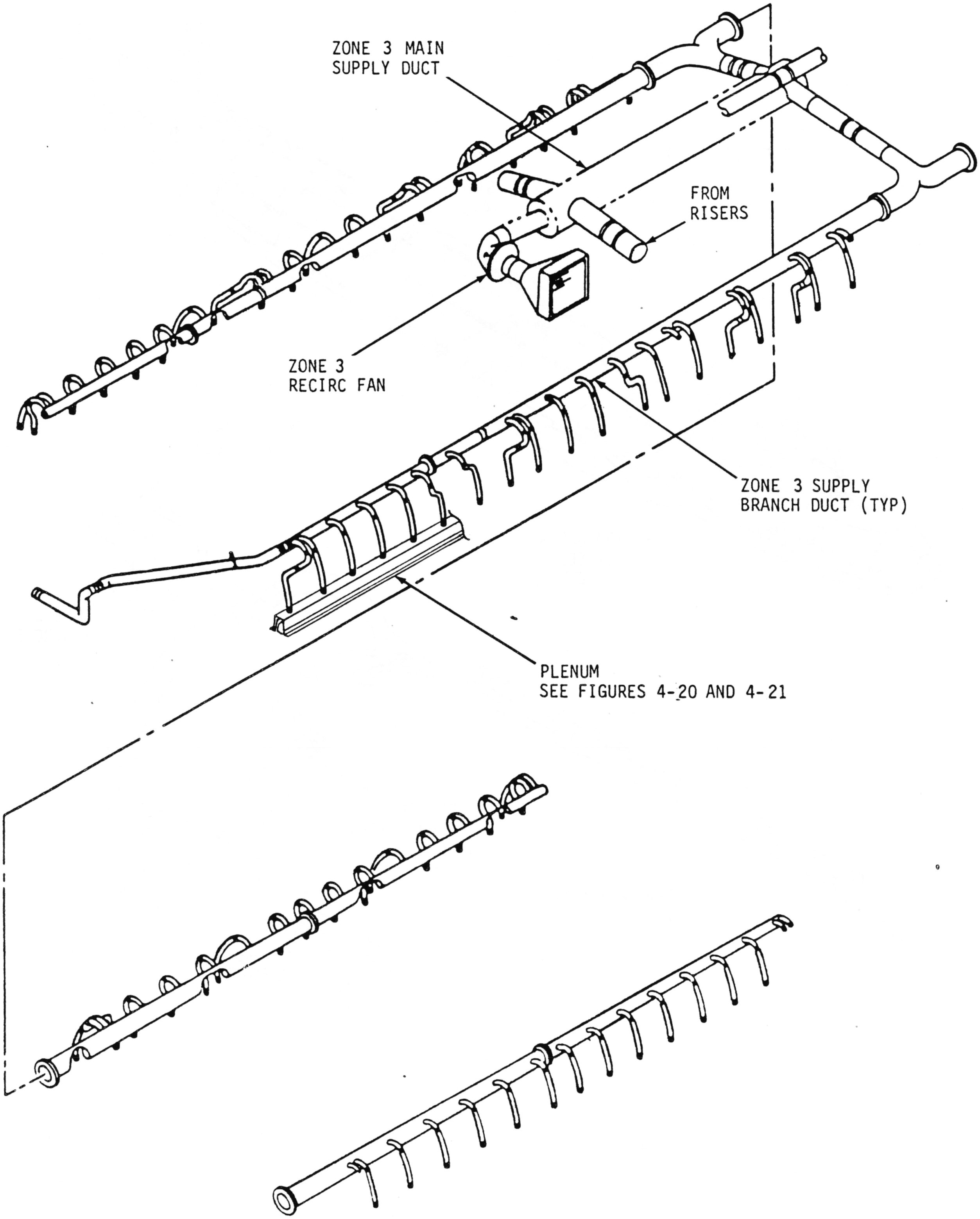


FIGURE 4-17. BOEING 747-100,-200,-300 MID PASSENGER CABIN DISTRIBUTION DUCTING

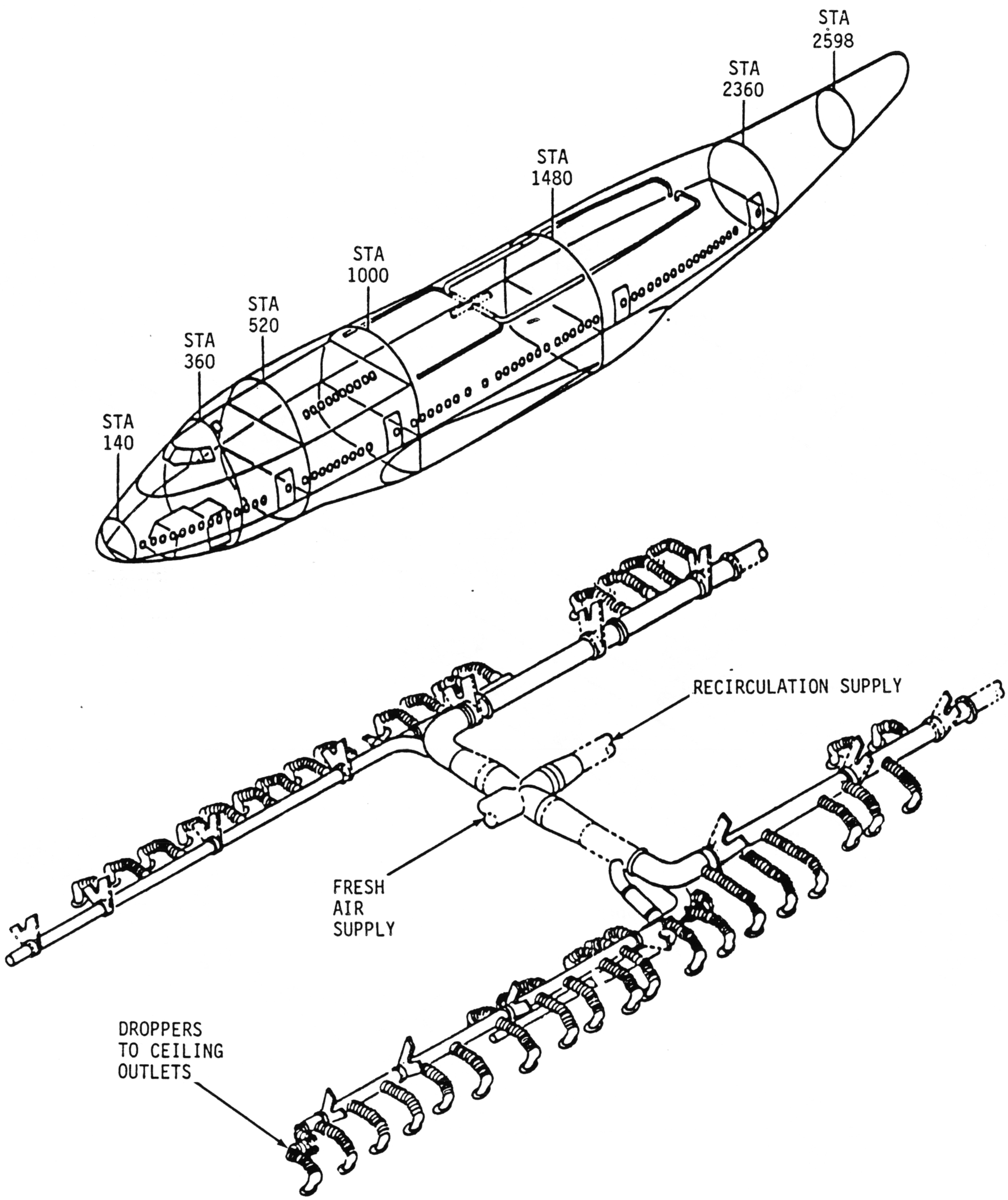


FIGURE 4-18. BOEING 747-SP MID PASSENGER CABIN DISTRIBUTION DUCTING

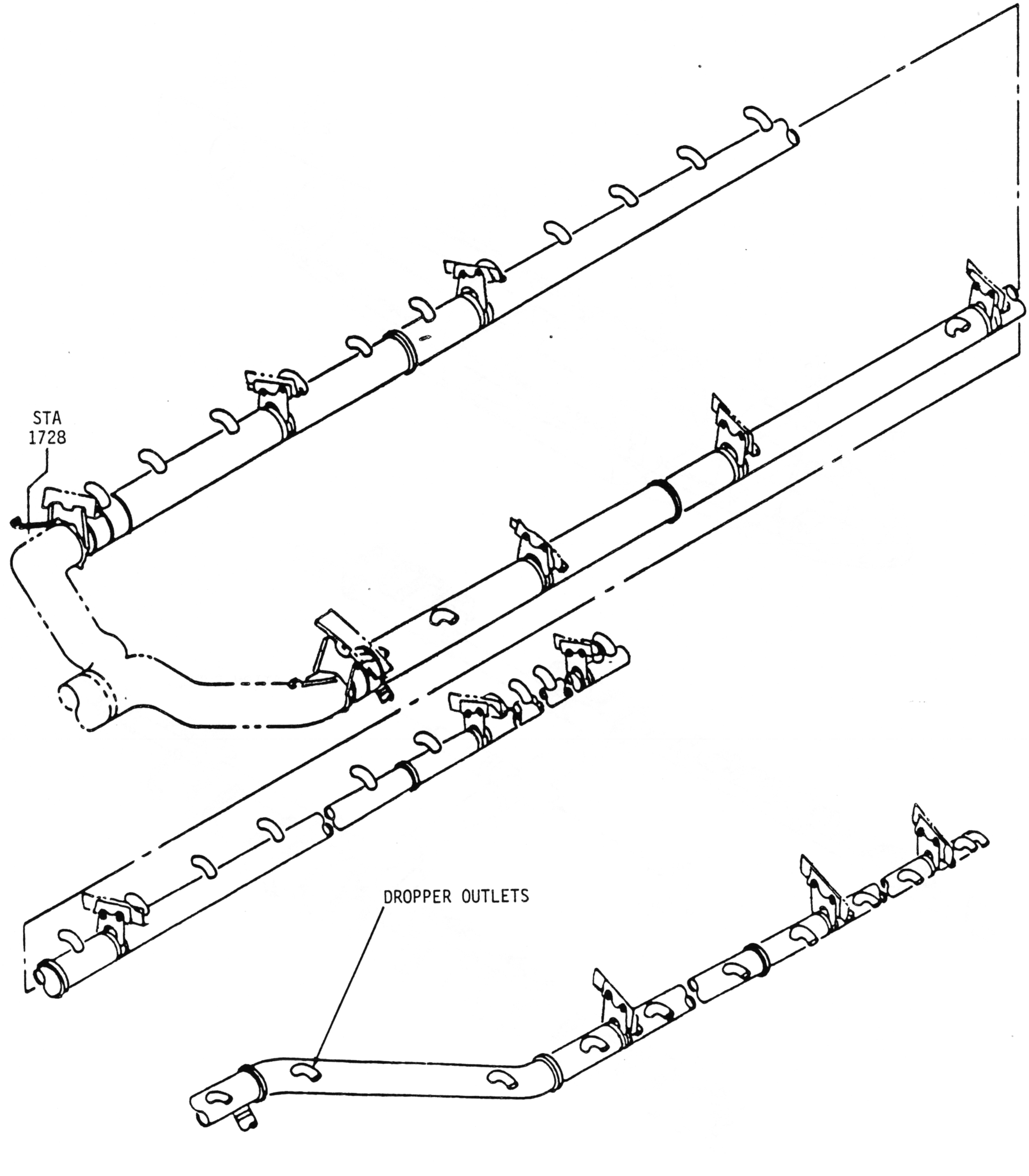


FIGURE 4-19. BOEING 747-100,-200,-300 AFT PASSENGER CABIN DISTRIBUTION DUCTING

BOEING 747

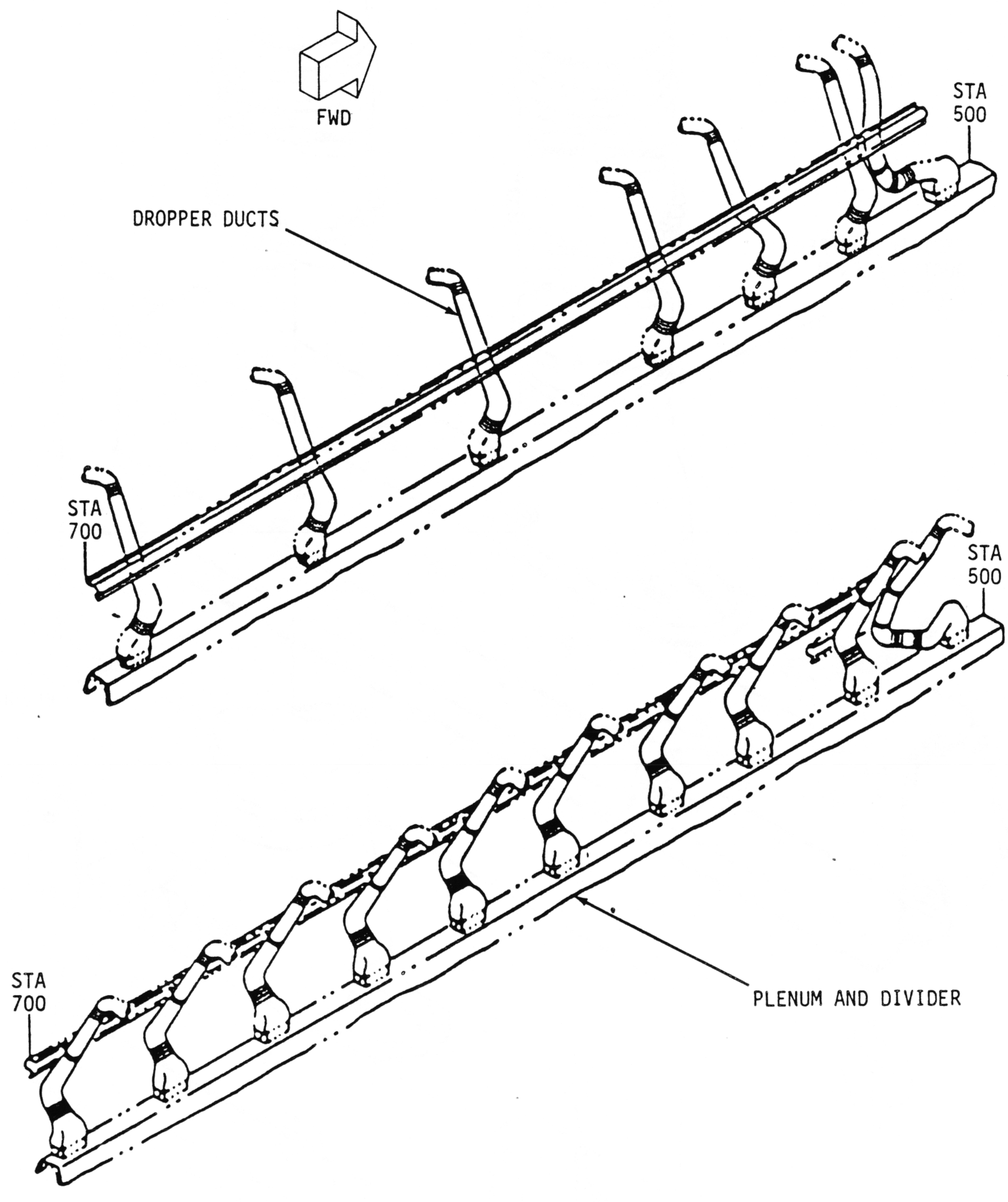


FIGURE 4-20. BOEING 747 TYPICAL SUPPLY DUCT TO PLENUM DROPPER DUCTS

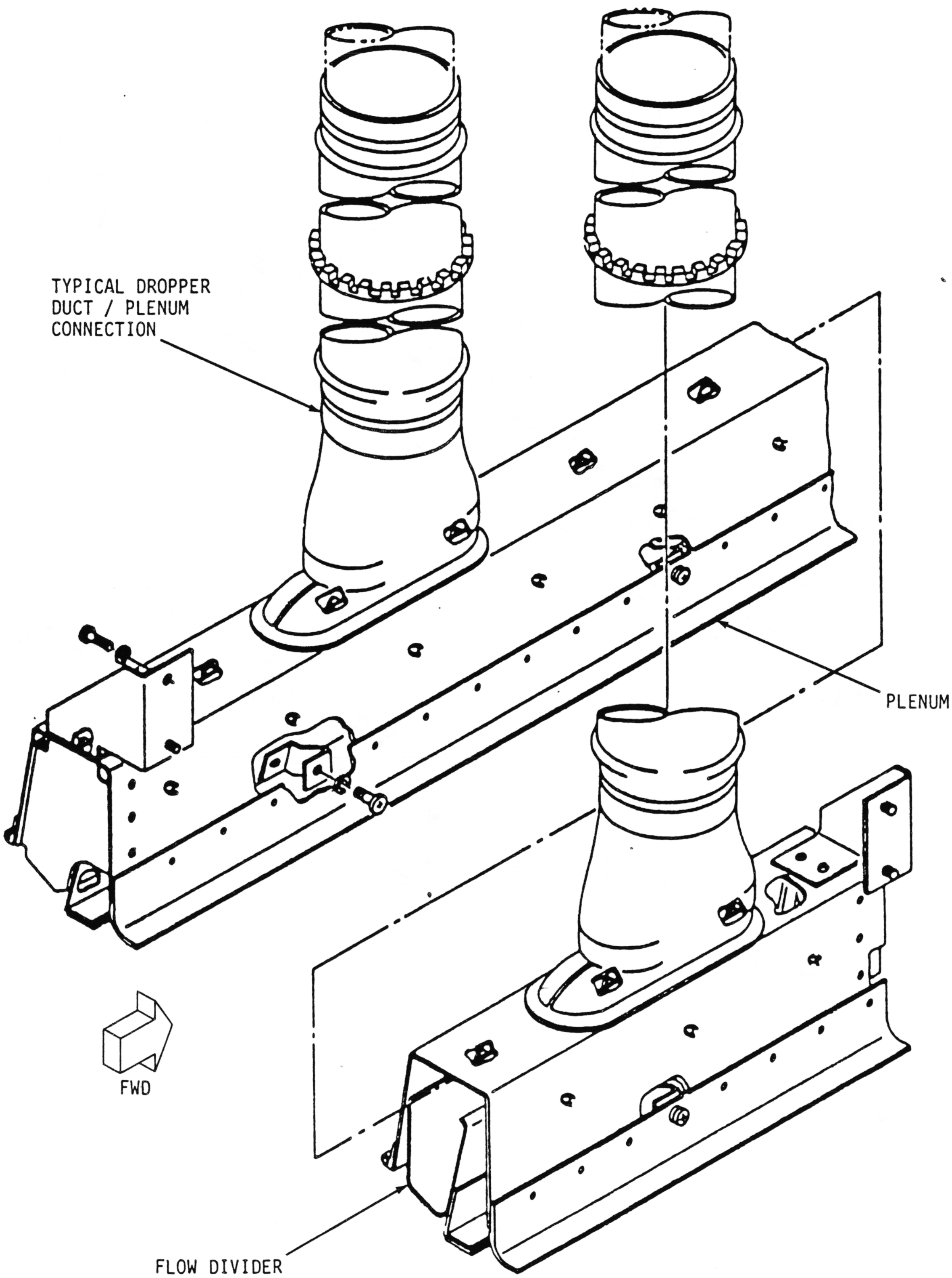


FIGURE 4-21. BOEING 747 AIR CONDITIONING PLENUM AND FLOW DIVIDER

BOEING 747-300

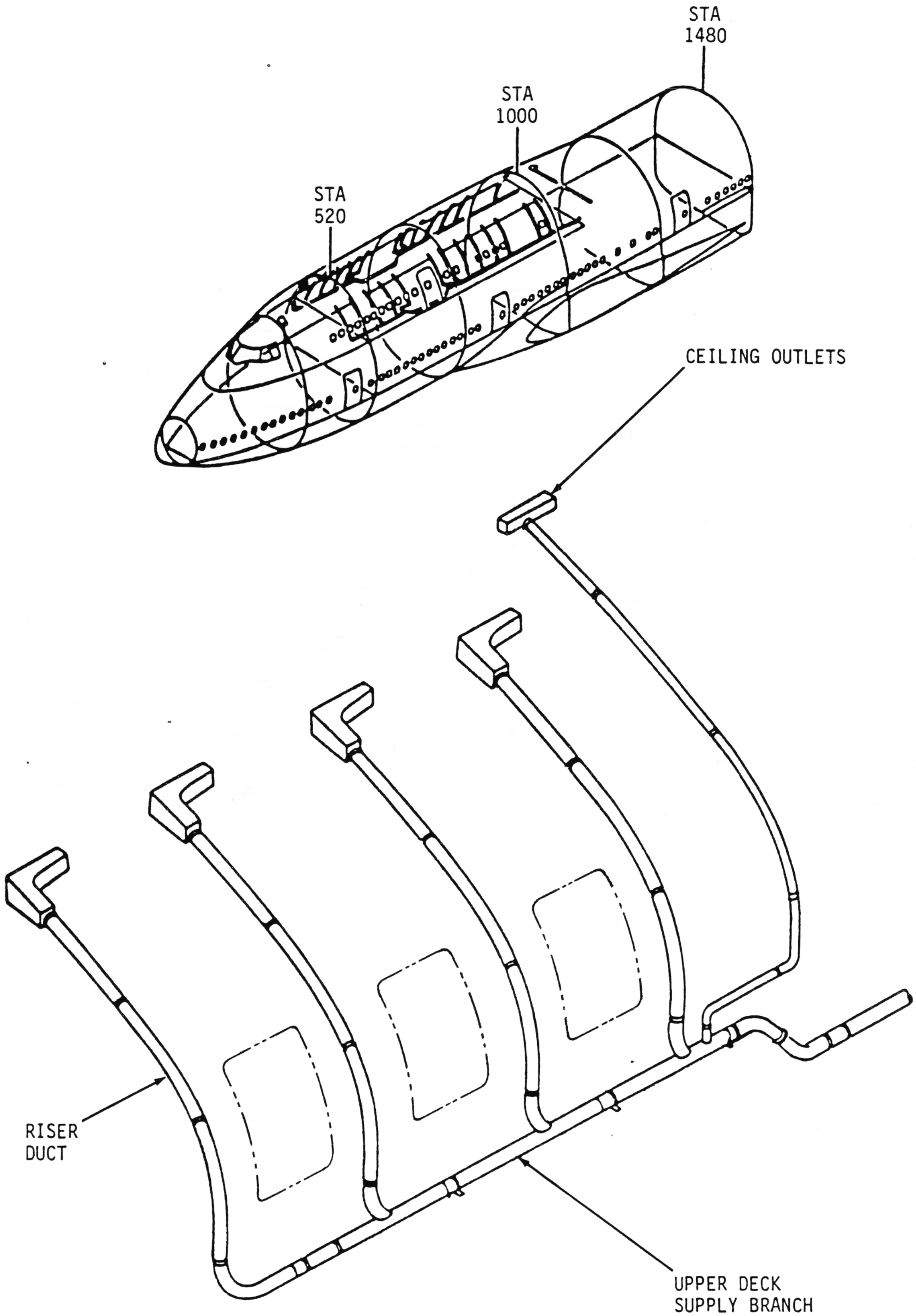


FIGURE 4-22. BOEING 747-300 UPPER DECK DISTRIBUTION DUCTING

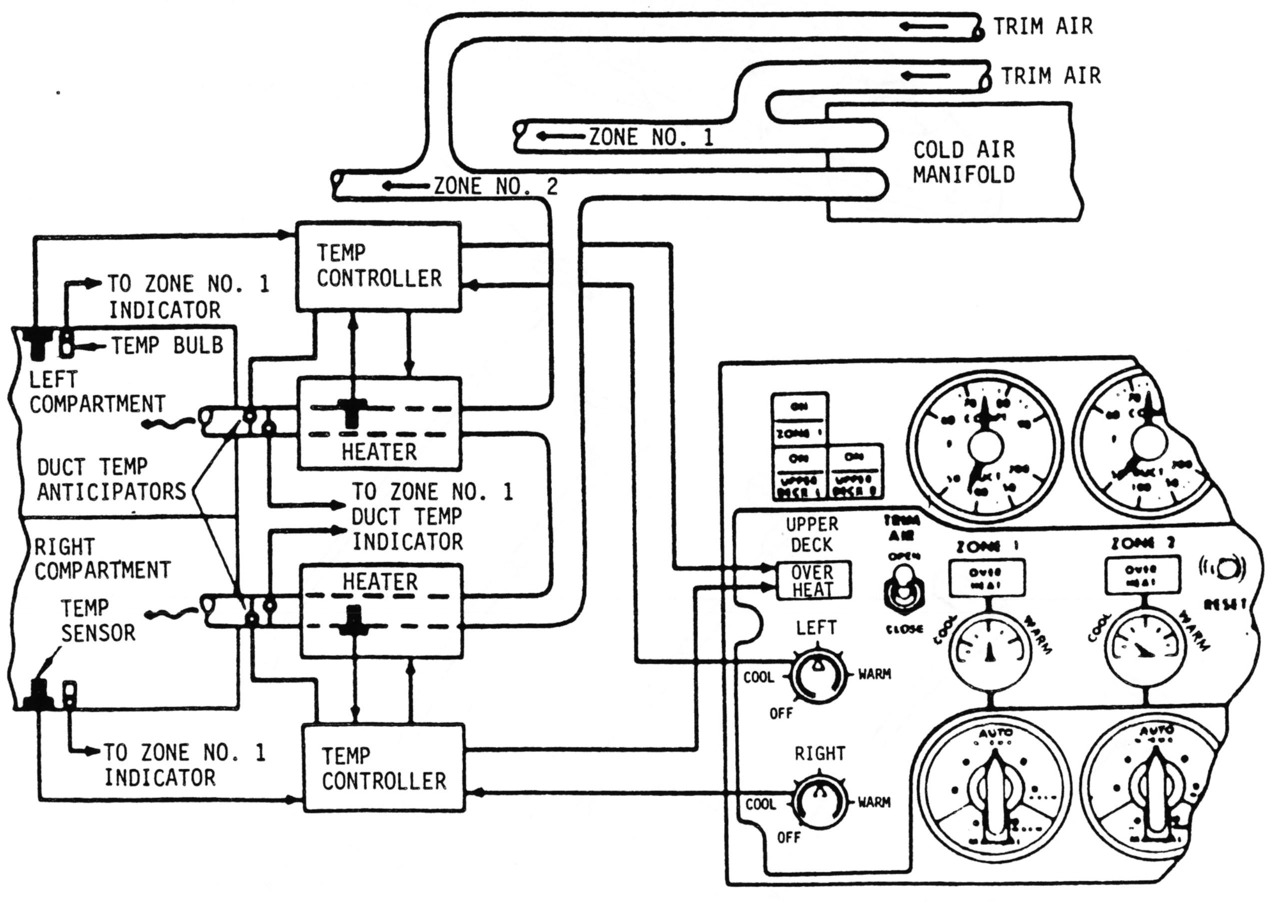


FIGURE 4-23. BOEING 747-100,-200 UPPER DECK HEATING EQUIPMENT

BOEING 747

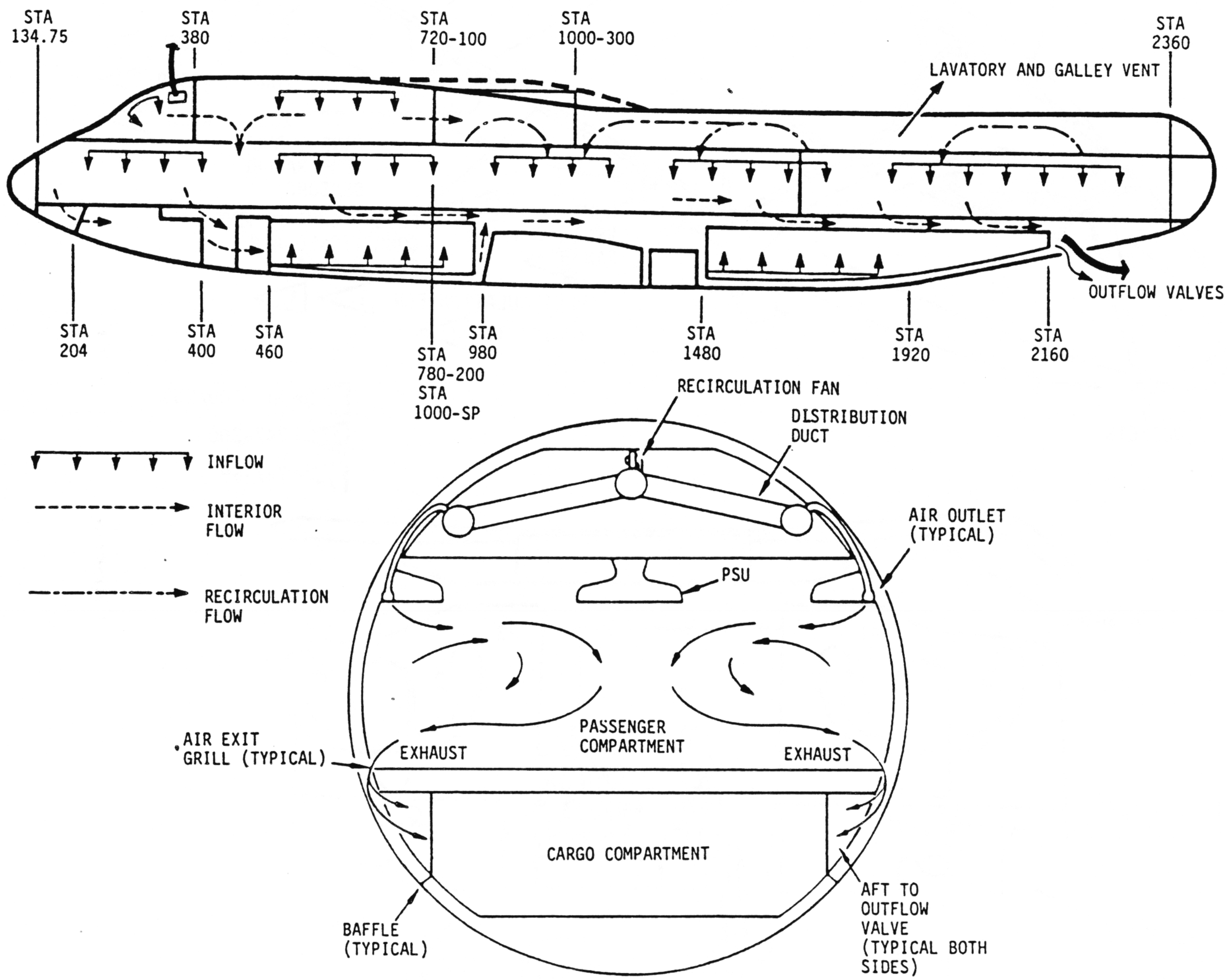
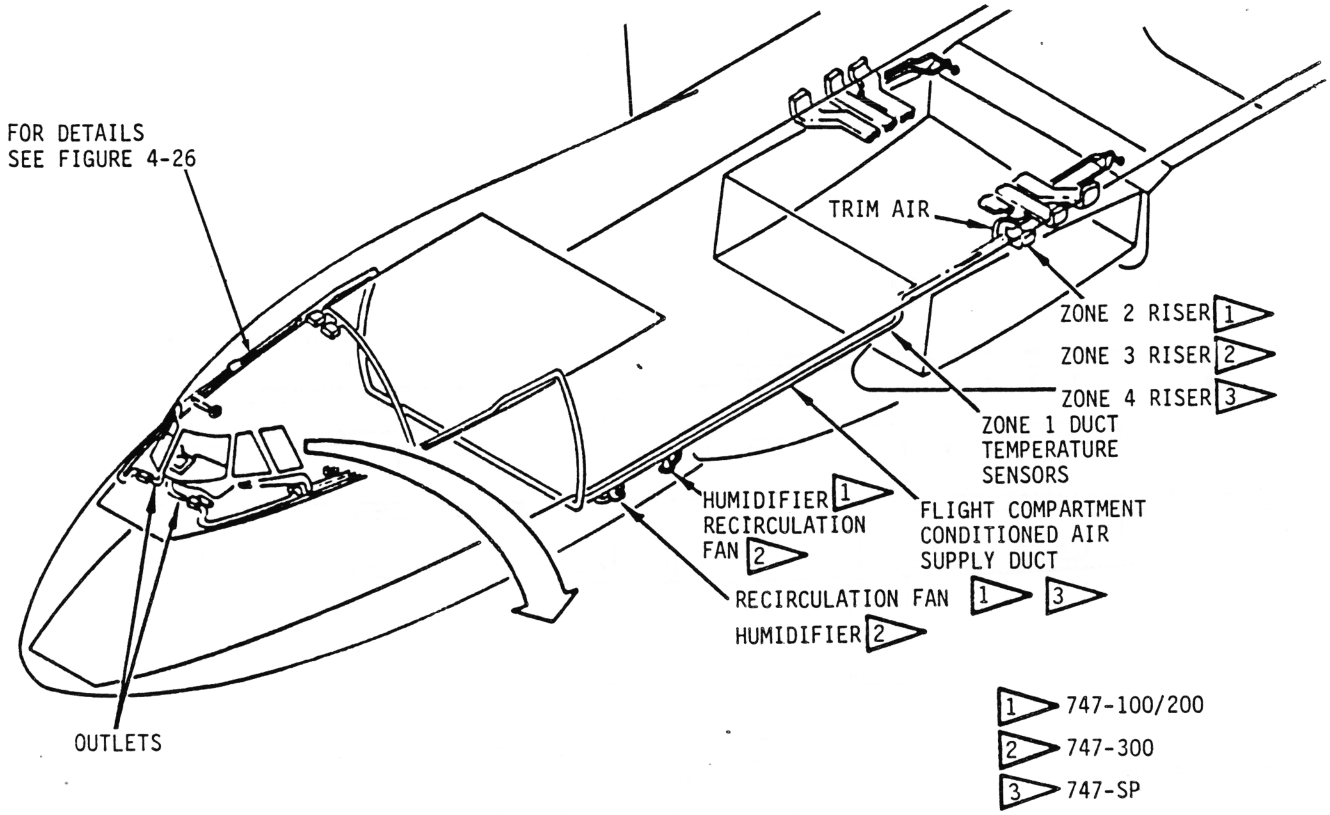


FIGURE 4-24. BOEING 747 PASSENGER CABIN AIR FLOW PATTERNS

BOEING 747



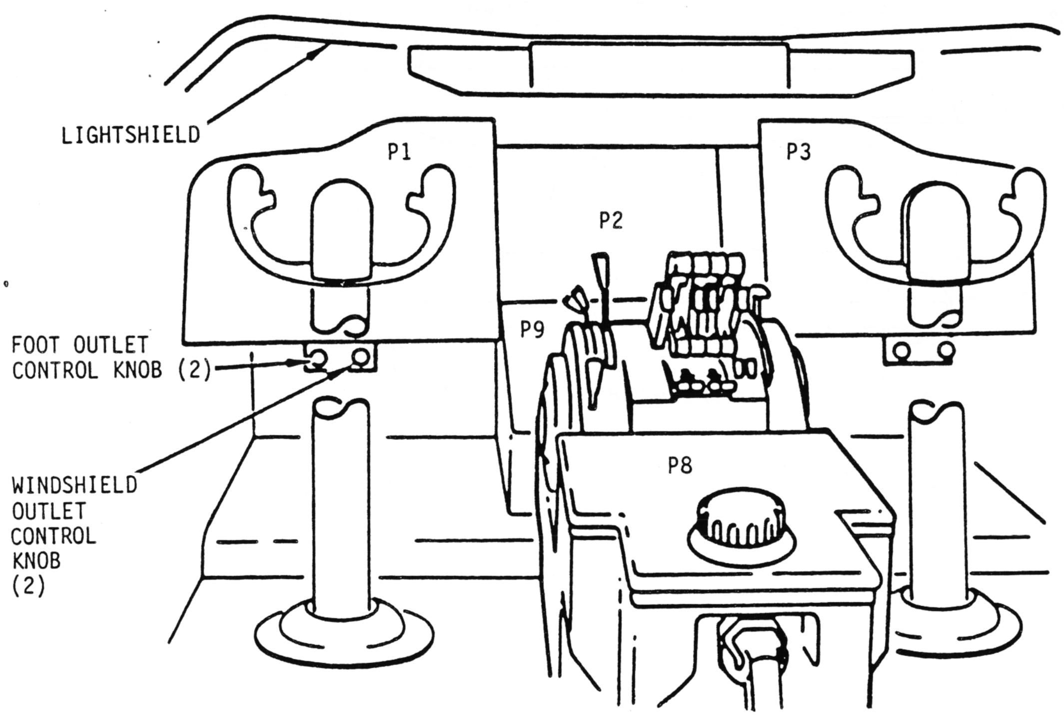


FIGURE 4-25. BOEING 747 FLIGHT DECK CONDITIONED AIR SUPPLY DUCTING

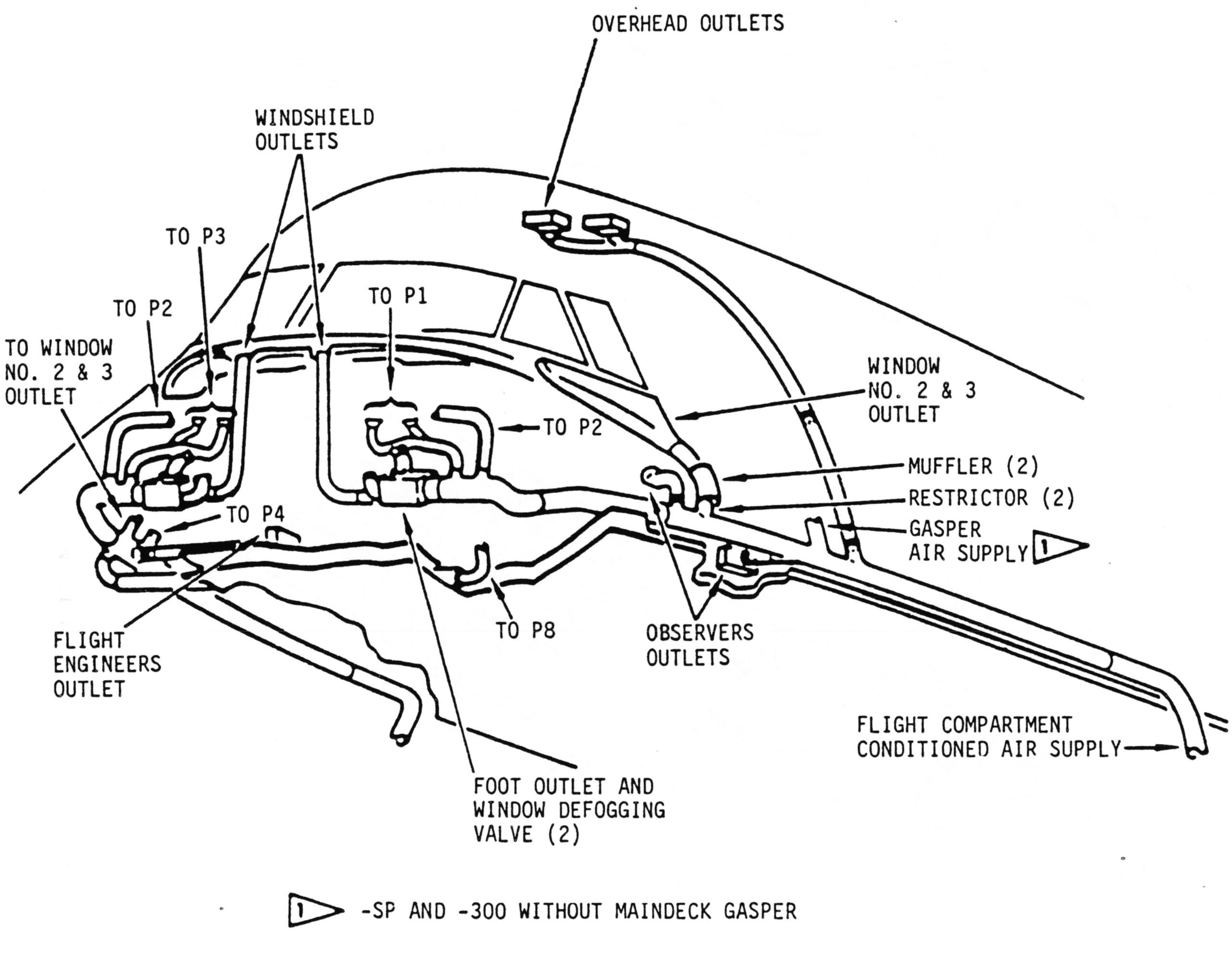


FIGURE 4-26. BOEING 747 FLIGHT DECK DISTRIBUTION DUCTING

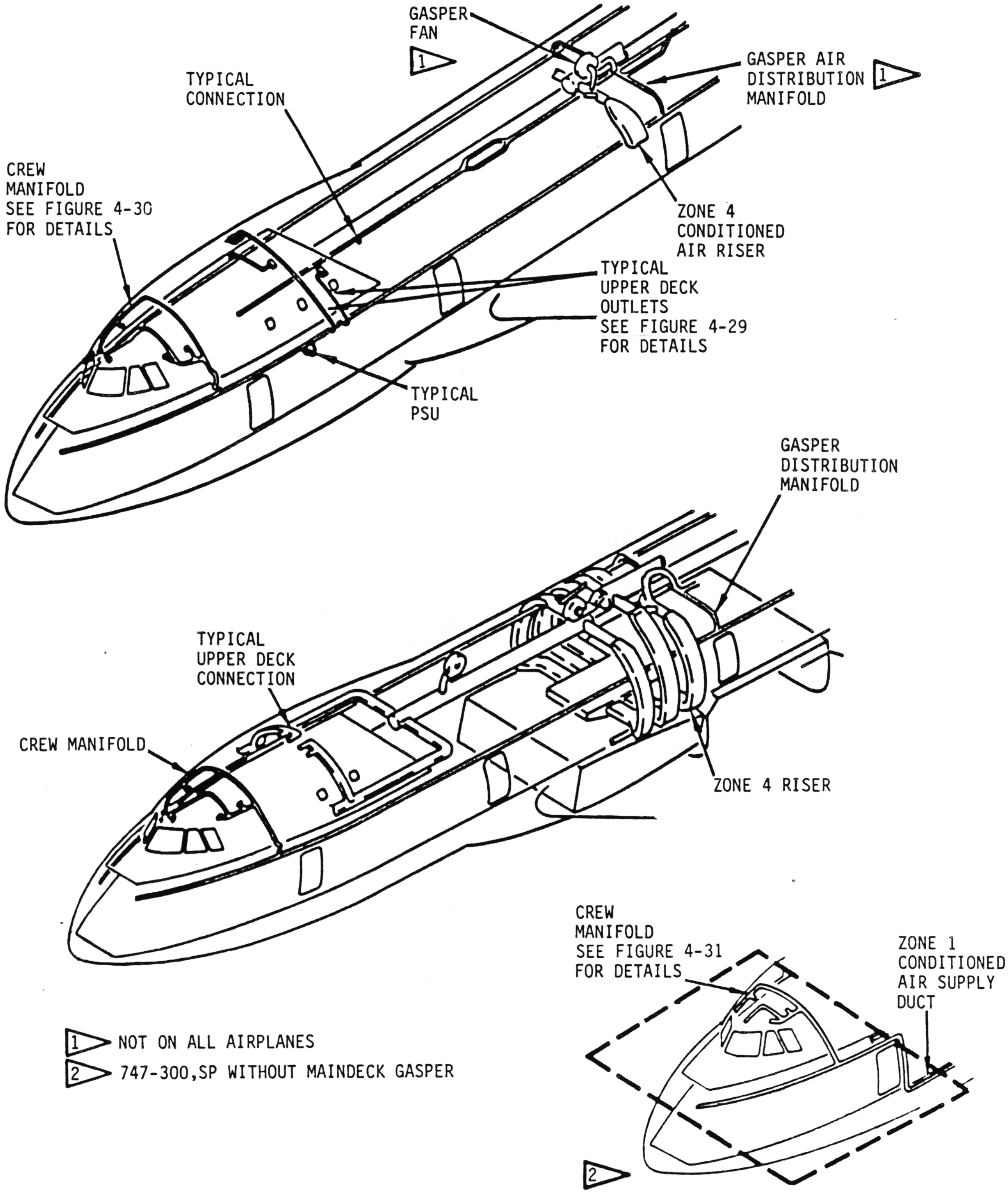


FIGURE 4-27. BOEING 747 INDIVIDUAL GASPER AIR DISTRIBUTION DUCTING

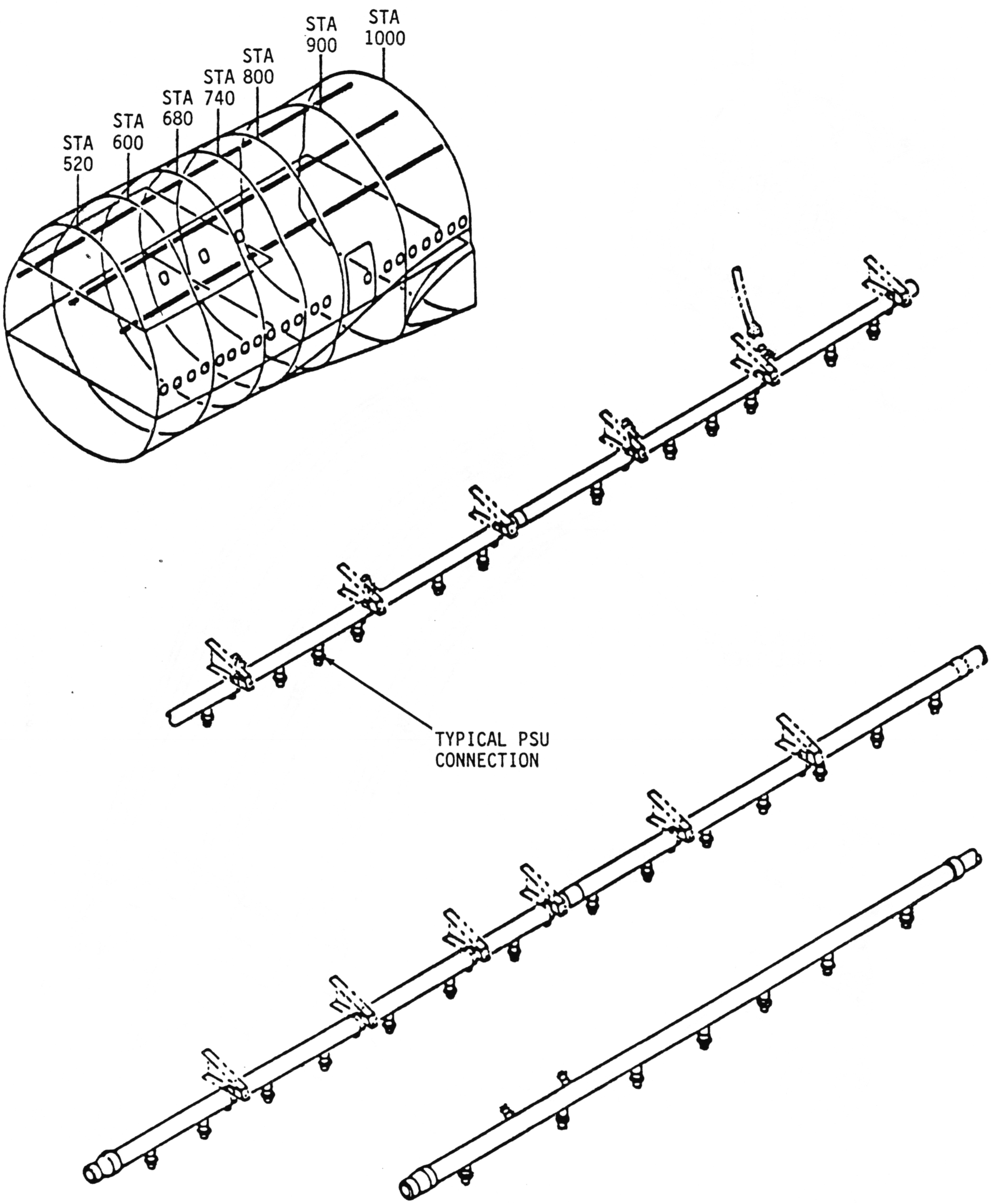


FIGURE 4-28. BOEING 747 INDIVIDUAL AIR DUCTS

BOEING 747

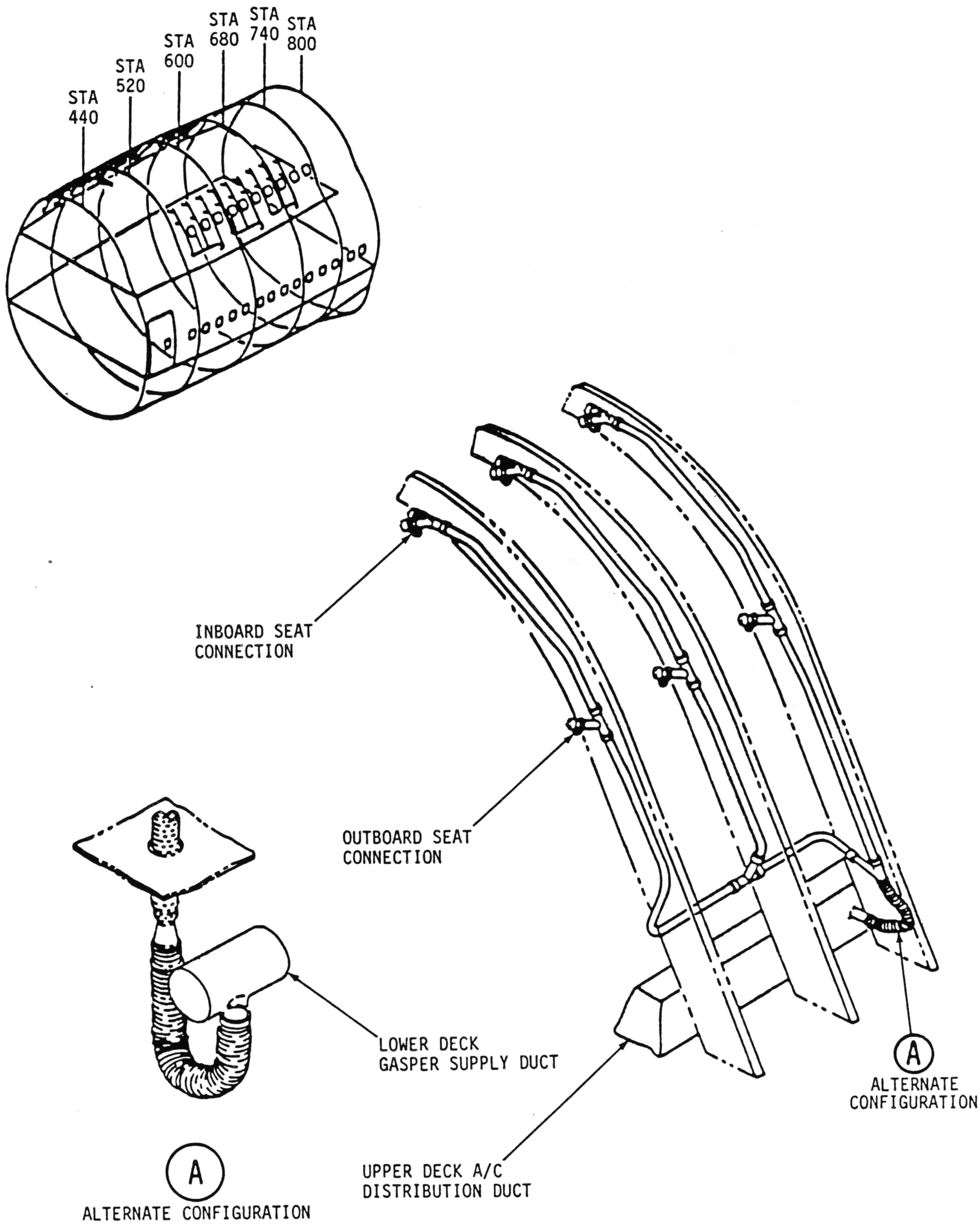


FIGURE 4-29. BOEING 747 UPPER DECK GASPER AIR DUCTING

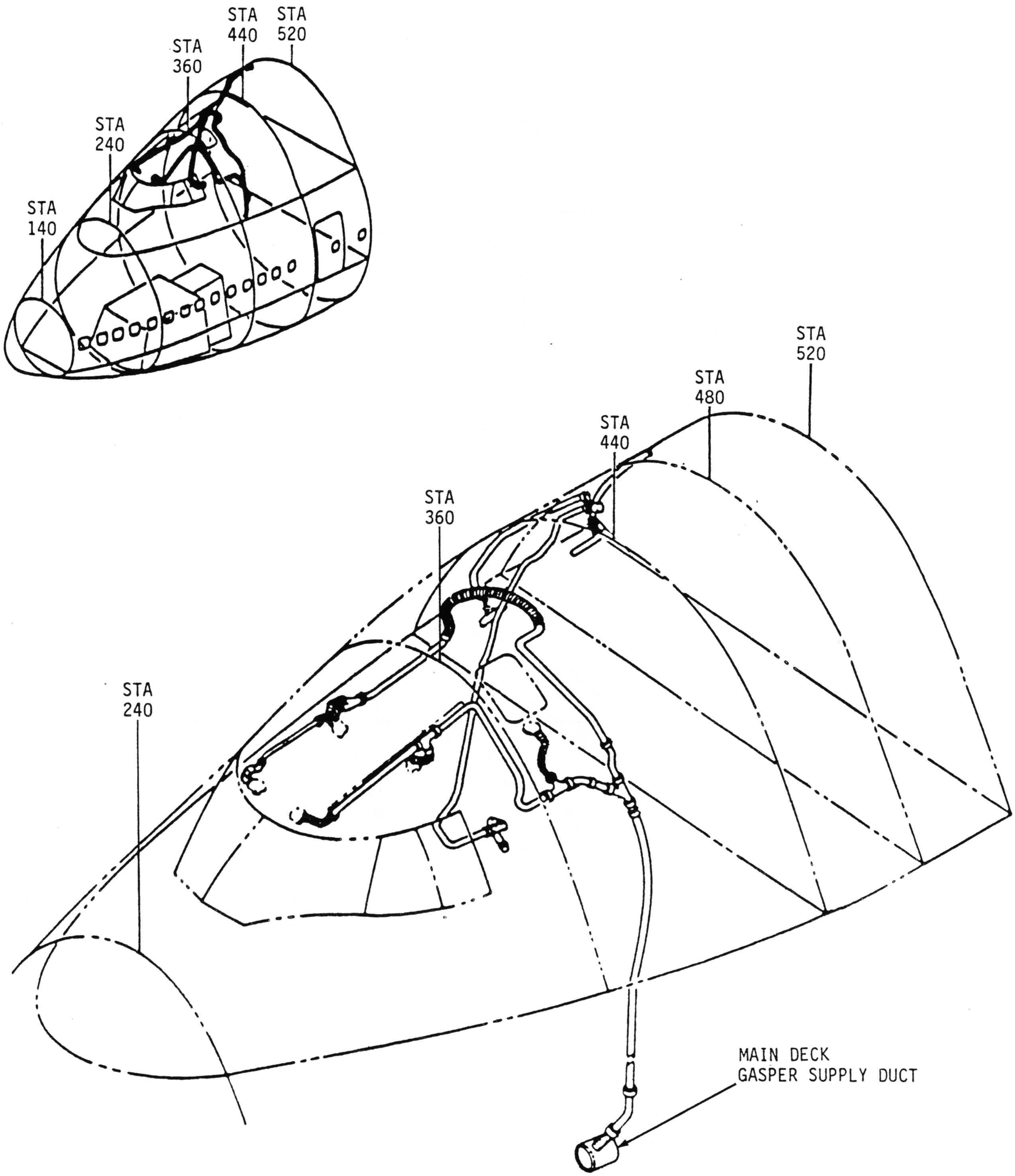
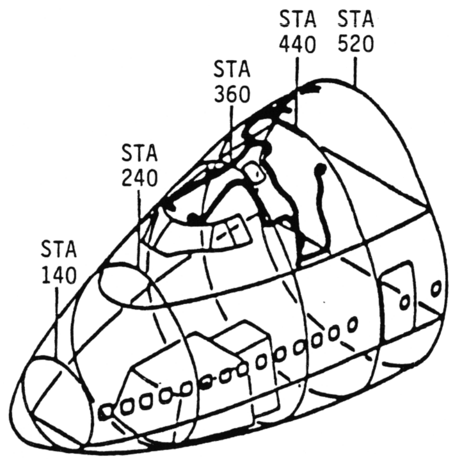


FIGURE 4-30. BOEING 747 MAIN DECK GASPER SYSTEM

BOEING 747-300,-SP



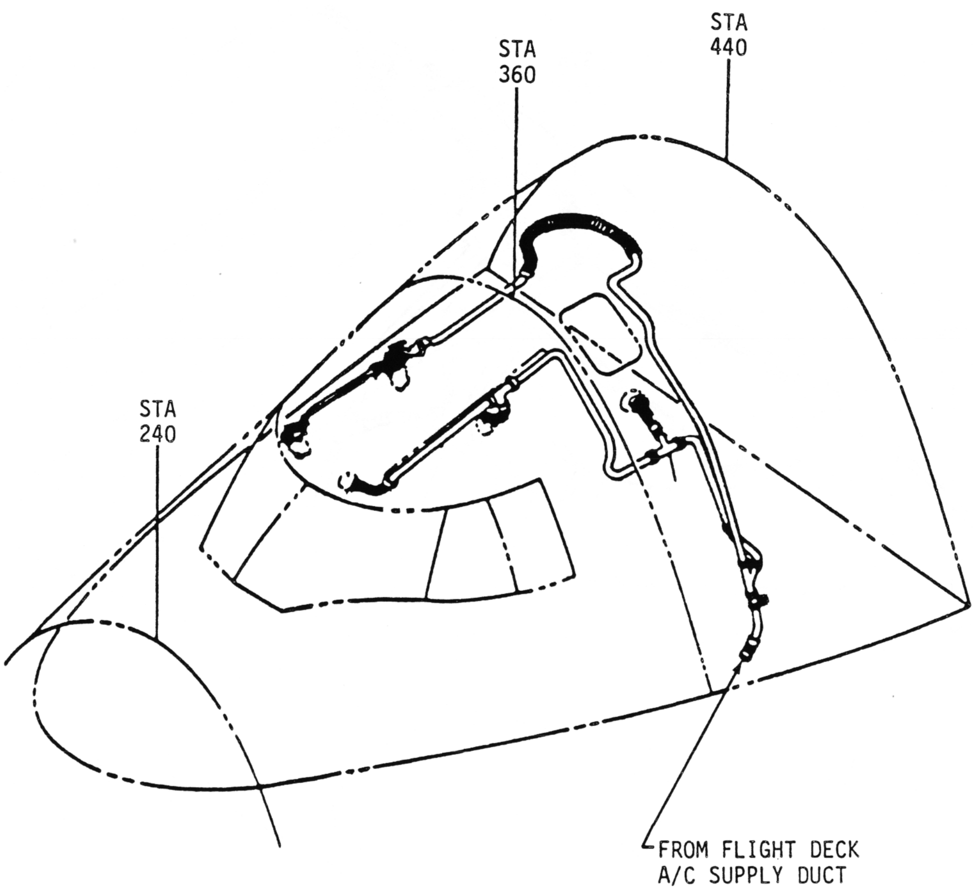


FIGURE 4-31. BOEING 747-300,-SP WITHOUT MAIN DECK GASPER SYSTEM

BOEING 747

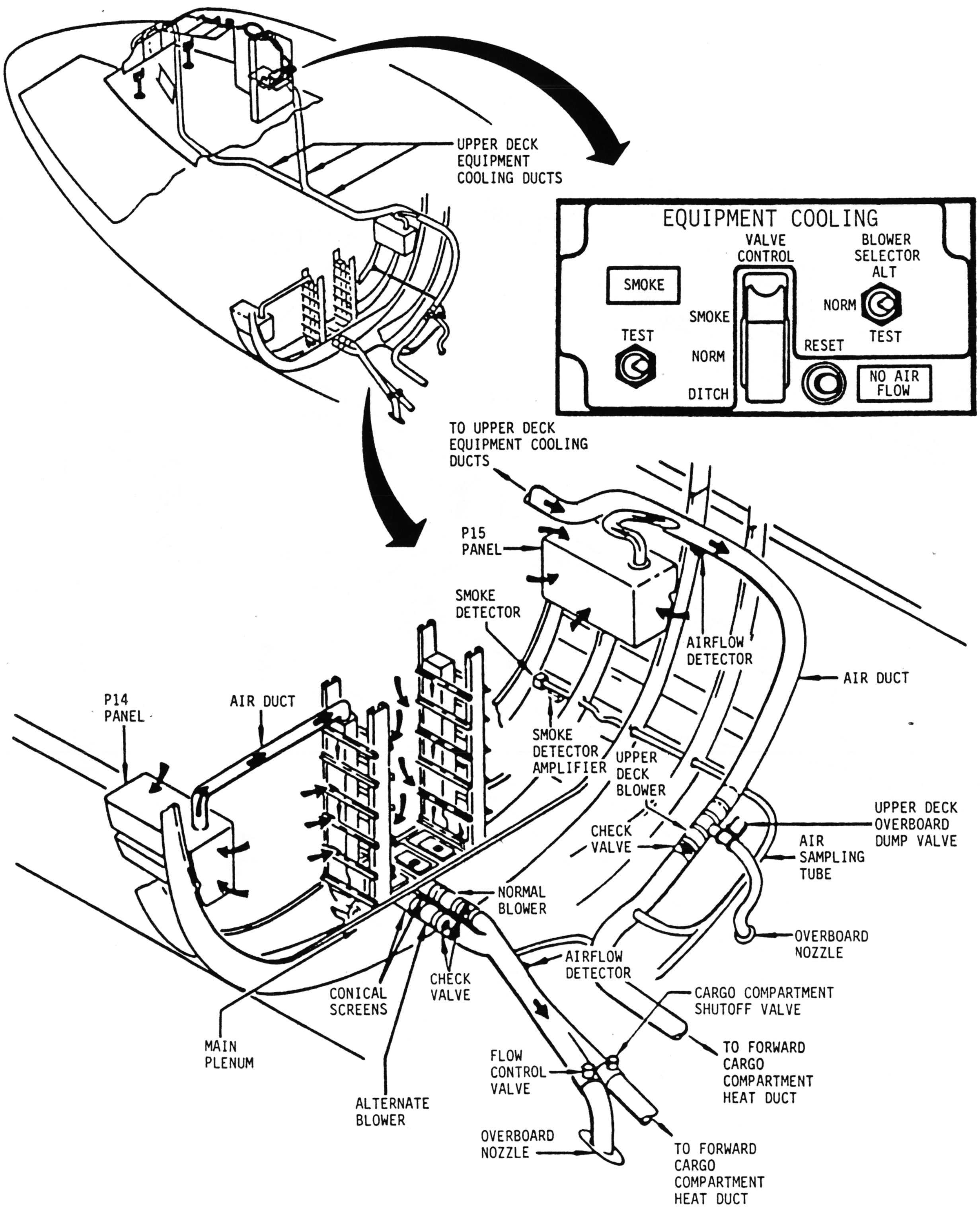


FIGURE 4-32. BOEING 747 EQUIPMENT COOLING SYSTEM

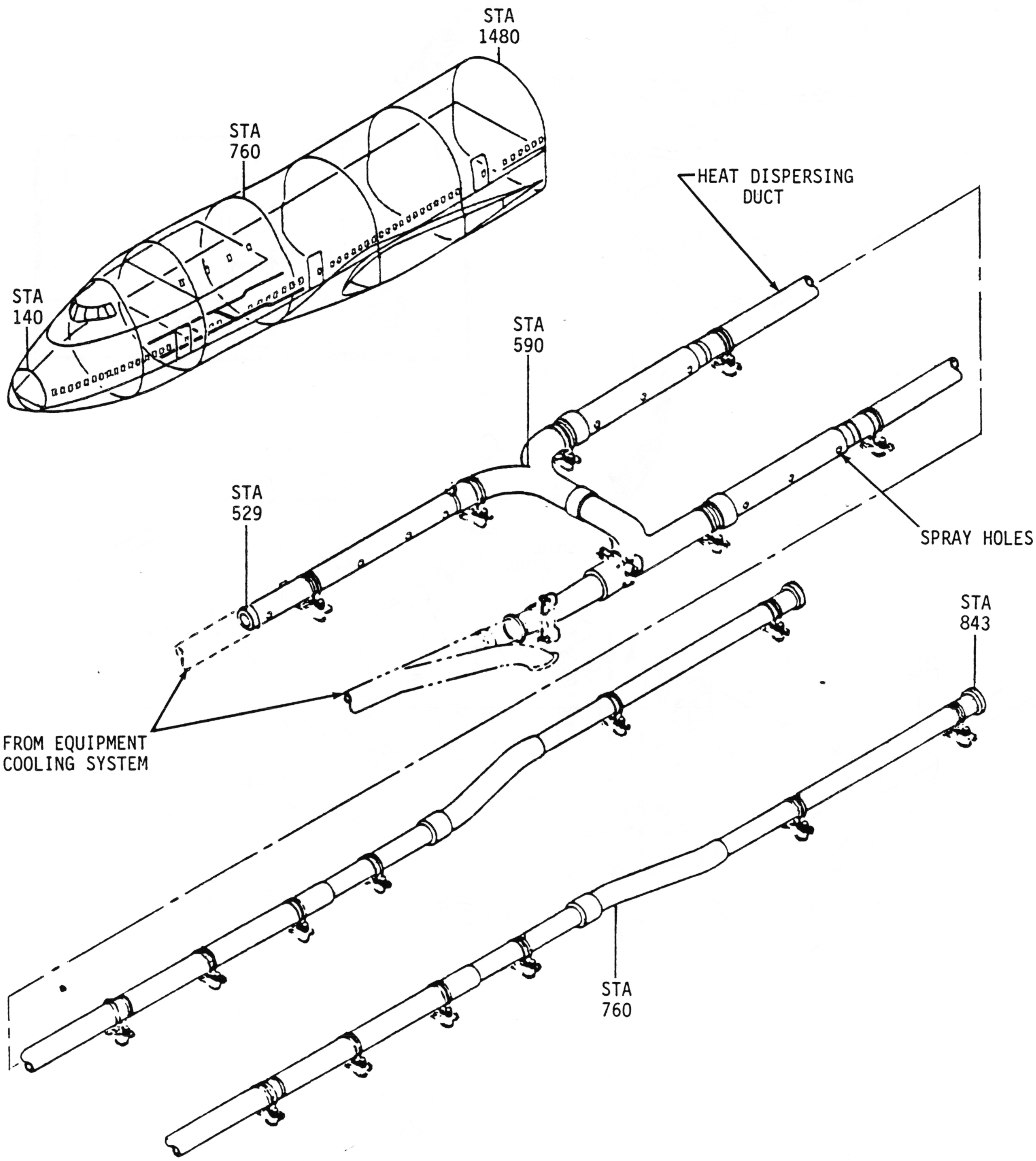


FIGURE 4-33. BOEING 747 FORWARD CARGO COMPARTMENT HEATING DUCTING

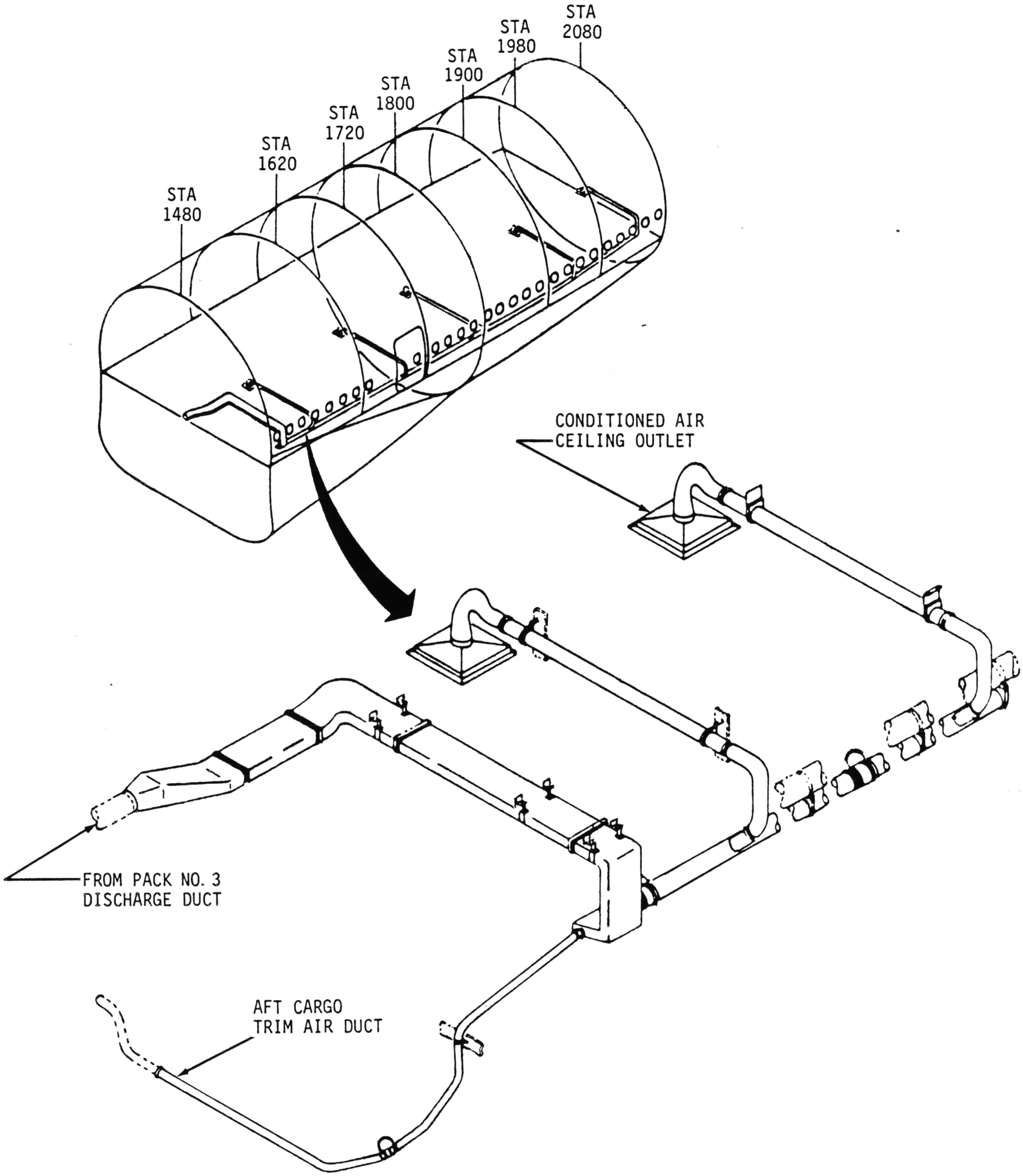


FIGURE 4-34. BOEING 747 AFT CARGO CONDITIONED AIR DISTRIBUTION DUCTING

BOEING 747

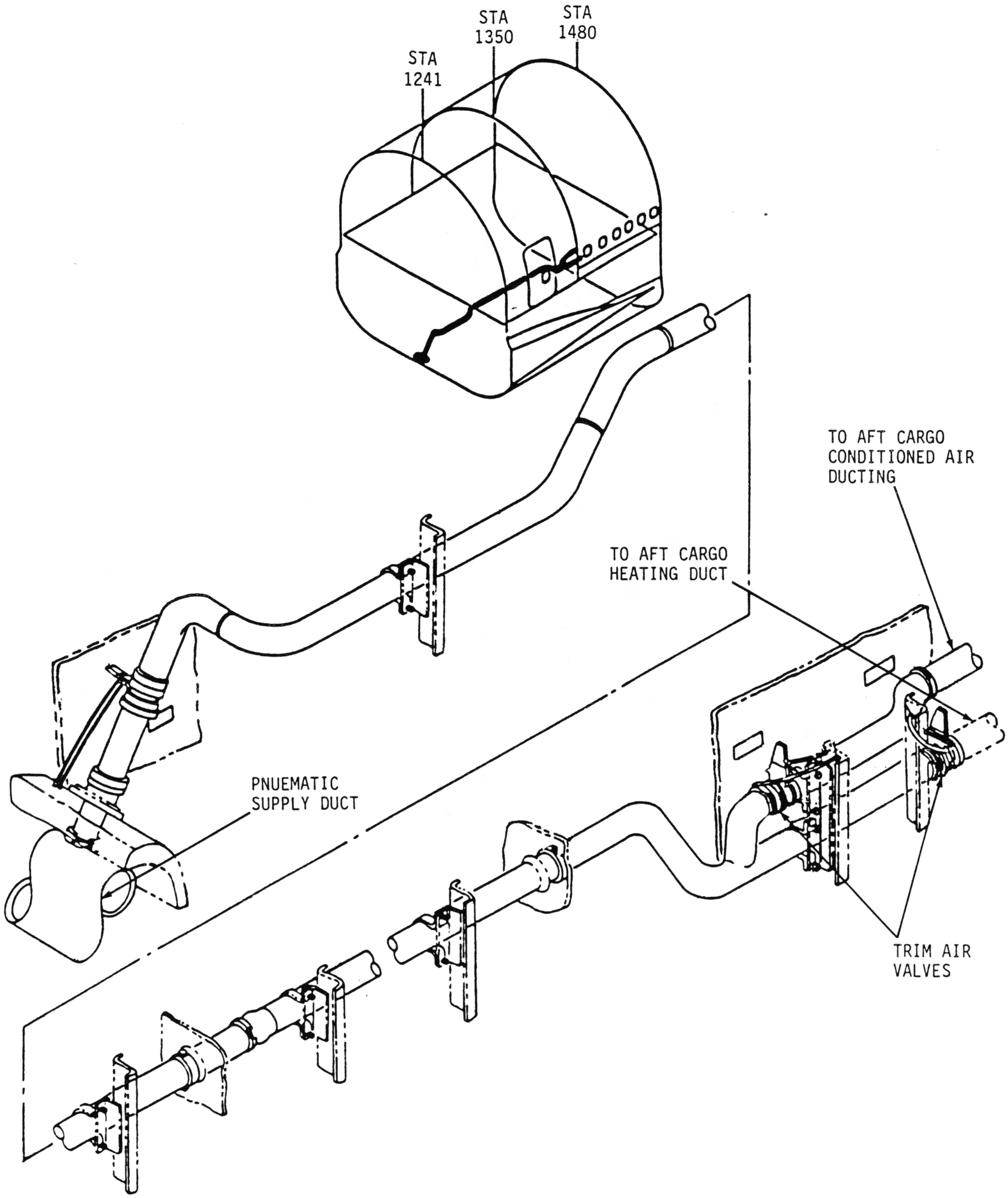


FIGURE 4-35. BOEING 747 AFT CARGO COMPARTMENT HOT AIR DISTRIBUTION

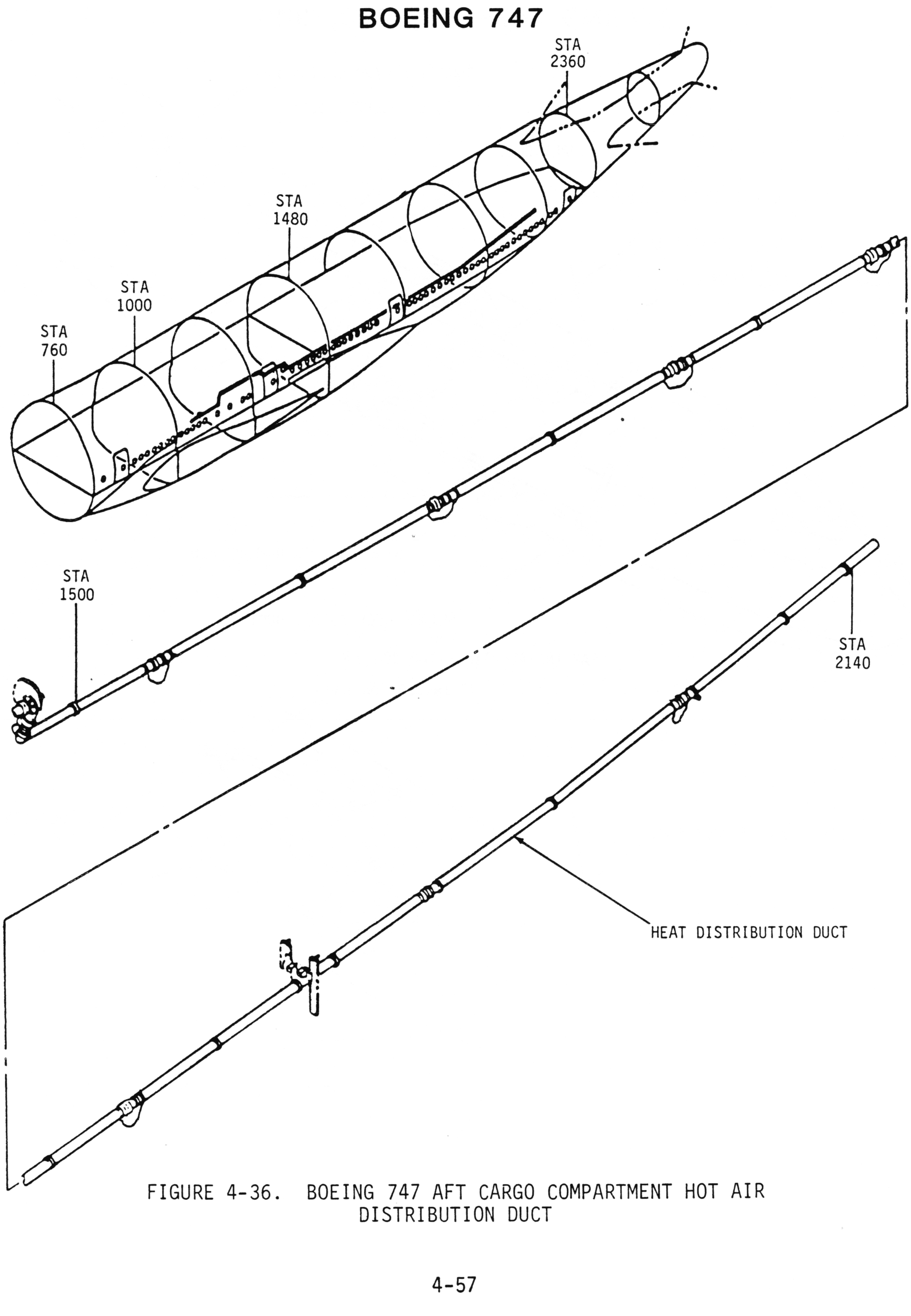
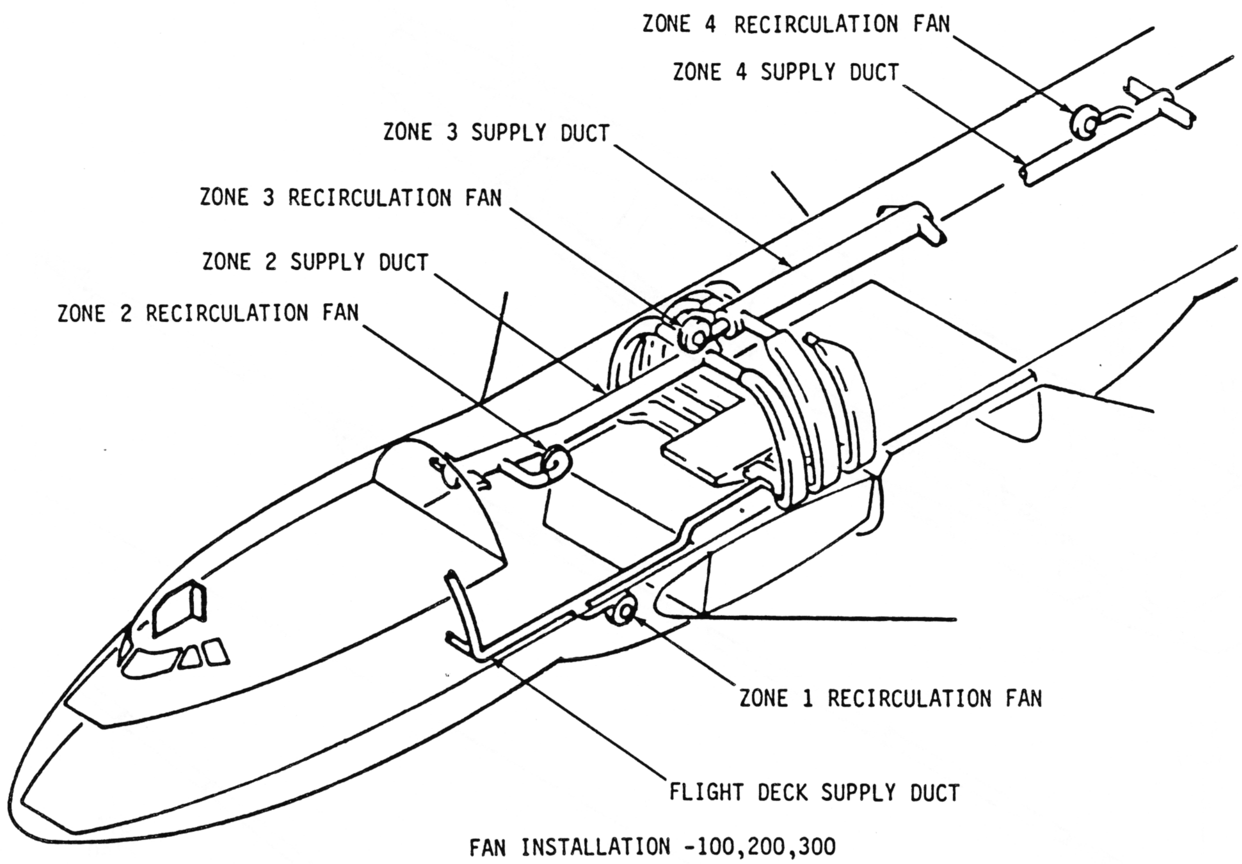
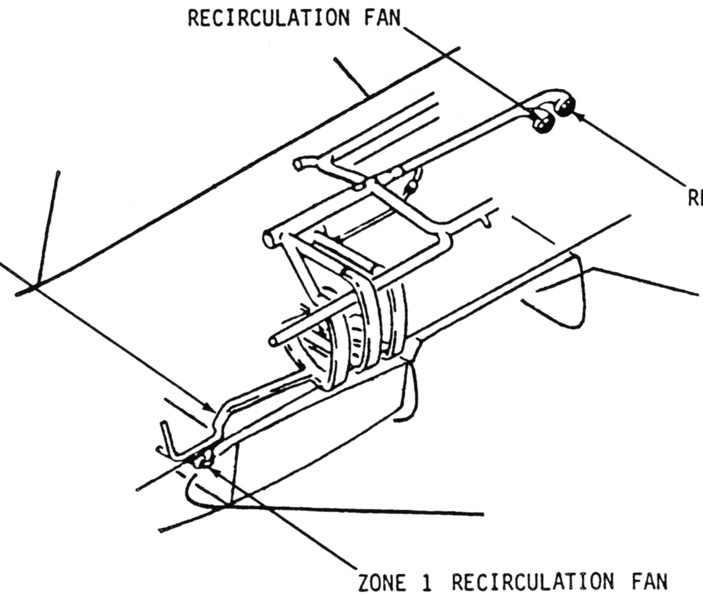


FIGURE 4-36. BOEING 747 AFT CARGO COMPARTMENT HOT AIR DISTRIBUTION DUCT

BOEING 747-100,-200,-300



FAN INSTALLATION -100,200,300



FAN INSTALLATION -SP
SEE FIGURE 4-38

FIGURE 4-37. BOEING 747-100,-200,-300 RECIRCULATION SYSTEM FANS

BOEING 747-SP

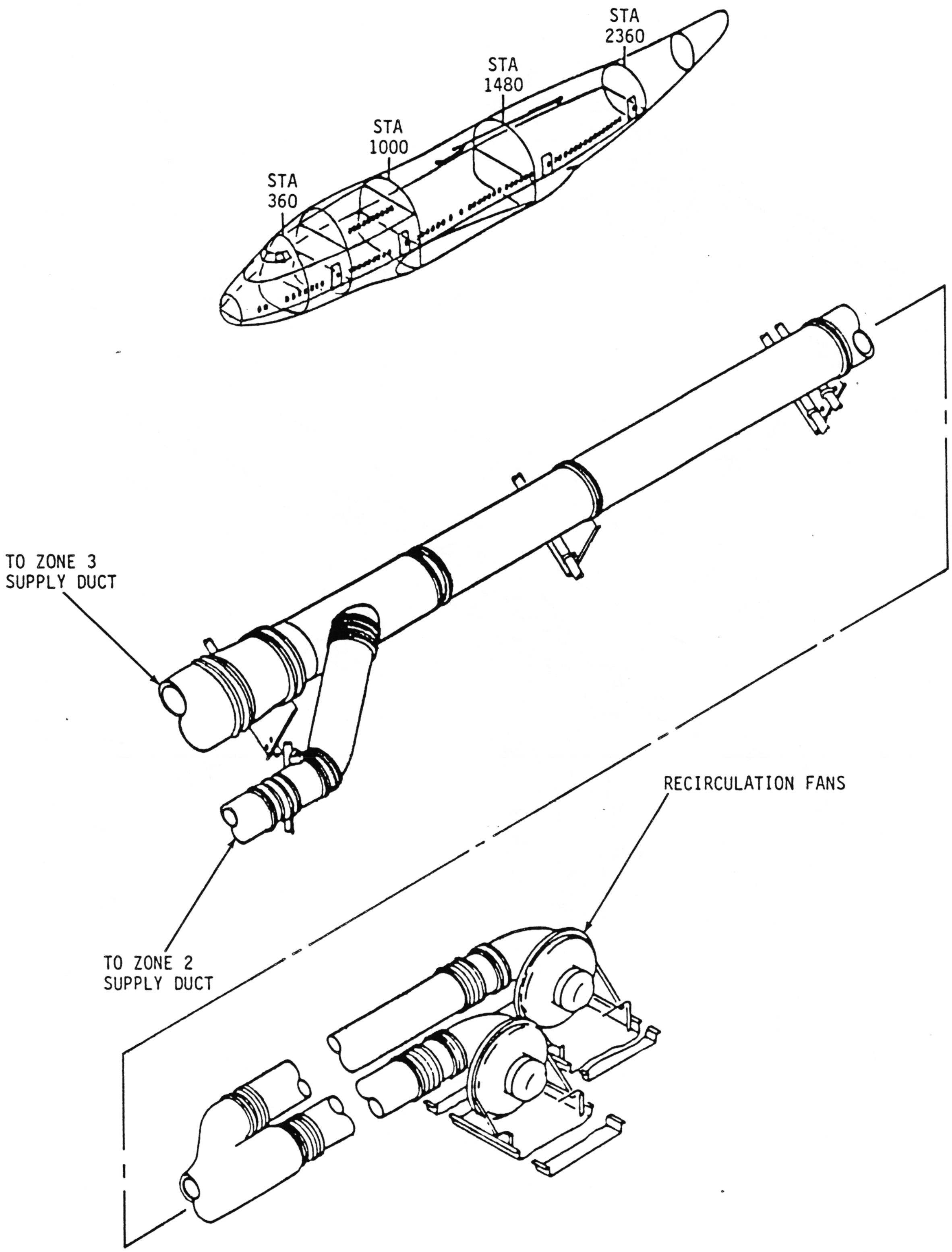


FIGURE 4-38. BOEING 747-SP RECIRCULATION SYSTEM

BOEING 747

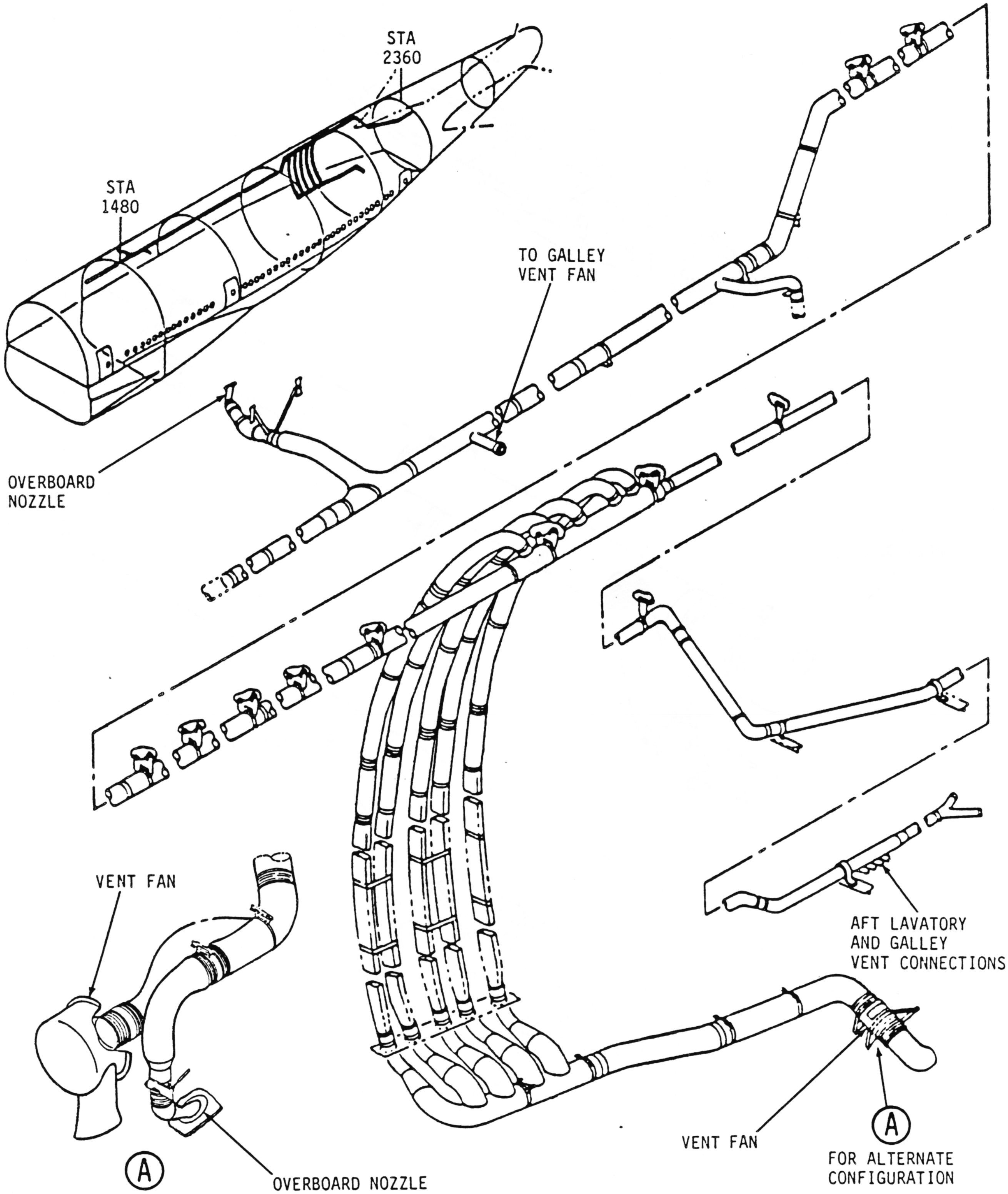


FIGURE 4-39. BOEING 747 LAVATORY/GALLEY VENT SYSTEM

BOEING 747

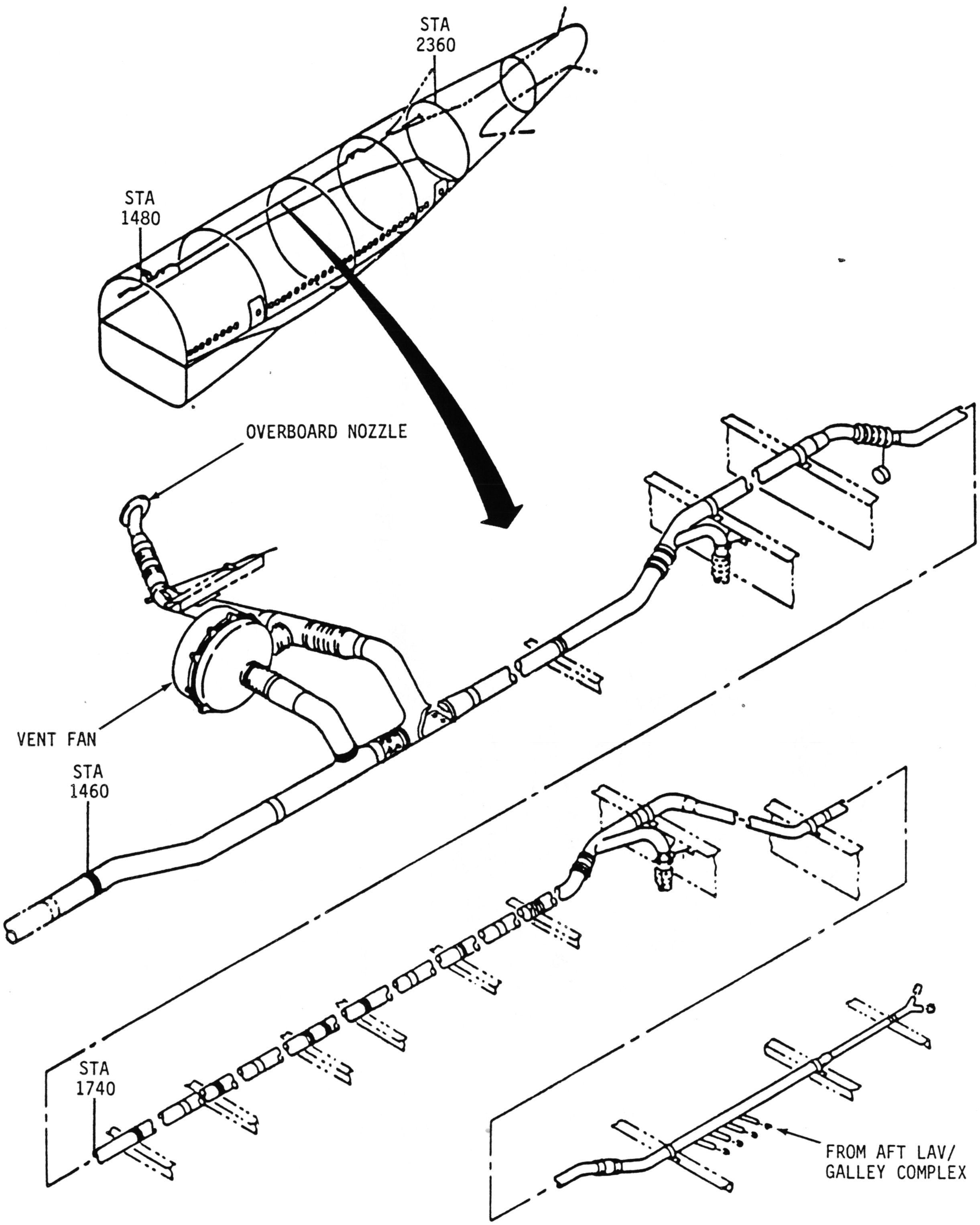


FIGURE 4-40. BOEING 747 LAVATORY/GALLEY VENT SYSTEM, ALTERNATE CONFIGURATION

BOEING 747-SP

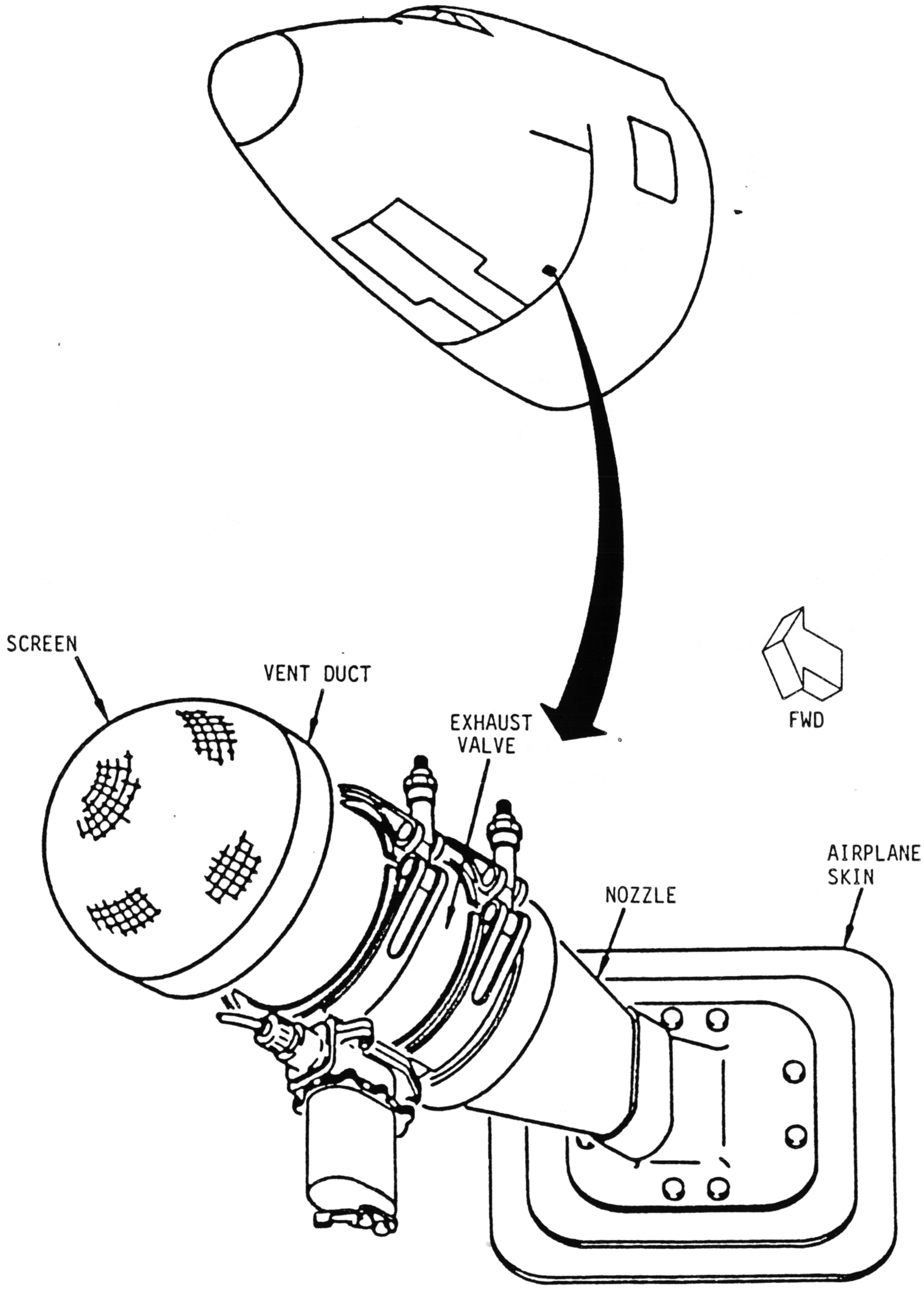


FIGURE 4-41. BOEING 747-SP AVIONICS COMPARTMENT VENT

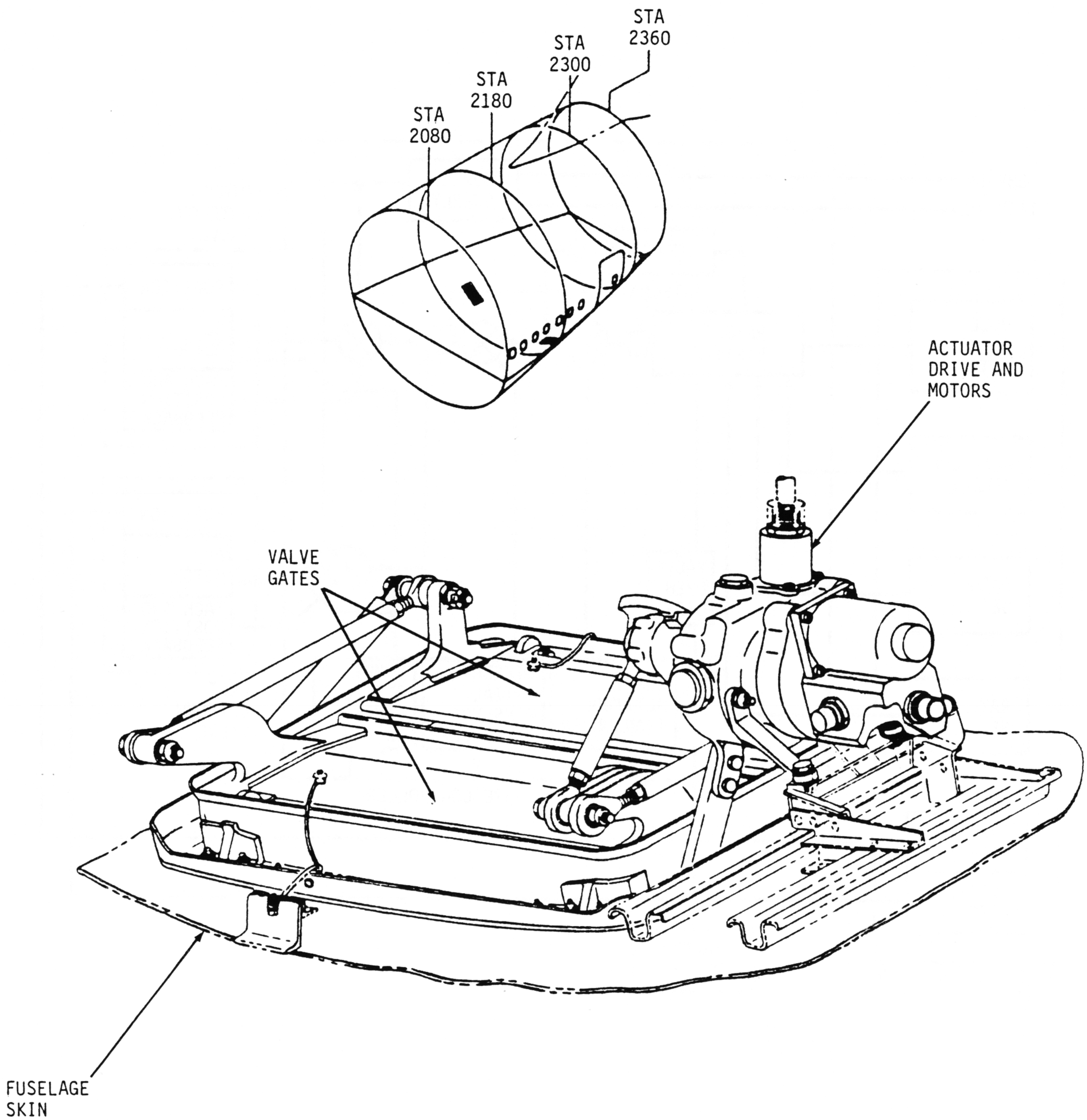


FIGURE 4-42. BOEING 747 PRESSURIZATION SYSTEM OUTFLOW VALVE

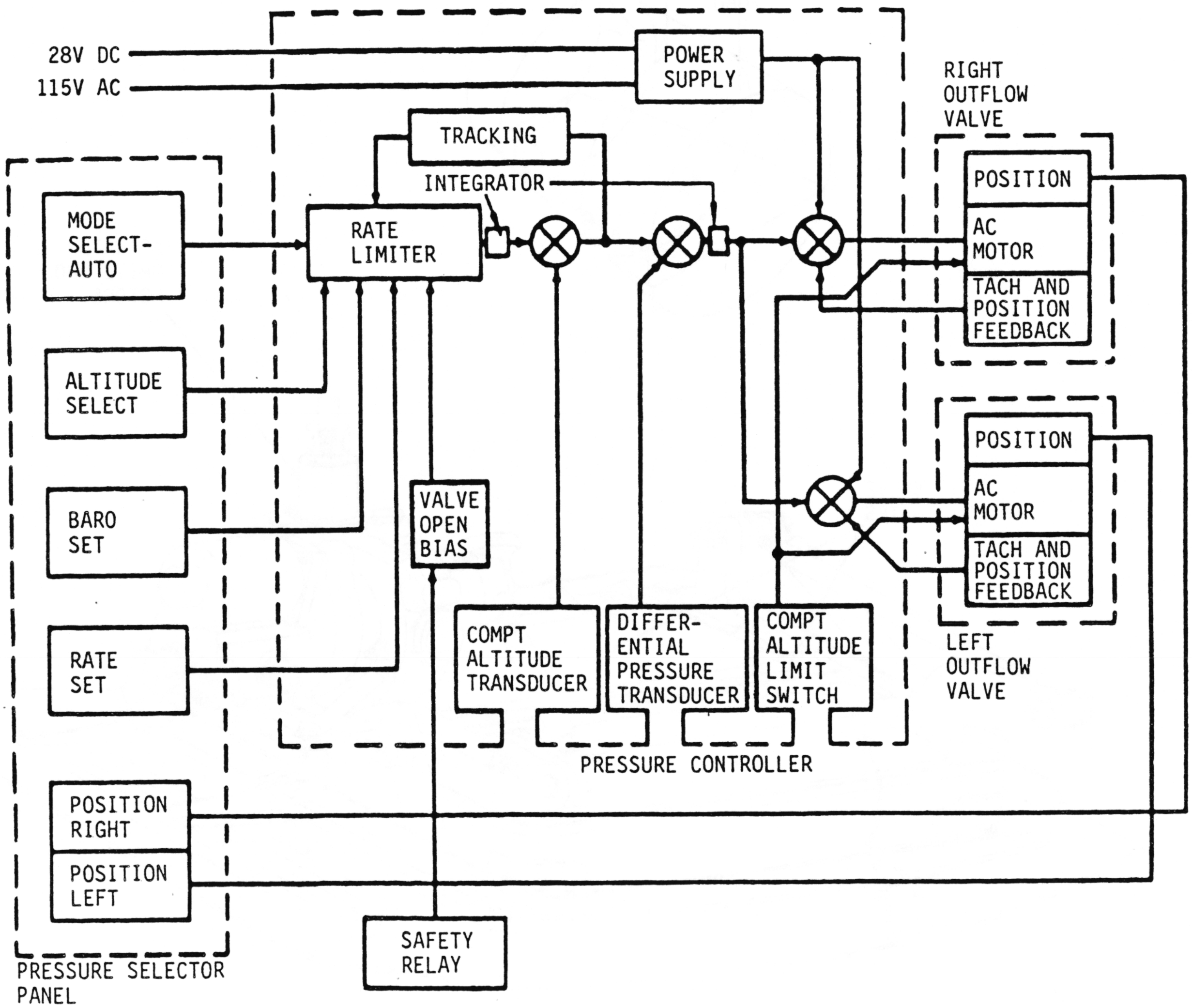


FIGURE 4-43. BOEING 747 PRESSURIZATION CONTROL AUTO MODE BLOCK DIAGRAM

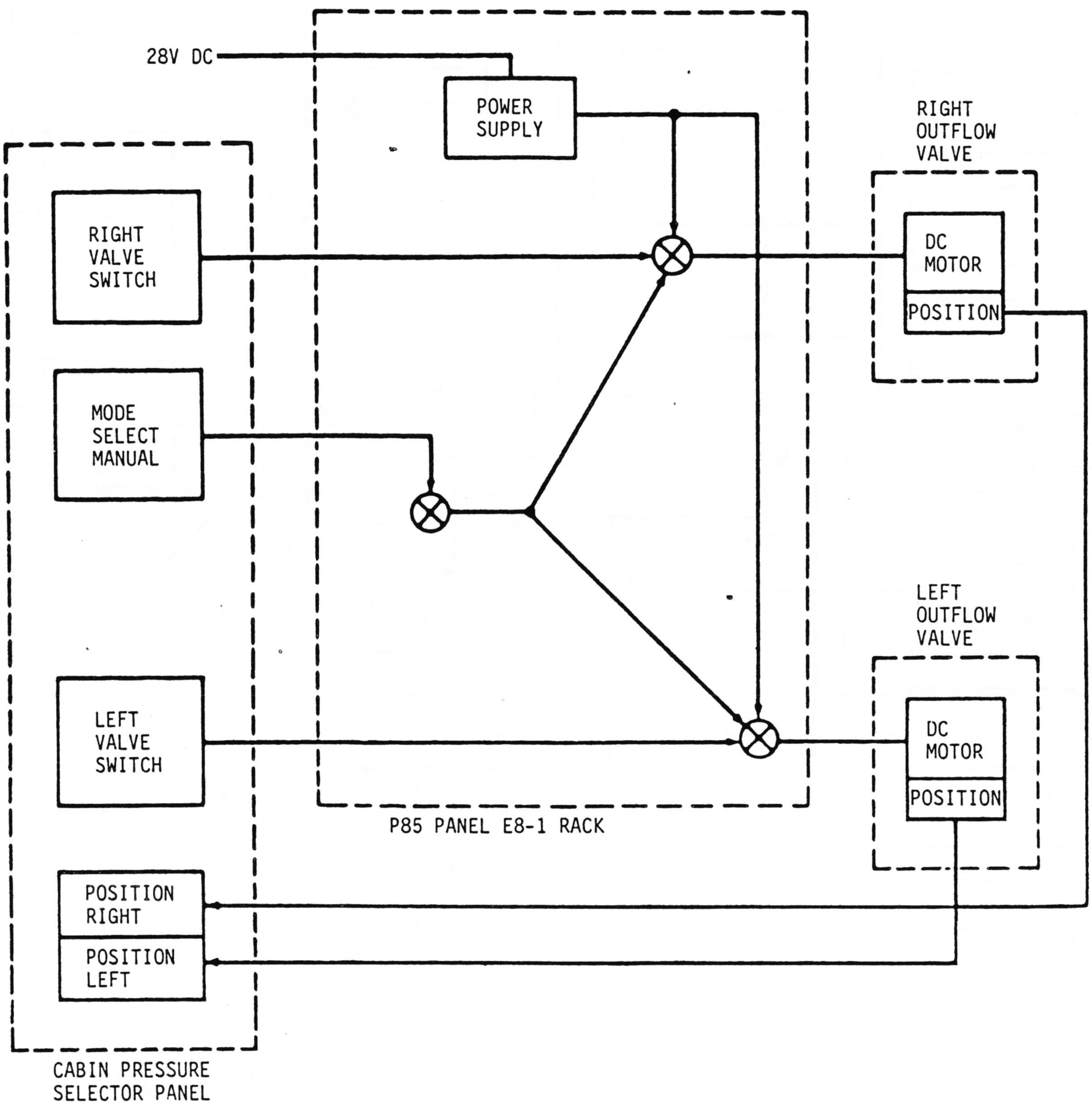


FIGURE 4-44. BOEING 747 PRESSURIZATION CONTROL MANUAL BLOCK DIAGRAM

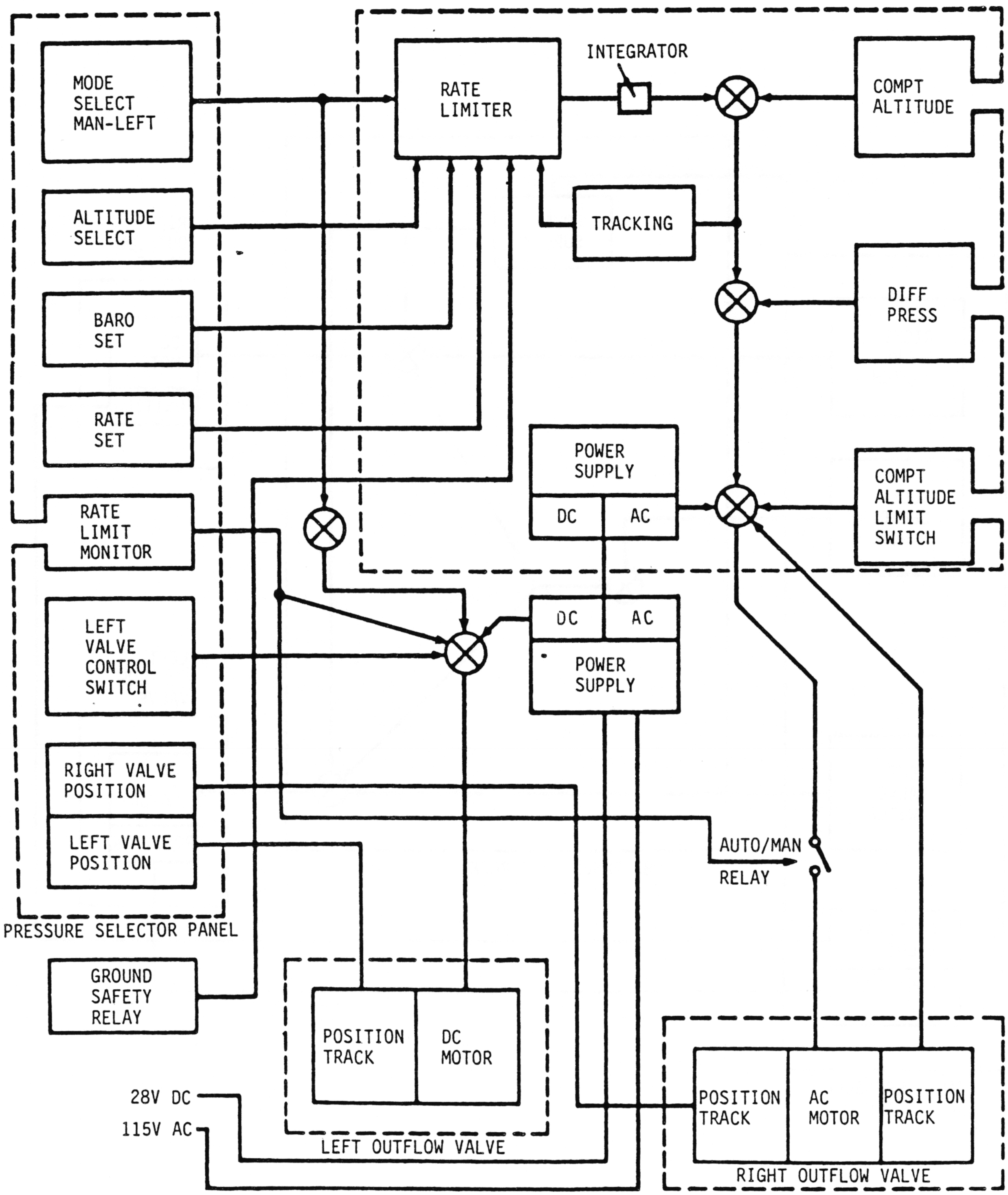


FIGURE 4-45. BOEING 747 PRESSURIZATION CONTROL MANUAL LEFT/RIGHT BLOCK DIAGRAM

BOEING 747

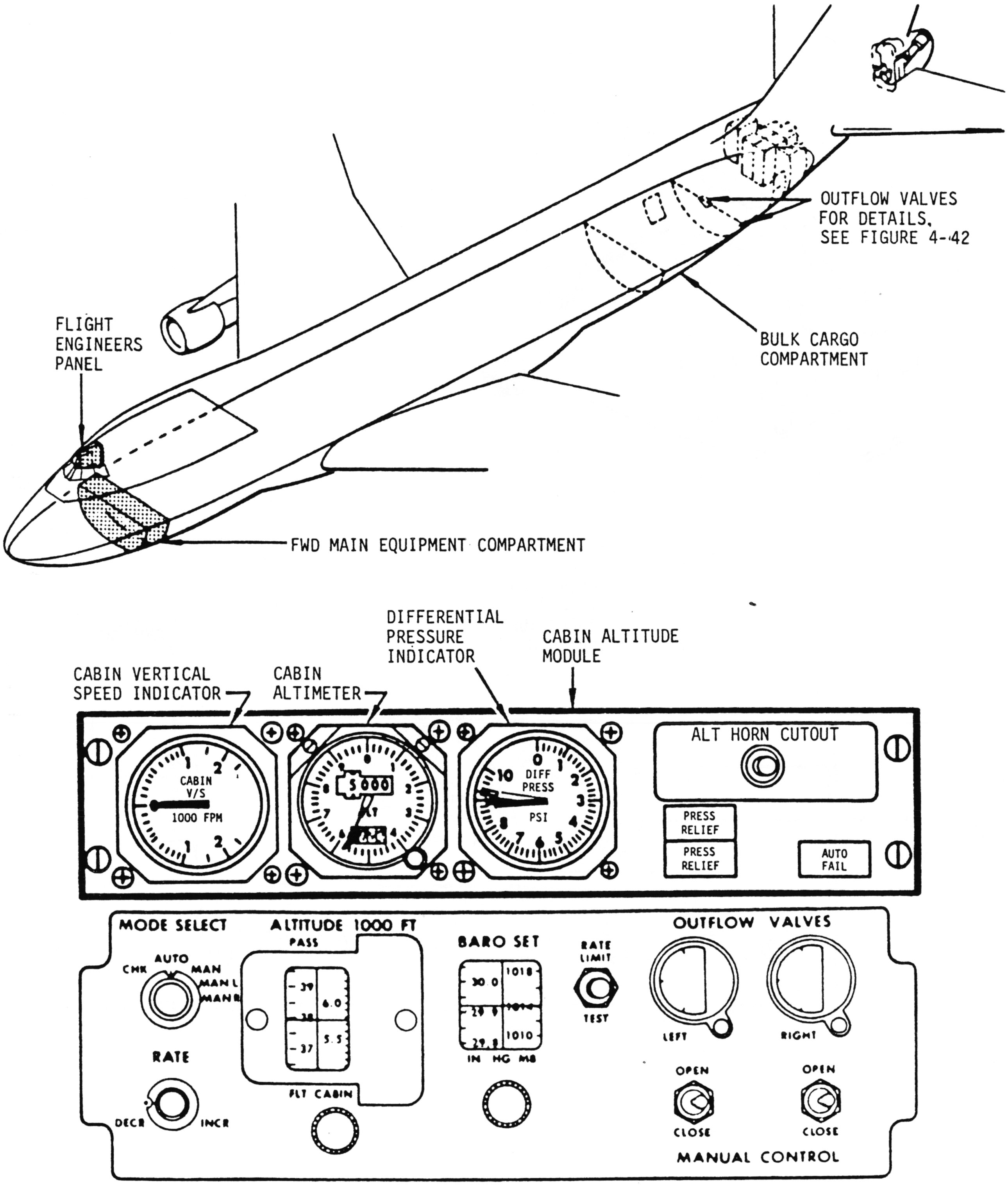


FIGURE 4-46. BOEING 747 PRESSURIZATION CONTROLS AND GUAGES

BOEING 747

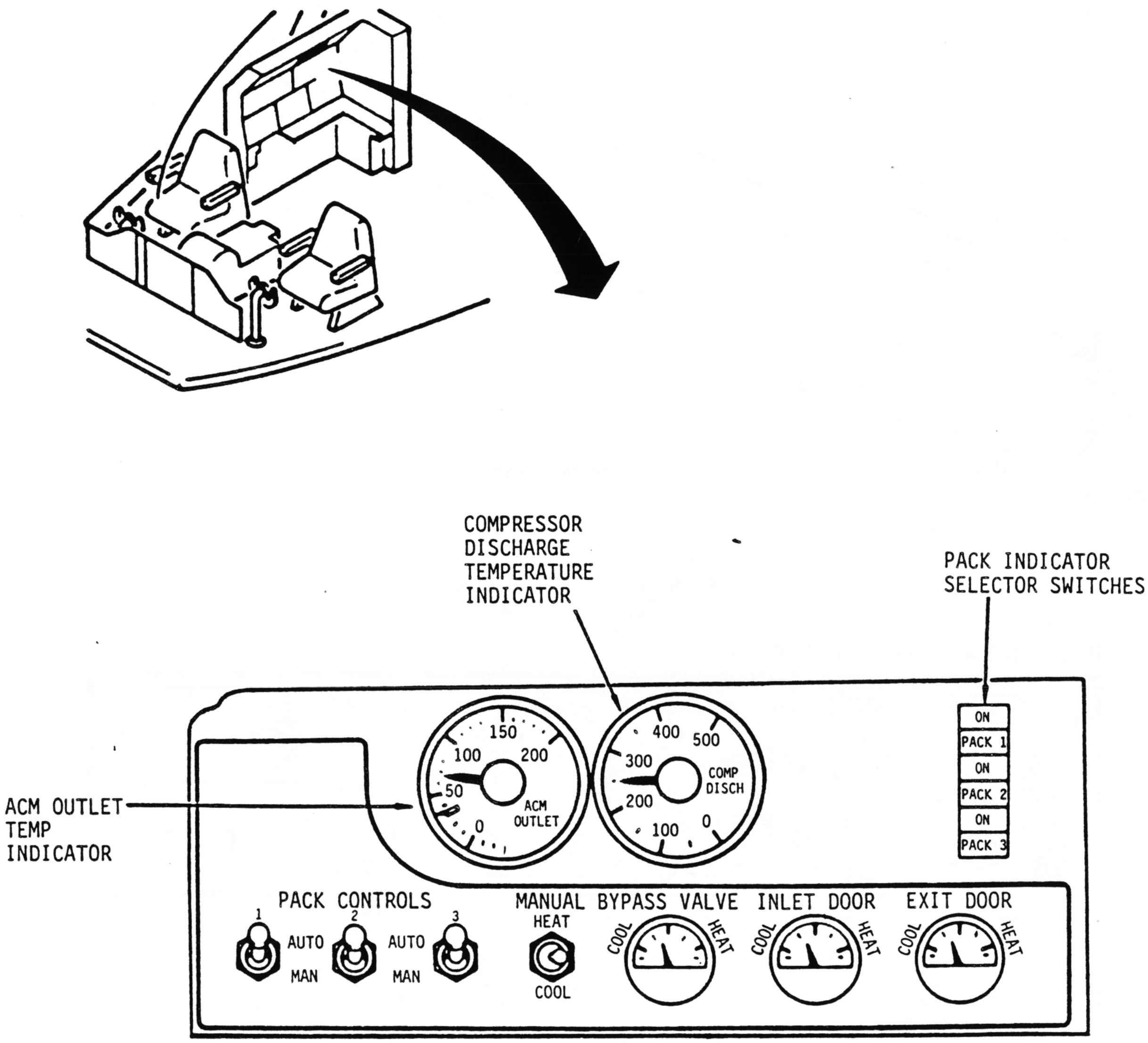
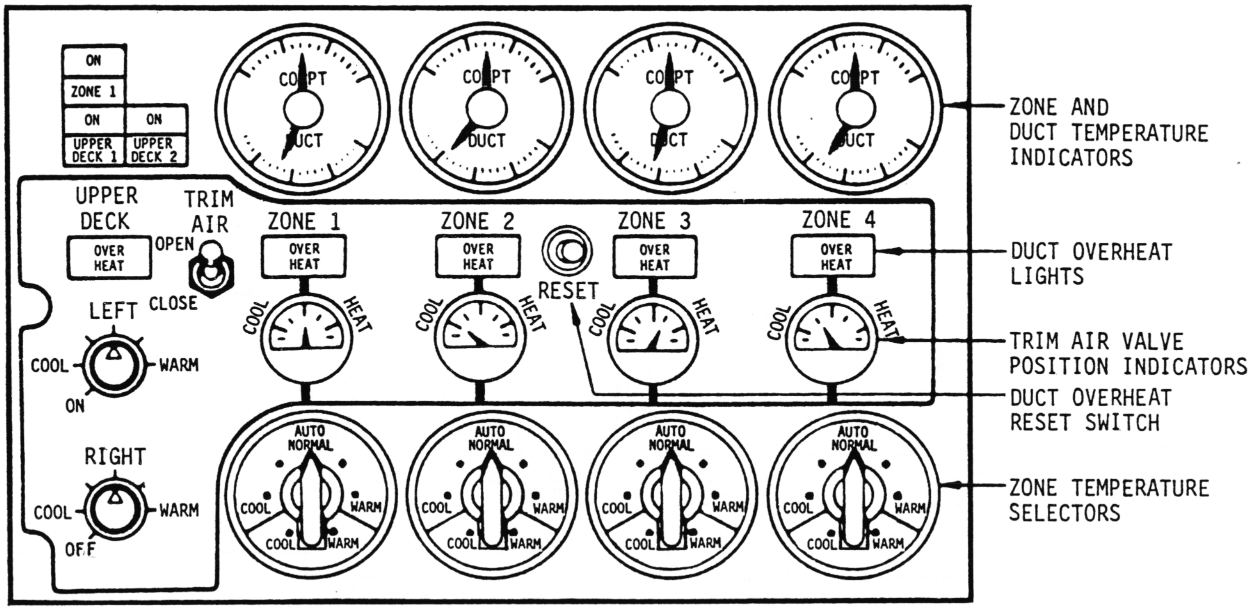


FIGURE 4-47. BOEING 747 A/C PACK CONTROLS

BOEING 747-100,-200,-300



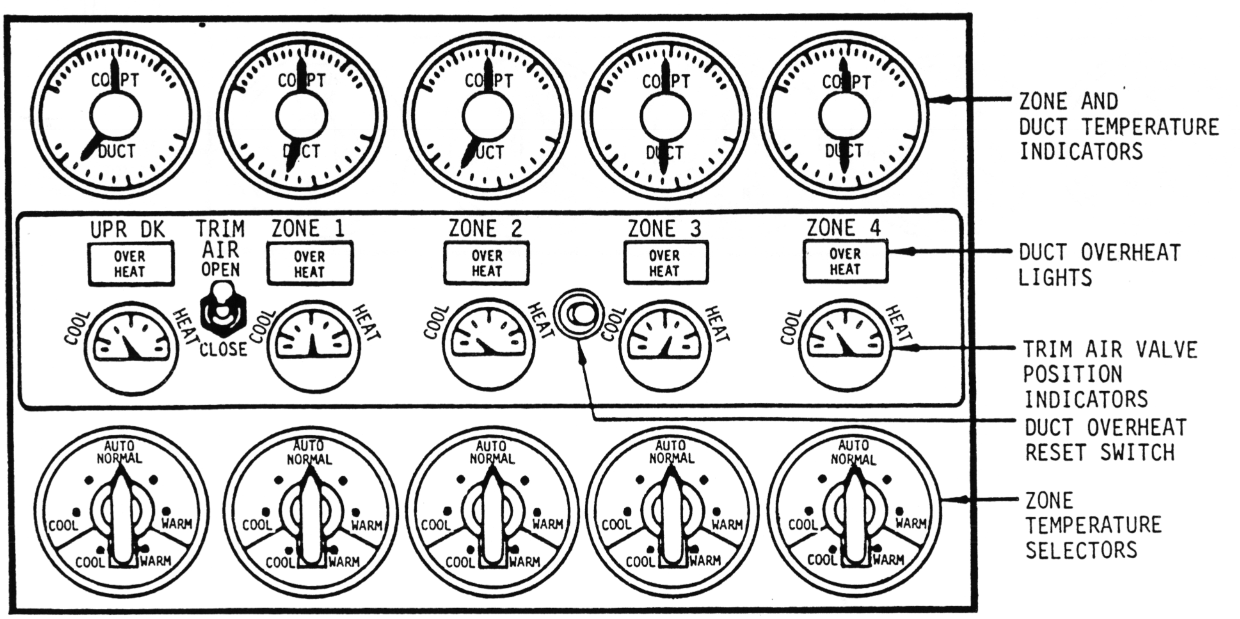


FIGURE 4-48. BOEING 747-100,-200,-300 TEMPERATURE CONTROLS

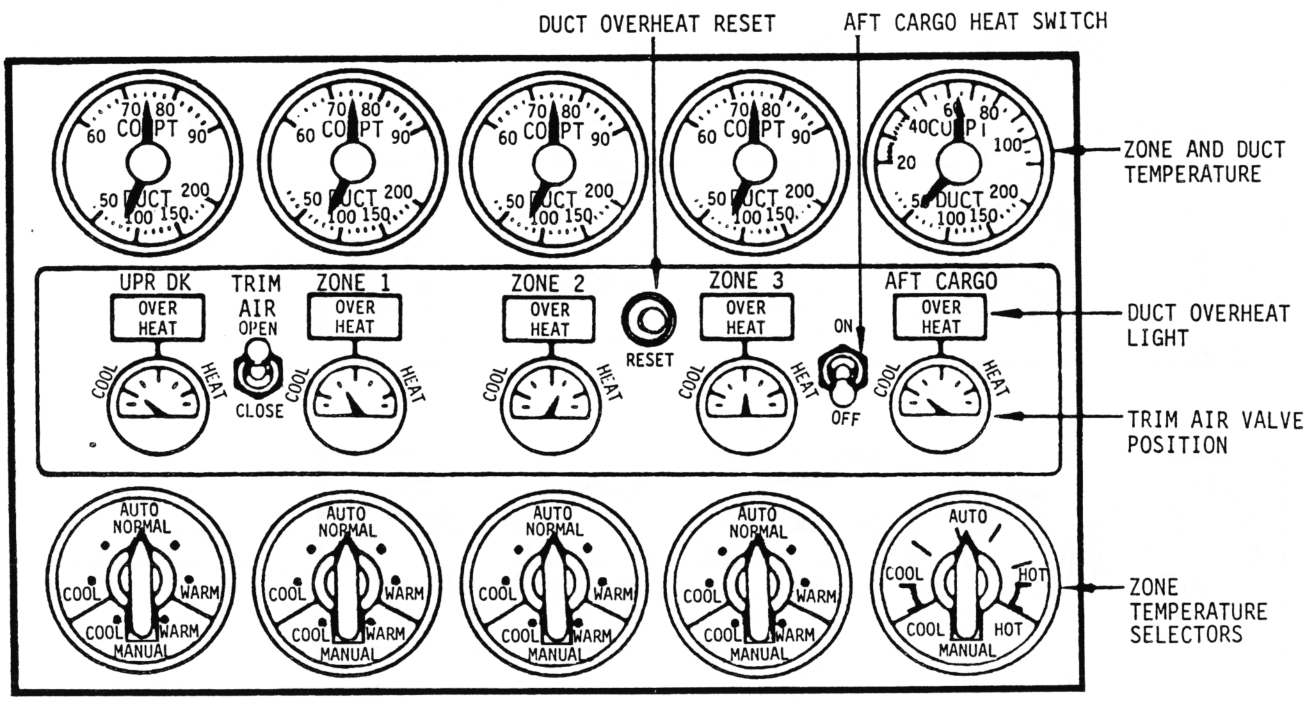


FIGURE 4-49. BOEING 747-SP TEMPERATURE CONTROLS

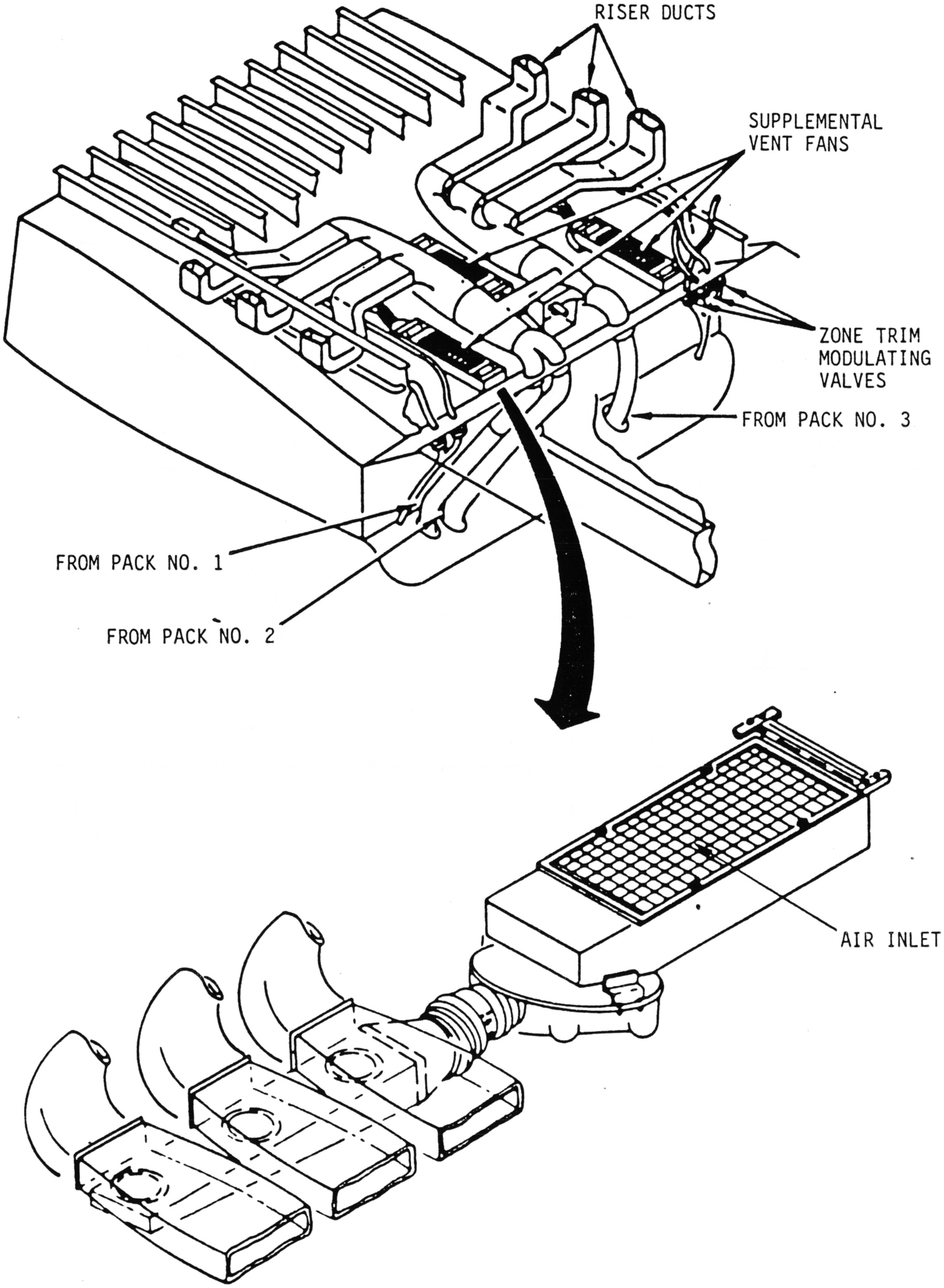


FIGURE 4-50. BOEING 747 SUPPLEMENTAL AIR SYSTEM

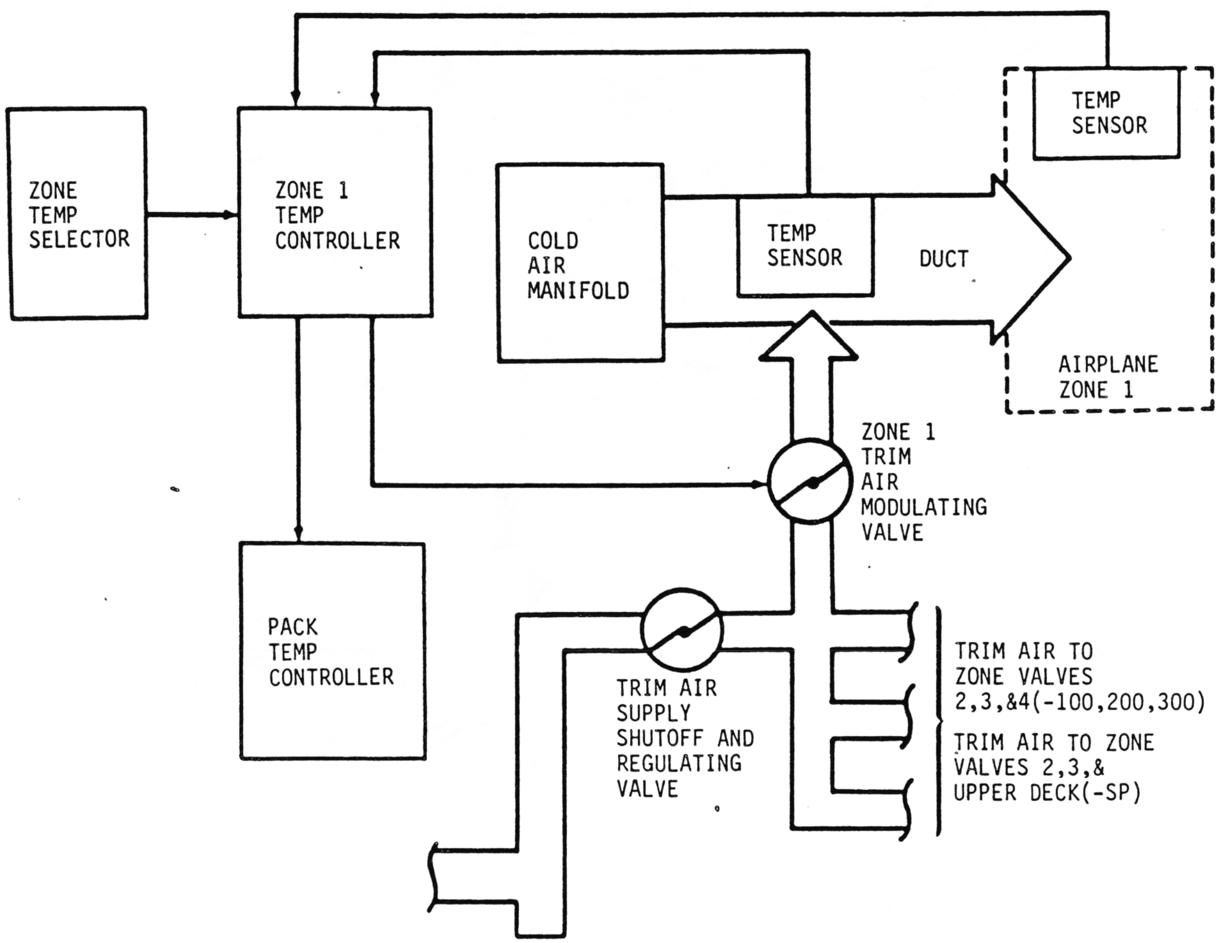


FIGURE 4-51. BOEING 747 ZONE TEMPERATURE CONTROL SCHEMATIC

SECTION 5

BOEING 757

Model Variation

The Boeing 757 was introduced in the early eighties as an all-new advanced technology replacement for current short-to-medium range narrow body jetliners. The 757 incorporates advanced high bypass engines and wing design to make it highly energy efficient and quiet. In addition, every major system has been upgraded or redesigned to incorporate the latest advancements in commercial jetliner technology.

The 757 was first flown on 2-19-82, and was certified on 12-21-82. It was placed into service on 1-1-83 by Eastern Airlines. Total program production as of 10-1-84 stands at 44 delivered, 108 on order, and 59 on option. The 757 is available in one version with three engine options, with passenger capacity configurations from 178 to 239 depending on seat pitch, lavatory and galley options, and the choice of overwing escape hatches or emergency exit door.

757 ECS

The 757 ECS is a two pack air cycle system that uses engine bleed-air as the air source. A block diagram of the system is shown in Figure 5-1. The air conditioning packs are located below the wing in an unpressurized area of the fuselage just forward of the wheel well. The air conditoning pack utilizes engine bleed-air from the compressor stages of both engines as an air source.

During ground operations, a pneumatic ground cart or the APU may be used as a hot air source. A schematic of the pack is shown in Figure 5-2. The hot bleed-air temperature and pressure are regulated by the pneumatic system before being supplied to the pack flow-control and shut-off valve. The flow-control valve regulates flow through the system to minimize variation in flow rate.

The flow-control valve has provisions for varying the flow through the system in two ways, high flow mode and normal flow adjustment. The high flow mode allows the pack to operate at 165% of normal flow if certain conditions are satisfied; more information is presented under ECS Controls. The normal flow adjustment allows the maintenance personnel to set the normal flow at 80%, 100%, or 120% of normal flow schedule. This is done by manually adjusting an orifice on the flow-control valve body, and cannot be adjusted from the flight deck.

After leaving the flow-control valve, hot air is routed to the pack low limit control valve, trim air system, and to the pack primary heat exchanger. Low limit control air is used to control ice formation in the condenser and prevent compressor overheat by limiting airflow through the compressor. The trim air system is used to provide zone temperature control by adjusting the temperature of the appropriate distribution system.

Most of the air flowing through the system is routed to the primary heat exchanger where it is cooled by ram air before being routed to the air cycle machine (ACM) compressor. The ACM compresses the air to higher pressure and temperature. The air is then cooled in the secondary heat exchanger by ram air. The air then flows through the water separation components before entering the turbine.

Water is extracted by first cooling the air in the reheater, further cooling in the condenser, then extraction in the water extractor. Extracted water is then sprayed on the secondary heat exchanger to increase the ram cooling effect. The air leaving the water extractor is passed through the reheater to be warmed by air exiting the secondary heat exchanger before passing to the turbine.

Air from the reheater is routed to the turbine, then expanded to produce cold air at the turbine outlet. This cold air then passes through the condenser and into the flight deck supply line and mixing manifold. The mixing manifold is shown in Figure 5-3. The temperature of the supply air is controlled by the zone heating system covered under ECS Controls. Pressures and temperatures at points A through E on Figure 5-2 are shown in Table 5-1.

Distribution

Air leaving the pack condenser is routed to the mixing manifold where it is mixed with recirculated air before being delivered to the distribution ducting.

The passenger cabin system is supplied from the mixing manifold by four rectangular risers, located behind the sidewall on both sides of the cabin just forward of the wing, (see Figure 5-4). The risers supply air to the overhead distribution duct that is located above the ceiling, (see Figure 5-5). The forward risers supply air to the forward passenger cabin zone, and the aft risers supply air to the aft passenger cabin zone. The overhead duct directs air into the passenger cabins through outlets in the bottom of the duct, and at the top of the sidewall. The outlet at the bottom of the duct exhausts air into the cabin through a nozzle-adapter assembly that forms the centerline joint in the ceiling panel, and runs the length of the passenger cabin (see Figure 5-6).

Outlets at the top of the sidewall are supplied by droppers from the overhead duct as shown in Figure 5-7. The sidewall outlet and grill are shown in Figure 5-8, and a detail at a typical dropper is shown in Figure 5-8. The outlets are located approximately every 20-inches along both sides of the cabin. A cross-section of the passenger cabin showing ducting arrangement is shown in Figure 5-9. Air flow patterns in the passenger cabin are shown in Figure 5-10.

The flight deck distribution system is shown in Figure 5-11. The distribution system is supplied from the left pack-condenser exit line by a duct running forward below the left-hand floor. Air enters the flight deck through four floor level outlets, four side window outlets, an overhead outlet, and front windshield diffuser. The side window outlets have electric supplemental heaters installed in the supply line to aid in keeping the windows clear. The overhead has an outlet running along the ceiling centerline that is the same as the passenger cabin nozzle, and is supplied by a duct located behind the left aft sidewall. This outlet also supplies air to the windshield diffusers.

Airflow rates entering the compartments are shown in Table 5-1. Air change rates are shown in Table 5-2 and compartment volumes are shown in Table 5-3.

Individual Gasper Air

In addition to the compartment conditioned air the passenger also has available a separate air outlet that may be used to further ventilate his personal space. On the 757, the gasper system is not a separate system of ducting, but rather an integral part of the passenger cabin and flight deck distribution systems.

The passenger cabin gasper outlets are supplied from the sidewall air droppers, and are located below the stowage bins (see Figure 5-8). The outlets are ball and socket type, adjustable for flow rate and direction.

The flight deck has five gasper outlets; one at each side of the instrument panel, one in each sidewall at the back of the panel, and one in the overhead area. The outlets are supplied from the flight deck distribution system.

Equipment Cooling

The 757 has two equipment cooling systems, forward and aft. The aft system uses blow through cooling to cool the aft equipment racks located just aft of the aft cargo door on the right-hand side of the aft cargo compartment. The forward equipment cooling system uses blow through and draw through airflow to cool the forward equipment racks, main panels, overhead panels and weather radar. A schematic of the equipment cooling systems is shown in Figure 5-12.

The forward equipment system comprises two subsystems, and uses both the blow-through and draw-through methods. The blow-through system uses two fans, mounted near the forward left corner of the forward cargo compartment, that draw air exhausted from the passenger cabin into the system through a filter or air cleaner. Only one fan is operated at a time; usually fan 2 is used in flight and fan 1 while the plane is on the ground. The fans force air into a system of ducts that route the air to the forward equipment rack and flight deck instrument panels. Air directed to the instrument panels passes through the overhead panels, main panels, and center aisle stand, and then into the flight deck compartment. The draw-through system uses the left recirculation system fan to draw air through the main panels, weather radar, and forward equipment rack to provide cooling airflow. After passing through the fan, the air is filtered by the recirculation filter, and then routed to the mixing manifold.

Operation of the system is automatic and thermostatically controlled between 50-70 °F.

Recirculation Systems

The 757 uses two recirculation systems, designated left and right. The recirculation systems return cabin exhaust air to the mixing manifold to be mixed with cold air before returning to the passenger cabin.

The right recirculation system is located to the right of the mixing manifold, just aft of the forward cargo compartment. The recirculation fan draws air from the mixing bay area through a high efficiency filter, and exhausts the air into the mixing manifold (see Figure 5-18).

The left system functions as a part of the equipment cooling system. The recirculation fan draws air from flight deck through the forward equipment racks and main instrument panels, and exhausts it through ducting to the recirculation filter mounted on the left side of the mixing manifold. The air is filtered, then routed to the mixing manifold (see Figures 5-12 and 5-18).

The recirculation system filters are two stage particulate filters rated at 1000 cfm airflow. The first stage is a fiberglass pad that traps large particulates. The second stage filter is a fiberglass pad high efficiency particulate filter that has a minimum arrestance of 95% of the smoke particles that are 0.3 microns or larger.

The recirculation fans are controlled by on-off switches located on the pilot's overhead panel. Thermal sensors prevent fan motor overheat.

Ventilation

Air is vented overboard by two systems; galley and lavatory ventilation, and pressurization control valves.

The galley and lavatory ventilation system uses a fan to draw air from the galley and lavatories into a system of ducting, and exhausts the air near the pressurization outflow valves so that it is dumped overboard. A schematic of the system is shown in Figure 5-12. The 757 generally carries four lavatories and two to four galleys. The galleys are usually placed in the forward and aft cabin, and provisions have been made for lavatory placement in the forward, mid, and aft cabin. The ventilation system connects all the lavatories and galleys through a system of ducts located above the ceiling and behind the right aft cabin sidewalls. The galleys have outlets in the ceiling panels (fitted with filters) that draw in air from the ceiling area. Air from the lavatories is drawn from underneath the toilet shroud and from ceiling outlets.

Flow through the system is driven by two fans mounted downstream of the ducting. The fans are mounted aft of the aft cargo compartment, and exhaust into the area near the outflow valve. Fan 2 usually operates during flight, and fan 1 operates while the airplane is on the ground. The fans are protected from overheat by 400 °F thermal sensors. Transfer to the standby fan is automatic when the primary fan fails. The motor will re-set when it cools to 340 °F.

The aft equipment cooling system also functions as a part of the ventilation system. Air is blown through the equipment and enters the galley and lavatory ventilation system upstream of the galley and lavatory fans.

The pressurization outflow valves are the primary method of exhausting air overboard. The 757 outflow valve is mounted on the lower right-hand fuselage, aft of the aft cargo compartment. The outflow valve is a dual gate type that responds to electric signals generated in the pressure controller to vary the size of the opening to maintain cabin pressure as requested. The outflow valve location is shown in Figure 5-19 and the valve is shown in Figure 5-20.

Pressurization Control

The 757 has an electrically operated and electronically controlled pressurization control system (PCS). The pressurization control system maintains a low cabin altitude during flight, and controls the cabin altitude rate of change by modulating the outflow valve opening. The 757 PCS has three operating modes, auto 1, auto 2, and manual.

Normal operation is on one of the auto modes, with the other auto mode acting as a standby. The manual mode further backs up the auto modes. A schematic of the pressurization control system is shown in Figure 5-21, and its limits of operation are shown in Table 5-3.

The auto modes consist of two identical electronic pressure controllers that accept inputs from the control panel, air data computer, and other control interfaces. The control panel is shown in Figure 5-22. Normally, one controller operates the outflow valve and the other remains in standby, monitoring system operation. Transfer to the backup controller is automatic if the selected controller should faild. To use the auto mode, the crew selects auto 1 or auto 2, and sets the landing altitude and the cabin altitude rate of change. The selected controller then modulates the outflow valve to maintain cabin pressure. Gauges are provided to monitor cabin altitude, differential pressure, and cabin altitude rate of change.

The manual mode can be used in case both auto controllers fail. The manual mode must be selected using the selector knob. When using the manual mode, the crew can only choose to have the cabin altitude descend, climb or remain unchanged. A switch on the control panel signals the outflow valve to open or close. The crew must monitor the gauges to maintain cabin conditions within desired limits. A gauge is also provided to show the outflow valve position.

Environmental Control System (ECS) Controls

The ECS control panel is shown in Figure 5-23. The ECS controls consist of switches to control the pack mode of operation, bleed-air source, recirculation fan operation, and compartment temperatures.

The pack control has two modes, auto and standby. The standby mode has three choices - N, W, or C (normal, warm, or cool).

The pack is started by putting the selector in auto or one of the standby modes. The flow of the pack is not adjustable by the crew, but the pack does have a high flow mode. High-flow mode occurs automatically when the system is operating on 1 pack, or the recirculation fan on the same side as the pack has failed or is off. When using the auto mode, the temperature of the pack outlet is limited between 140 -35 °F (0 °F above 31,000 feet) by automatic control systems.

The standby modes are used when the auto mode is inoperative, or the heating or cooling are high. The standby modes N, W, or C, allow the crew to select a specific operating mode in response to ambient conditions.

The N mode (normal mode) can be considered as a backup to the auto mode. The pack operation is essentially the same, but high-flow mode is locked out.

The W mode (warm mode) is used when heating is required; this places the pack in heat-exchanger-cooling mode and holds the low-limit control valve closed.

The C mode (cool mode) puts the packs in the full-cooling mode. This provides the maximum amount of cooling available.

The bleed-air source is the compressor stages of both engines while in flight, or the APU or a ground cart during ground operation of the packs. The switches permit shutdown of bleed-air sources when not needed.

Re-circulation fan switches allow the crew to shut off the recirculation fans when less airflow is desired, or to force the packs into high-flow mode. The re-circulation fans should also be shut off during a fire situation to avoid dispersing smoke from the lower areas into the passenger cabin.

The 757 temperature control uses a three zone control system; flight deck, forward passenger cabin, and aft passenger cabin. A schematic of the zone temperature control system is shown in Figure 5-22. The zone temperature control system mixes hot air with cold pack discharge air to provide temperature controlled air to all cabins.

To operate the zone temperature control system, the crew first turns the trim air switch to on. This enables hot air to flow to the zone temperature control valves. The temperature control valves respond to the temperature selector and compartment temperature sensor, to mix the correct amount of hot and cold air to achieve the desired temperature. The temperature is selected between 63 - 85 °F by the crew and thermostatically maintained by the zone temperature control system.

The temperature controls can also be operated manually. When using the manual mode, the selector knob controls the position of the corresponding trim air valve. Compartment temperature must be monitored on the gauges provided.

Electrical energy requirements of the various ECS components and controls are shown in Tables 5-5 and 5-6. Figures quoted are for loads when the particular component is operating. It should be noted that some components operate continuously, and others intermittently.

TABLE 5-1. BOEING 757 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (lb/min/pack)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (cfm)	% RECIRC	TOTAL (cfm)	% RECIRC
SEA LEVEL TAKEOFF	78	3,296	48	283	0
5,000 FT CLIMB	74	3,284	47	287	
10,000 FT CLIMB	74	3,251	48	289	
25,000 FT CRUISE	67	3,212	49	284	
30,000 FT CRUISE	64	3,250	48	289	
35,000 FT CRUISE	64	3,711	55	269	
42,000 FT CRUISE	57	3,645	54	269	
20,000 FT DESCENT	72	3,682	53	272	
10,000 FT DESCENT	76	3,645	54	274	0

TABLE 5-2. BOEING 757 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	15.9	30.5	60.6
5,000 FT CLIMB	16.1	30.4	61.5
10,000 FT CLIMB	15.7	30.1	61.9
25,000 FT CRUISE	15.1	29.7	60.9
30,000 FT CRUISE	15.6	30.1	61.9
35,000 FT CRUISE	15.4	34.3	57.6
42,000 FT CRUISE	15.5	33.8	57.6
18,500 FT DESCENT	16.0	34.1	58.3
10,000 FT DESCENT	15.5	33.8	58.7

TABLE 5-3. BOEING 757 VENTILATION PARAMETERS

VOLUMES (CU FT)		757	
TOTAL PRESSURIZED		13,786	
PASSENGER CABIN		6,480	
CONTROL CABIN		280	
FWD CARGO		700	
AFT CARGO		1,090	
PRESSURIZATION			
MAX ΔP (PSI)			
CONTROLLER		8.6	
SAFETY VALVE		8.95 - 9.42	2 STAGE
CABIN ALTITUDE CHANGE RATES		CLIMB	DESCENT
CONTROLLER	MAX (FT/MIN)	2,000	1,200
CONTROLLER	MIN (FT/MIN)	50	30

MAXIMUM CABIN ALTITUDE-MANUAL LIMITS TO 11,500 (FT)

AUTO MODE ALLOWS LANDING FIELD ALTITUDE OF 14,000 (FT)

TABLE 5-4. BOEING 757 SYSTEM TEMPERATURES AND PRESSURE (REF 7)

(°F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		PACK OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	62	354	37	354	15.1	10	14.7	35	14.7	59	14.7	75	14.7	99
5,000 FT CLIMB	59	351	34	351	15.1	11	14.7	35	14.7	60	14.7	75	12.2	81
10,000 FT CLIMB	57	348	34	348	15.1	-3	14.7	35	14.7	48	14.7	75	10.1	63
25,000 FT CRUISE	50	343	31	343	14.4	6	14.1	35	14.1	58	14.1	75	5.45	10
30,000 FT CRUISE	44	339	30	339	13.3	7	12.9	35	12.9	56	12.9	75	4.36	-8
35,000 FT CRUISE	51	338	24	338	12.3	16	11.9	35	11.9	64	11.9	75	3.46	-26
42,000 FT CRUISE	50	363	24	363	11.3	10	10.9	35	10.9	64	10.9	75	2.48	-30
20,000 FT DESCENT	30	344	27	344	14.1	21	13.7	35	13.7	71	13.7	75	6.75	27
10,000 FT DESCENT	38	349	33	349	14.8	2	14.3	35	14.3	57	14.3	75	10.11	63

TABLE 5-5. BOEING 757 AC ELECTRICAL ENERGY REQUIREMENTS (REF 15)

EQUIPMENT	POWER REQD	WATTS	VARS.	SOURCE
Aft Equipment Vent Fan No. 2	115V 400 Hz 3Ø	994	423	AC Ground Service
Aft Equipment Supply Fan No. 2 Power	115V 400 Hz 3Ø	400	300	AC Ground Service
L Recirc Fan	115V 400 Hz 3Ø	4,160	3,120	AC Misc Left
Aft Equipment Vent Fan No. 1	115V 400 Hz 3Ø	994	423	AC Misc Left
Aft Equipment Supply Fan No. 2	115V 400 Hz 3Ø	400	300	AC Misc Left
Pack Flow Indicator	115V 400 Hz 1Ø	10	-	AC Left Sec 1 ØA
Cabin Zone Controller	115V 400 Hz 1Ø	61	30	AC Left Sec 1 ØA
Cabin Pressure Controller, Auto 1	115V 400 Hz 1Ø	235	176	AC Left Sec 1 ØC
R Pack Standby Power	115V 400 Hz 1Ø	207	100	AC Left Sec 1 ØC
L Pack Auto Power	115V 400 Hz 1Ø	62	30	AC Left Sec 1 ØC
Equipment Cooling Supply Fan No. 1	115V 400 Hz 3Ø	3,050	1,206	AC Left Sec 3
Fwd Cargo Fan Power	115V 400 Hz 3Ø	994	423	AC Utility Left
Aft Cargo Heater Power	115V 400 Hz 3Ø	5,500	-	AC Utility Left
Capt Aux Heater Low	115V 400 Hz 1Ø	305	-	AC Utility Left ØB
Capt Aux Heater High	115V 400 Hz 1Ø	305	-	AC Utility Left ØC
R Pack Auto Power	115V 400 Hz 1Ø	62	30	AC Right Sec 1 ØA
F/D Zone Trim Valve	115V 400 Hz 1Ø	31	15	AC Right Sec 1 ØA
Fwd Zone Trim Valve	115V 400 Hz 1Ø	31	15	AC Right Sec 1 ØA
Flt Deck Fan Control	115V 400 Hz 1Ø	45	22	AC Right Sec 1 ØA
Fwd Zone Fan Control	115V 400 Hz 1Ø	45	22	AC Right Sec 1 ØA
Aft Zone Fan Control	115V 400 Hz 1Ø	45	22	AC Right Sec 1 ØA
Cabin Pressure Controller Auto 2	115V 400 Hz 1Ø	235	176	AC Right Sec 1 ØB
L Pack Standby Power	115V 400 Hz 1Ø	207	100	AC Right Sec 1 ØB
Aft Zone Trim Valve	115V 400 Hz 1Ø	31	15	AC Right Sec 1 ØB
Equipment Cooling Supply Fan 2	115V 400 Hz 1Ø	3,050	1,206	AC Right Sec 3
R Recirc Fan	115V 400 Hz 3Ø	4,160	3,120	AC Utility Right
Aft Cargo Fan Power	115V 400 Hz 3Ø	994	423	AC Utility Right
First Officer Aux Heater, Lo	115V 400 Hz 1Ø	305	-	AC Utility Right ØB
First Officer Aux Heater, Hi	115V 400 Hz 1Ø	305	-	AC Utility Right ØC
Cabin Altimeter Ind	115V 400 Hz 1Ø	4	-	AC Standby
Cabin Pressure Ind	115V 400 Hz 1Ø	2	-	AC Standby

TABLE 5-6. BOEING 757 DC ELECTRICAL ENERGY REQUIREMENTS (REF 15)

EQUIPMENT	POWER REQD	LOAD	SOURCE
Aft Equipment Exhaust Fan #2 Control	28 VDC	.38	DC Ground Handling
L Recirc Fan Control	28 VDC	.50	DC Left Sec 1
Aft Equip Vent Fan 1 Control	28 VDC	.15	DC Left Sec 1
R Pack Standby Control	28 VDC	1.00	DC Left Sec 1
L Pack Auto Cotrol	28 VDC	.30	DC Left Sec 1
L Pack Flow Control	28 VDC	2.65	DC Left Sec 1
Fwd Cargo Fan Control	28 VDC	.30	DC Left Sec 1
Aft Cargo Heat control	28 VDC	.50	DC Left Sec 1
E/E Equip Flow Dectector	28 VDC	.60	DC Left Sec 1
Equip Cool Supply Fan #1 Control	28 VDC	.30	DC Left Sec 1
Aft Equip Supply Fan #1 Control	28 VDC	.15	DC Left Sec 1
Zone Temp Indication	28 VDC	.25	DC Left Sec 1
Cabin Trim Air	28 VDC	1.00	DC Left Sec 1
R Recirc Fan Control	28 VDC	.50	DC Right Sec 1
Aft Equip Vent Fan #2 Control	28 VDC	.15	DC Right Sec 1
L Pack Standby Control	28 VDC	1.00	DC Right Sec 1
R Pack Auto Control	28 VDC	.30	DC Right Sec 1
R Pack Flow Control	28 VDC	2.65	DC Right Sec 1
Aft Cargo Fan Control	28 VDC	.51	DC Right Sec 1
Equip Cooling Supply Fan #2 Control	28 VDC	.30	DC Right Sec 1
Aft Equip Supply Fan #2 Control	28 VDC	.15	DC Right Sec 1
Smoke Clearance Inop Control	28 VDC	.50	Battery Bus
Equip Cooling Smoke Clearance	28 VDC	1.36	Battery Bus
Cabin Altitude/Pressure Manual	28 VDC	1.19	DC Standby
Cabin Altitude/Pressure Selector	28 VDC	.08	DC Standby
E/E Cooling Ground Warning	28 VDC	.60	Hot Battery Bus

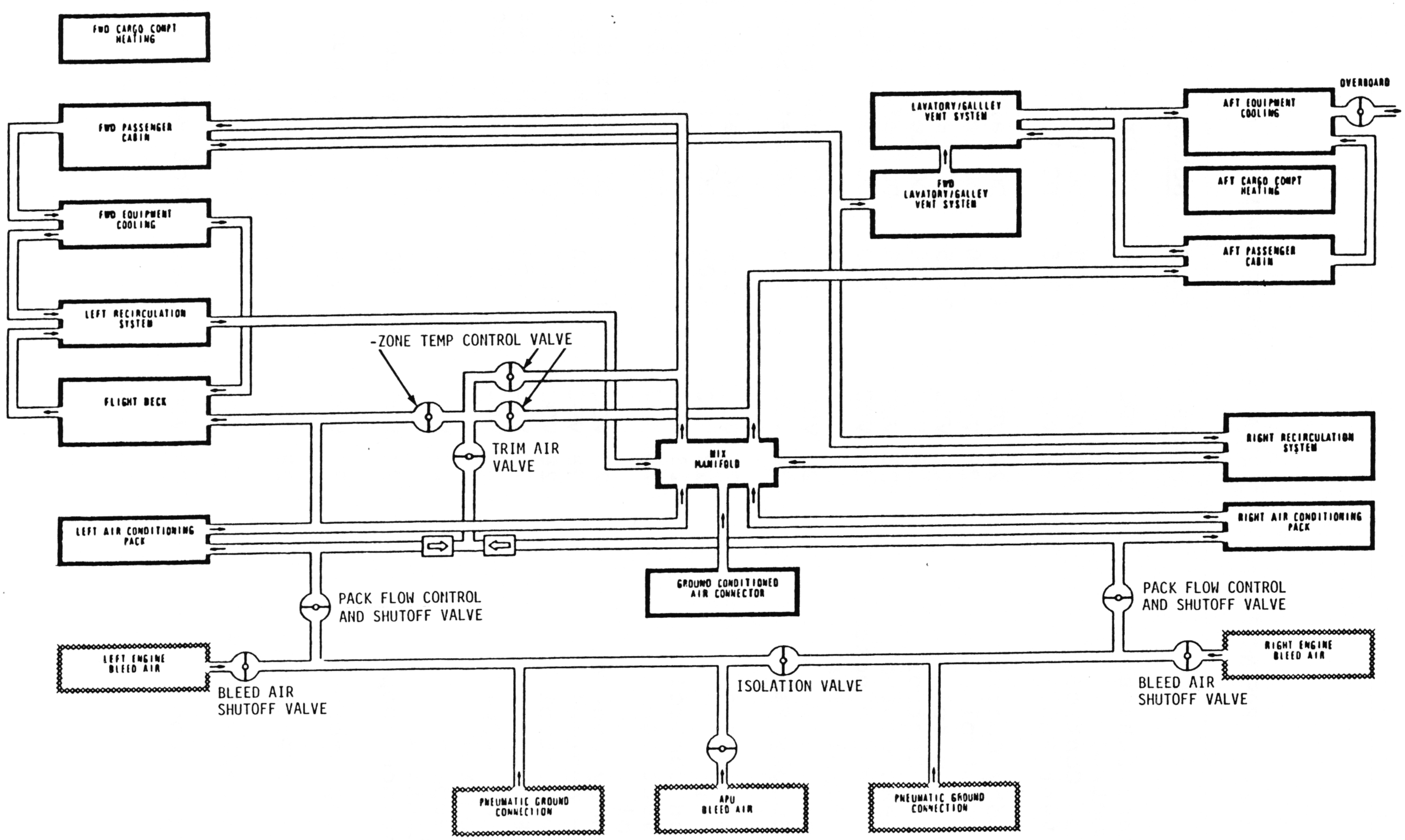


FIGURE 5-1. BOEING 757 AIR CONDITIONING SYSTEM BLOCK DIAGRAM

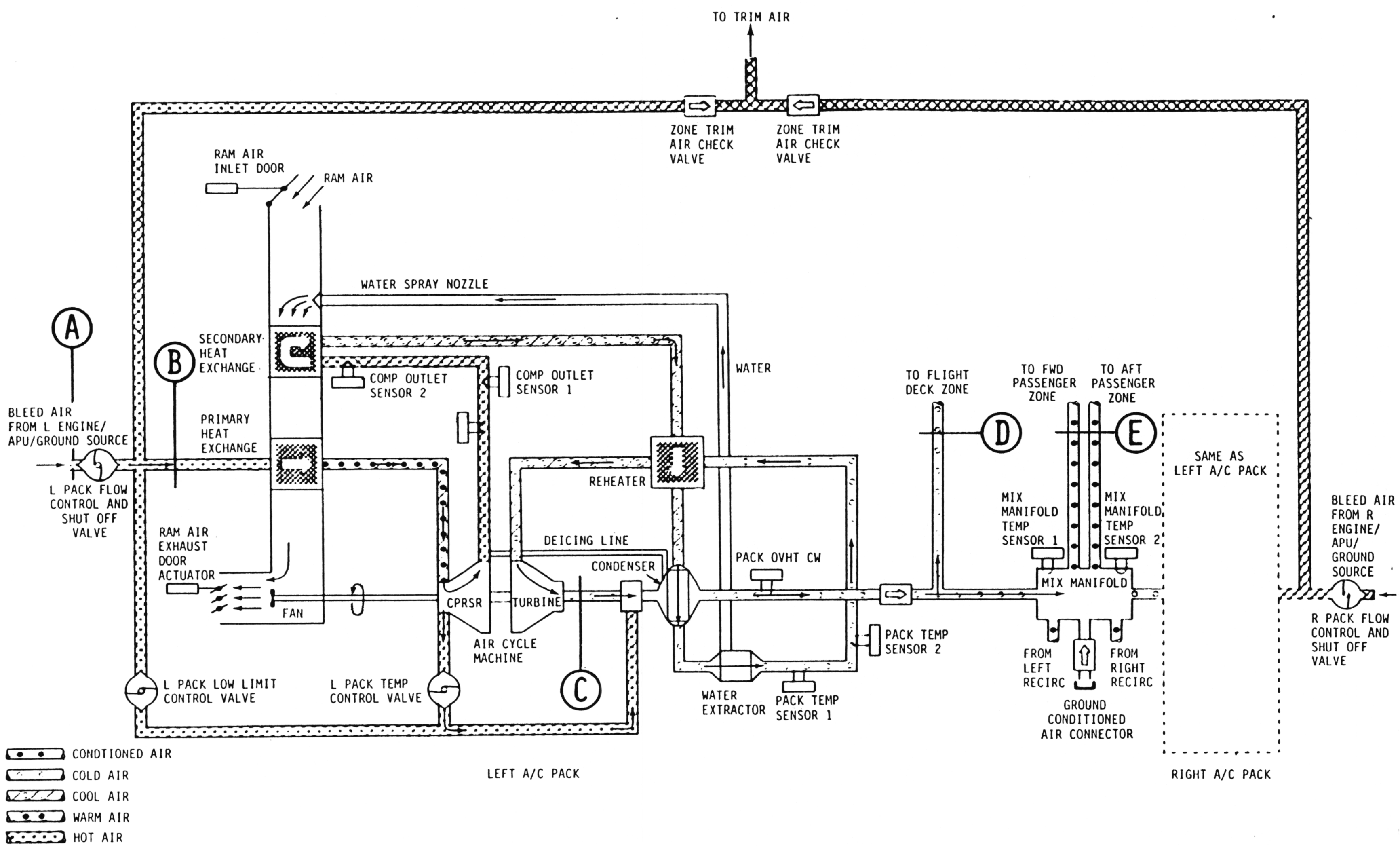


FIGURE 5-2. BOEING 757 COOLING PACK SCHEMATIC

BOEING 757

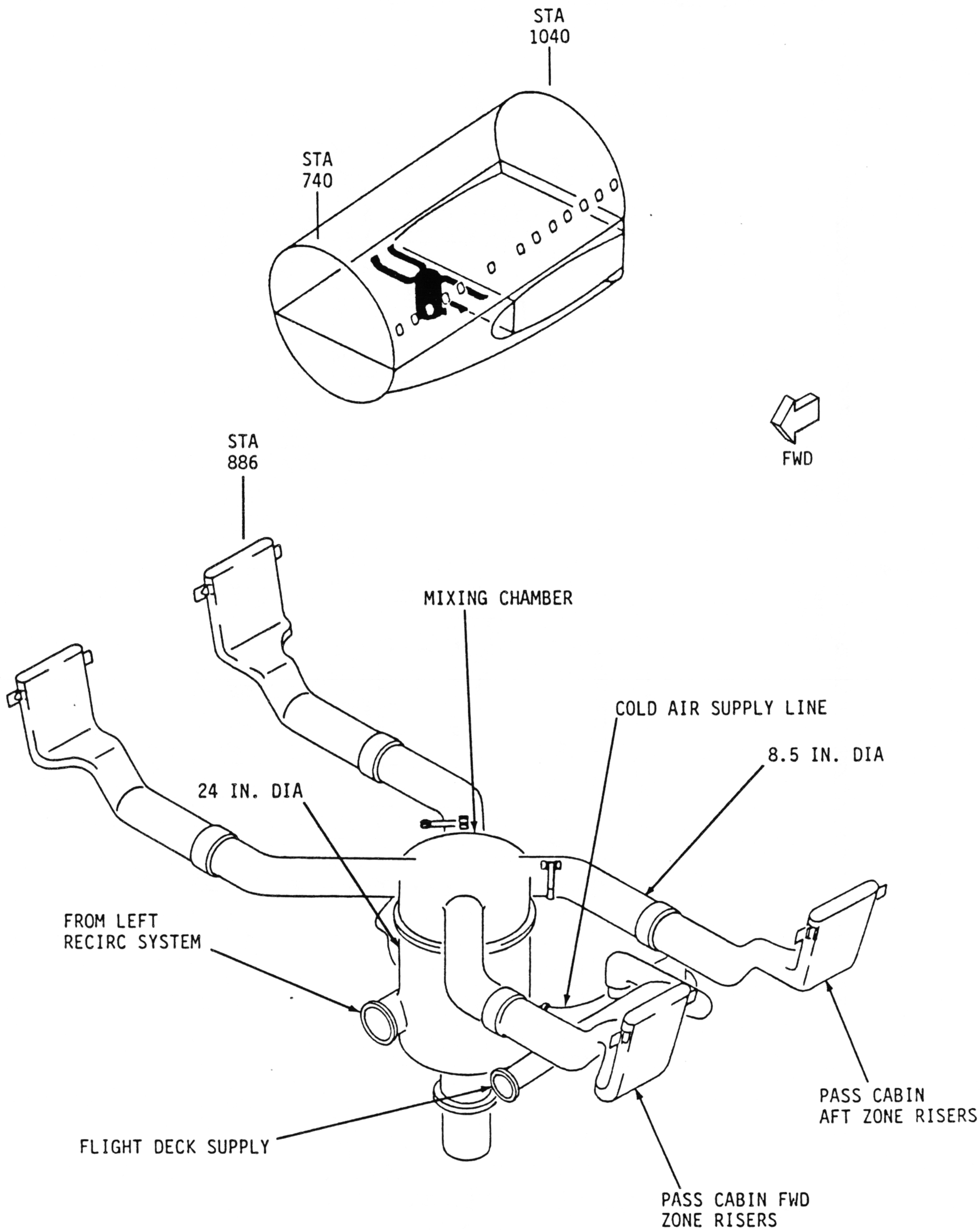


FIGURE 5-3. BOEING 757 MIXING AND DISTRIBUTION MANIFOLD

BOEING 757

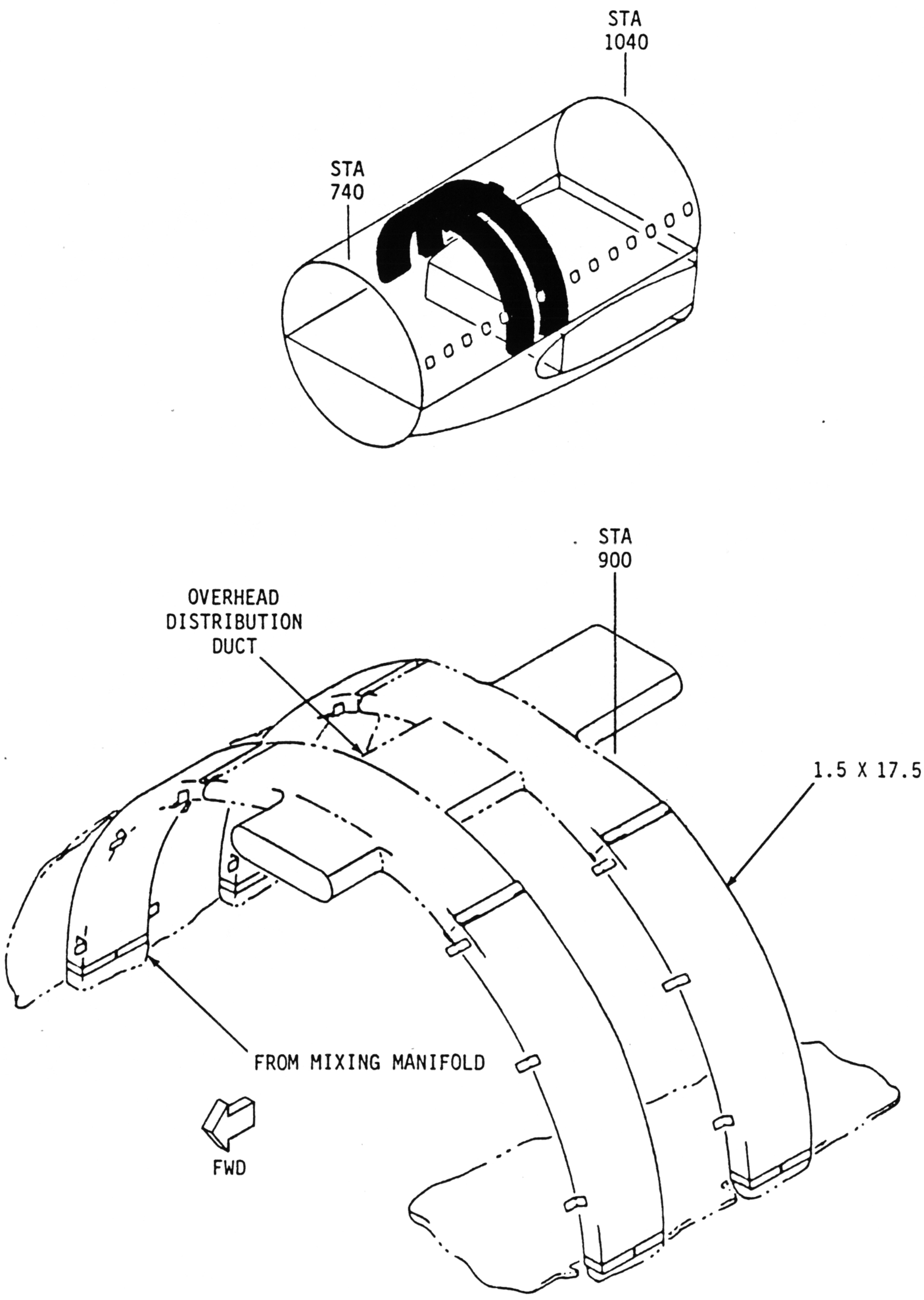


FIGURE 5-4. BOEING 757 PASSENGER CABIN OVERHEAD RISERS

BOEING 757

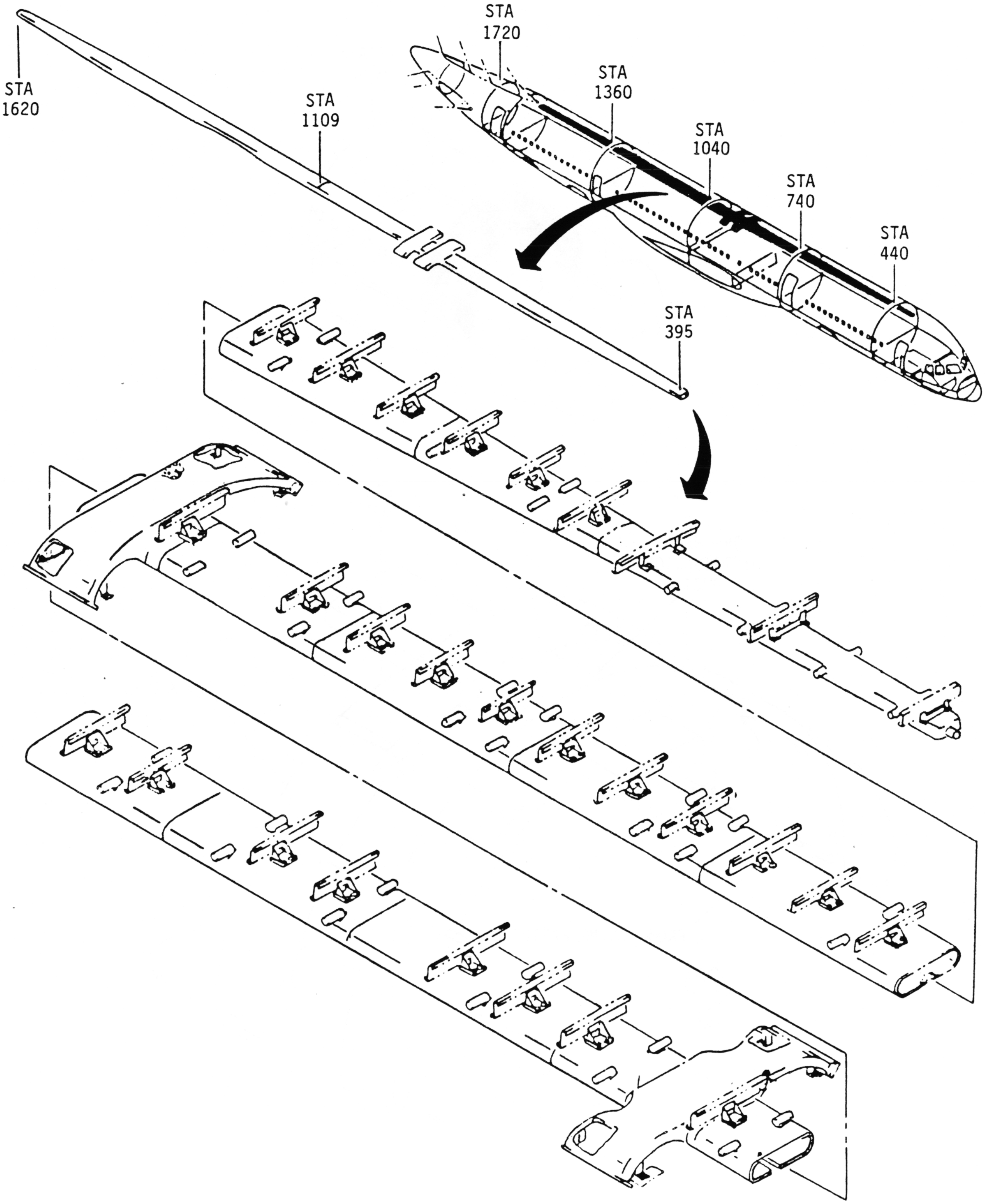


FIGURE 5-5. BOEING 757 PASSENGER CABIN OVERHEAD DISTRIBUTION DUCTING

BOEING 757

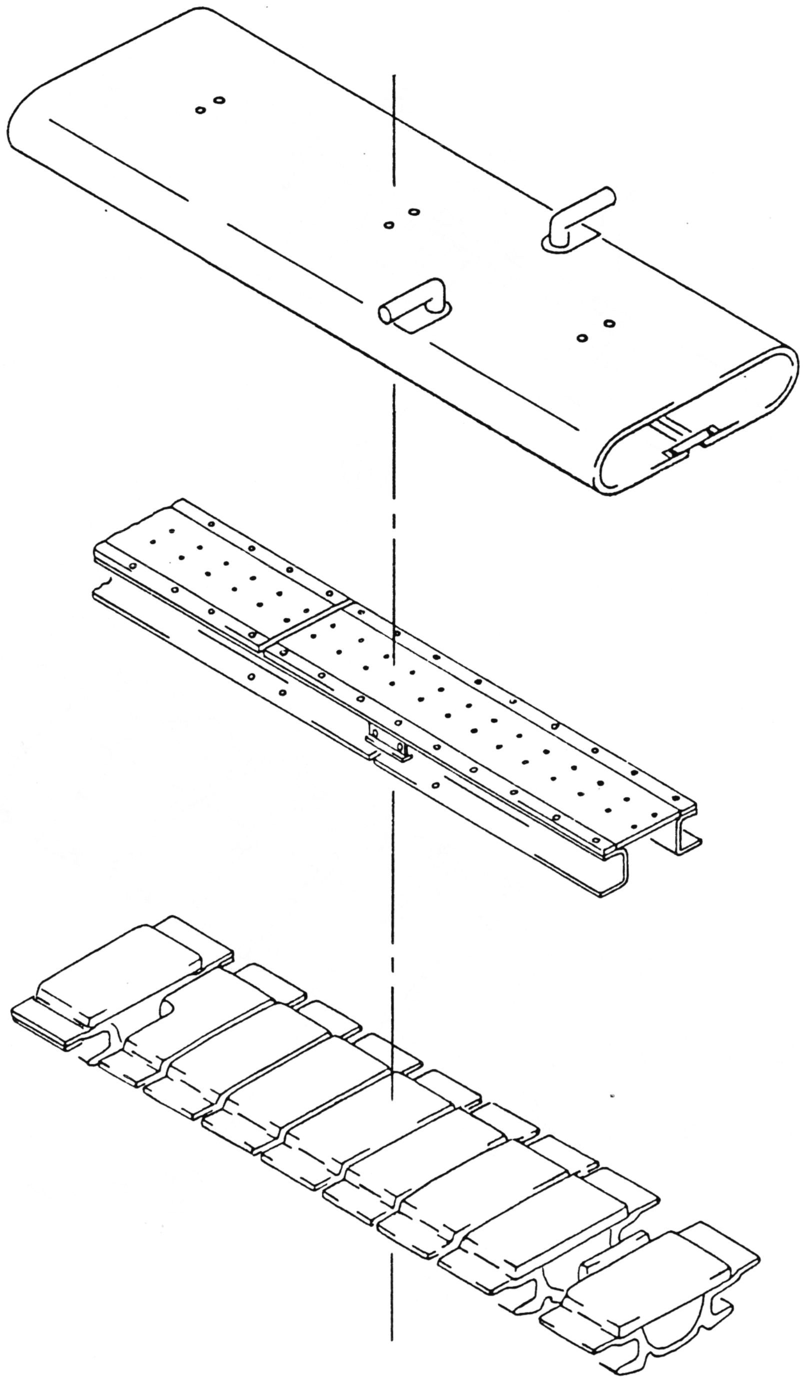
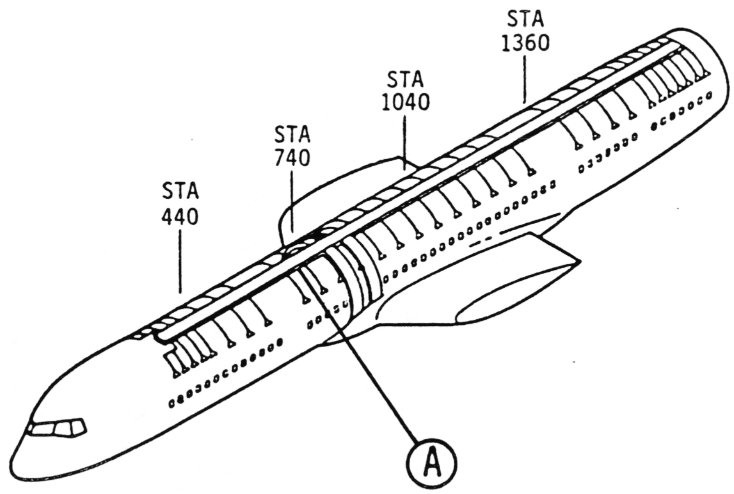


FIGURE 5-6. BOEING 757 OVERHEAD CEILING OUTLET

BOEING 757



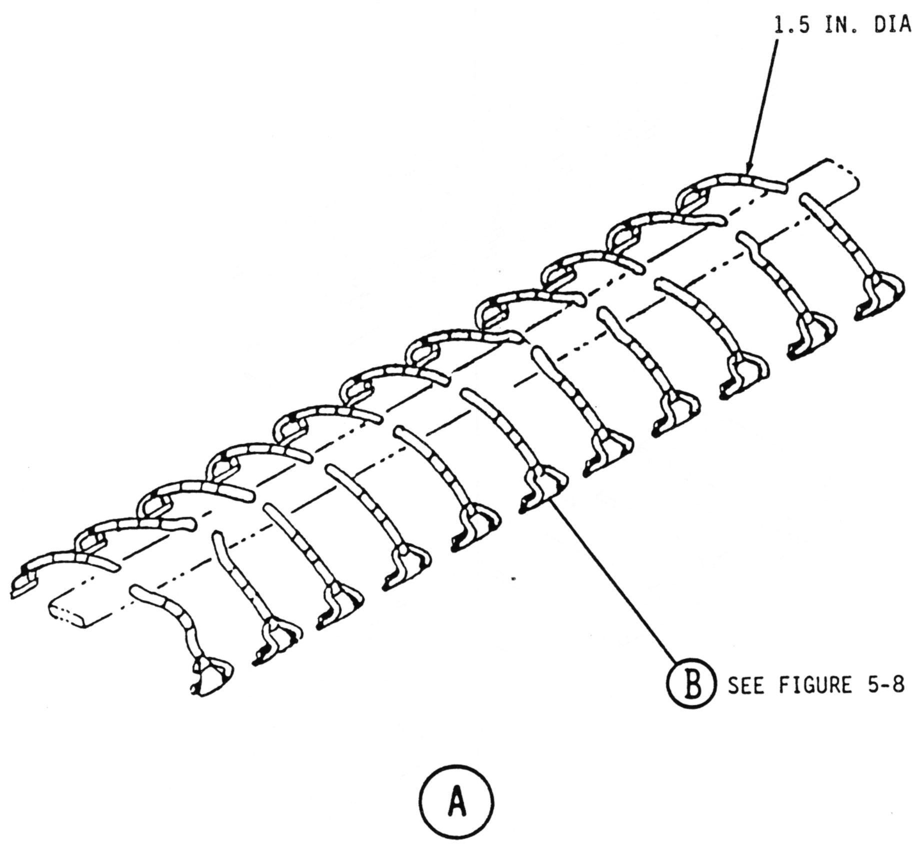


FIGURE 5-7. BOEING 757 SIDEWALL AIR DUCTS

BOEING 757

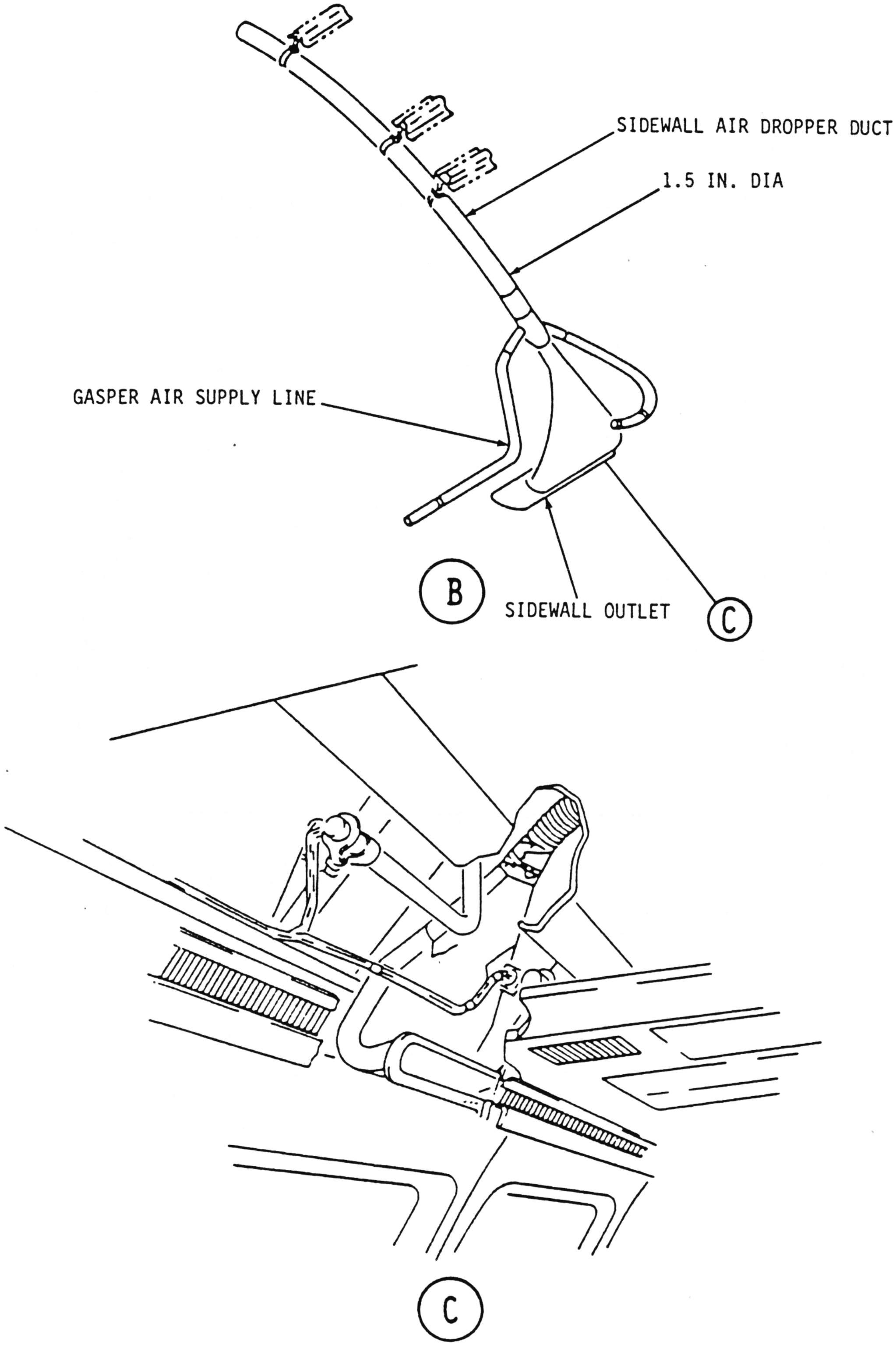


FIGURE 5-8. BOEING 757 AIR CONDITIONING SYSTEM OUTLETS

BOEING 757

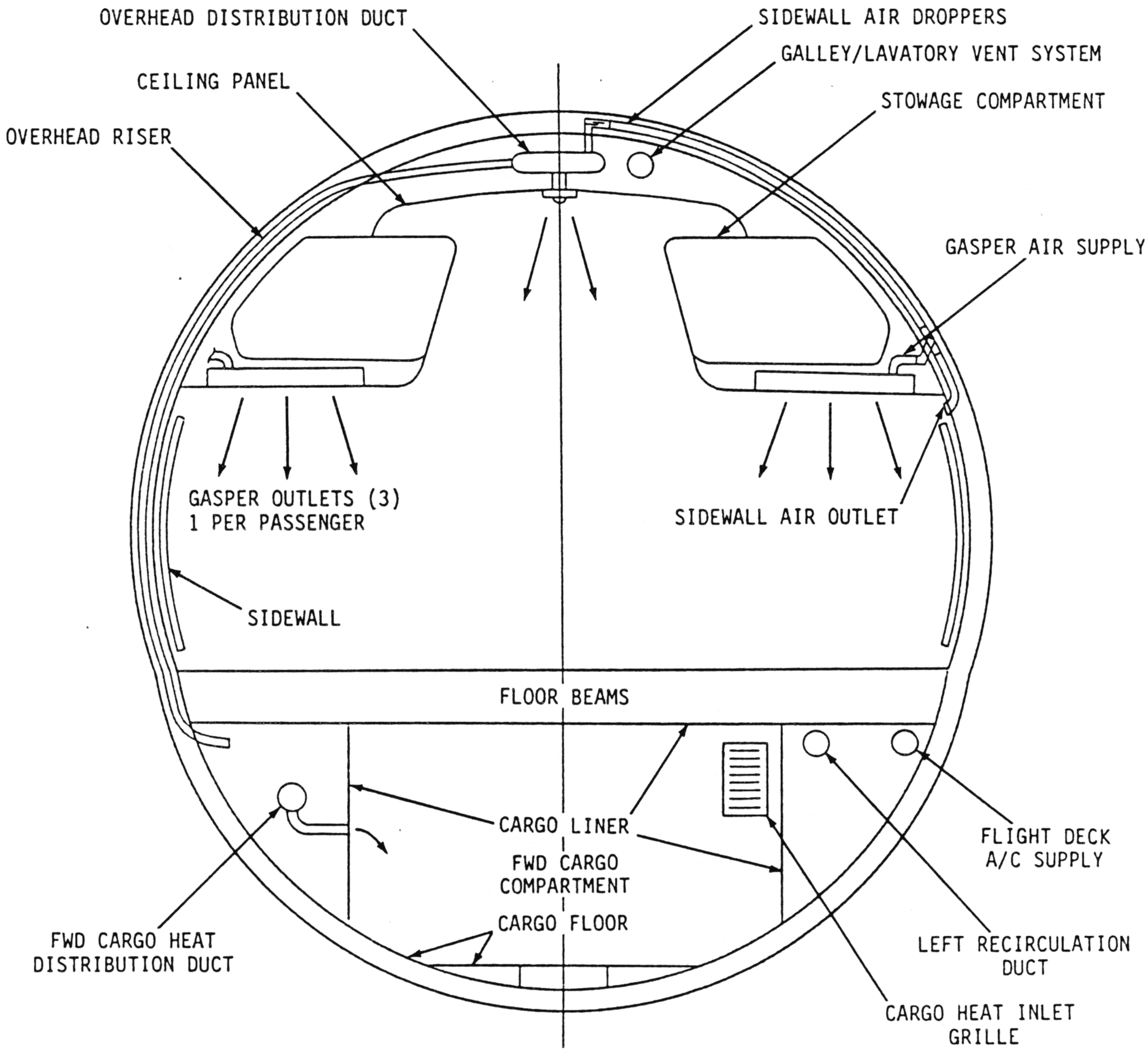


FIGURE 5-9. BOEING 757 PASSENGER CABIN CROSS SECTION

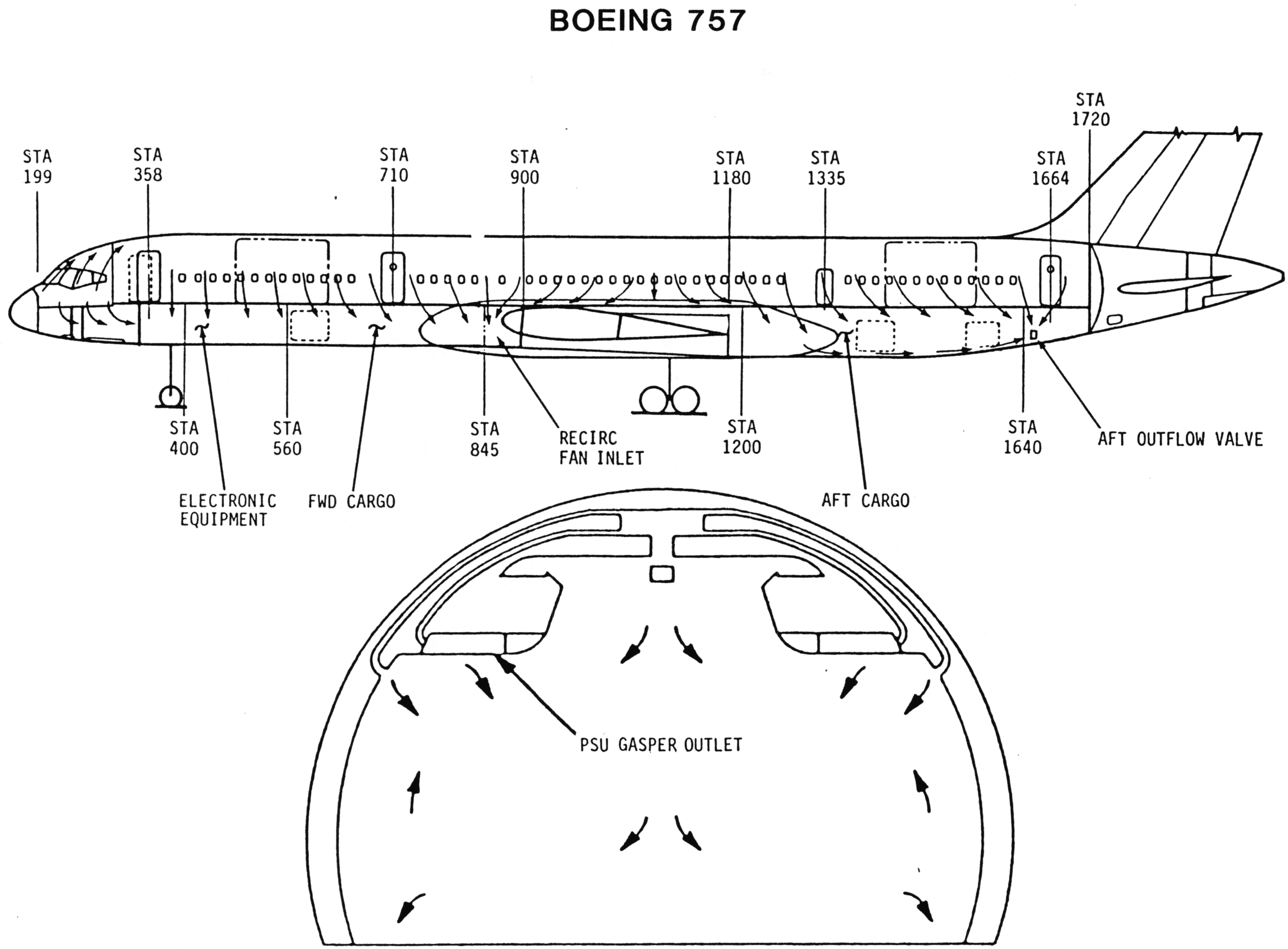
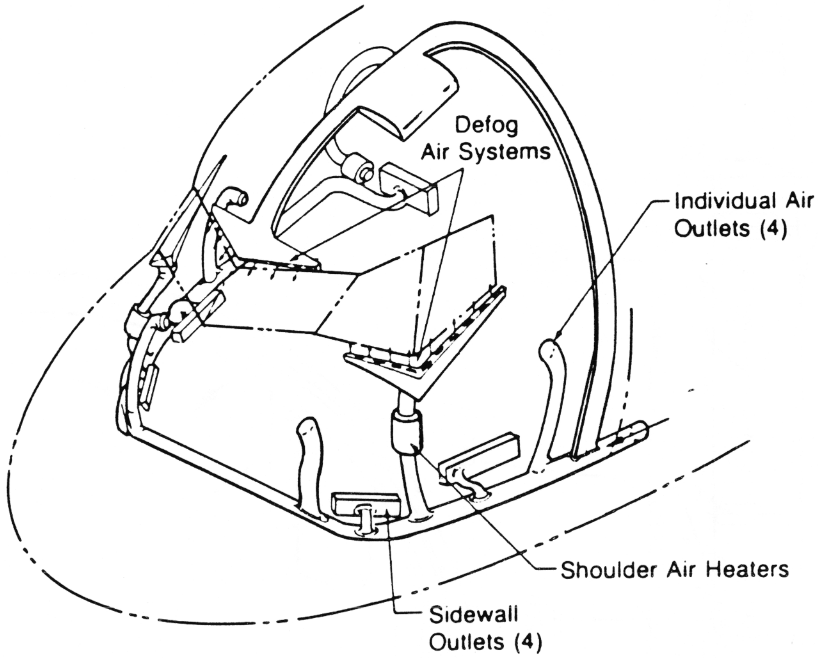
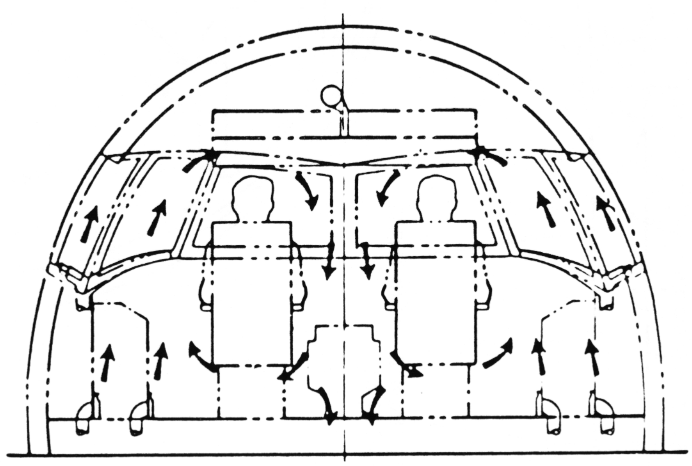


FIGURE 5-10. BOEING 757 PASSENGER CABIN AIRFLOW PATTERNS

BOEING 757



FLIGHT DECK DISTRIBUTION DUCTING



FLIGHT DECK AIRFLOW

FIGURE 5-11. BOEING 757 FLIGHT DECK COOLING

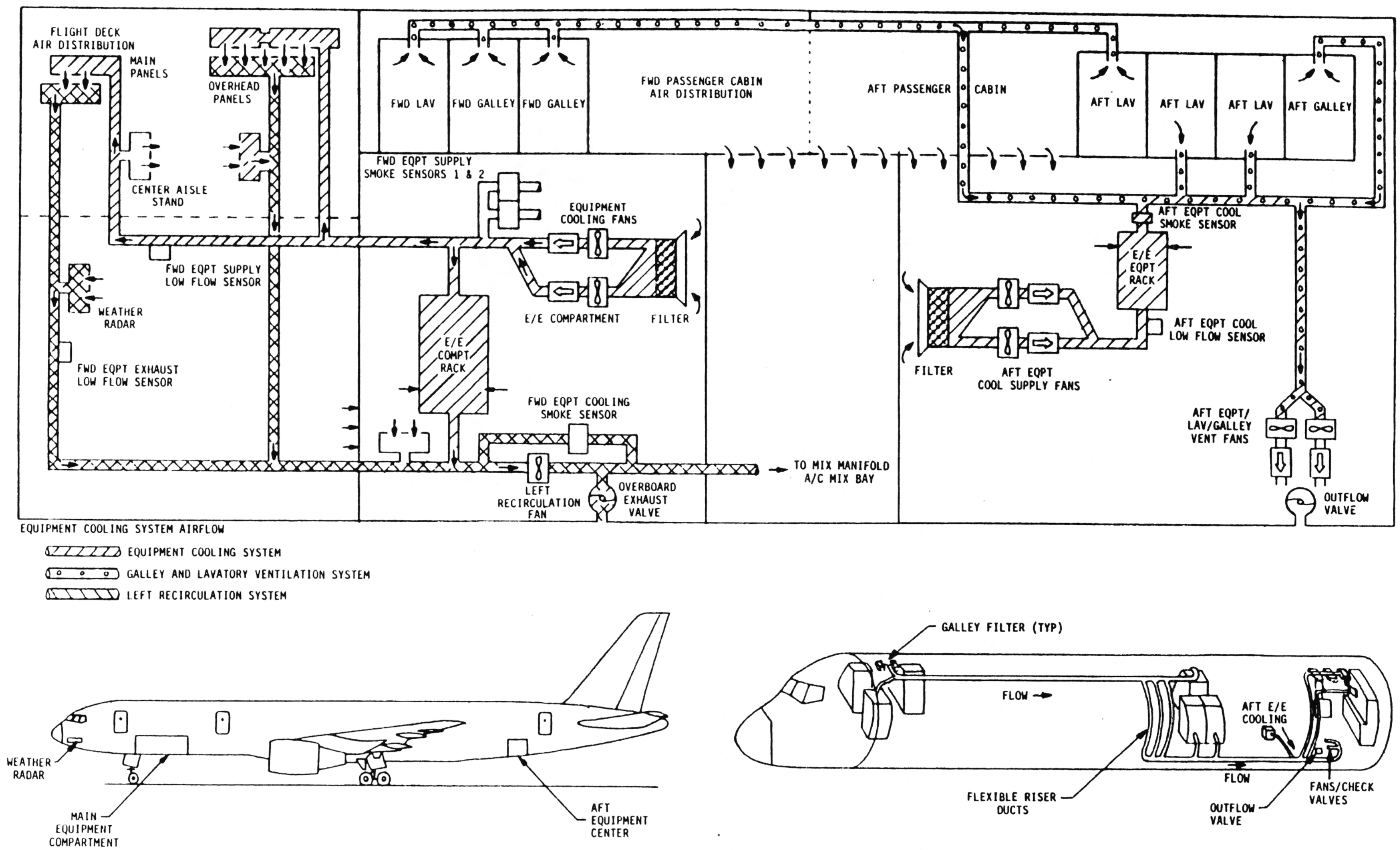
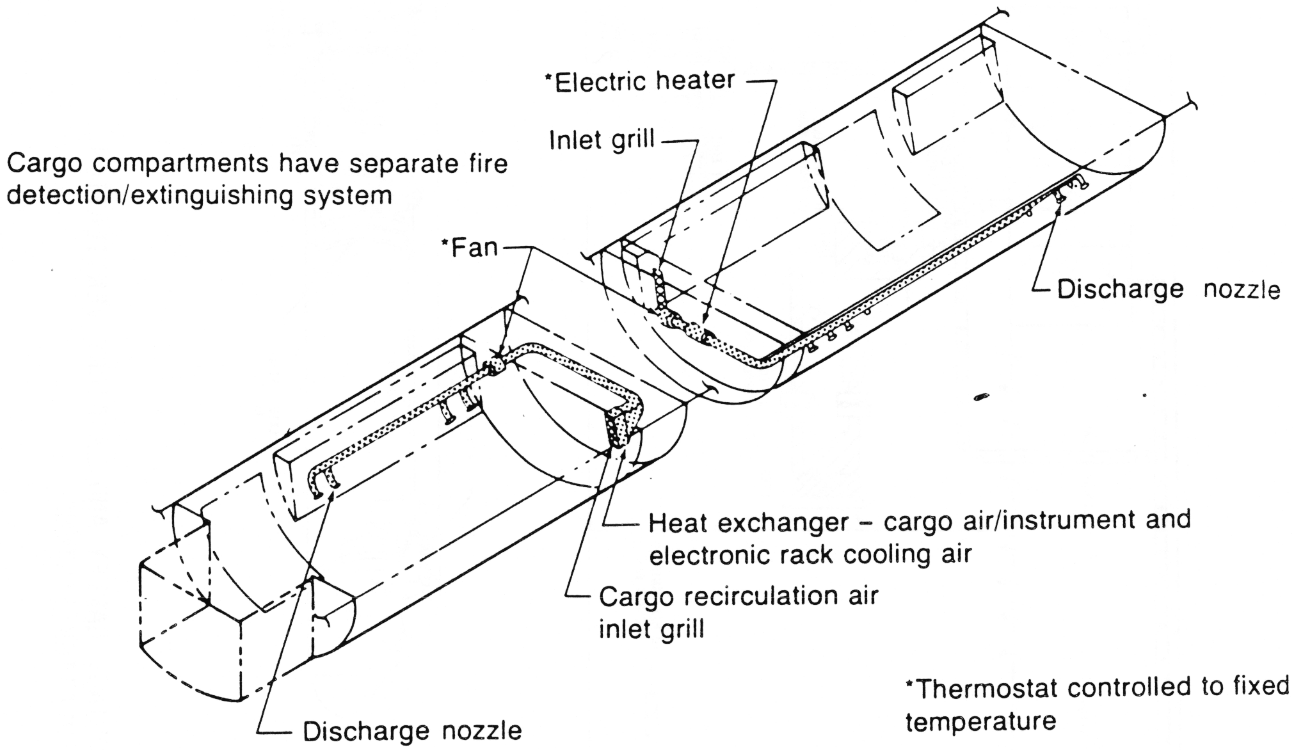
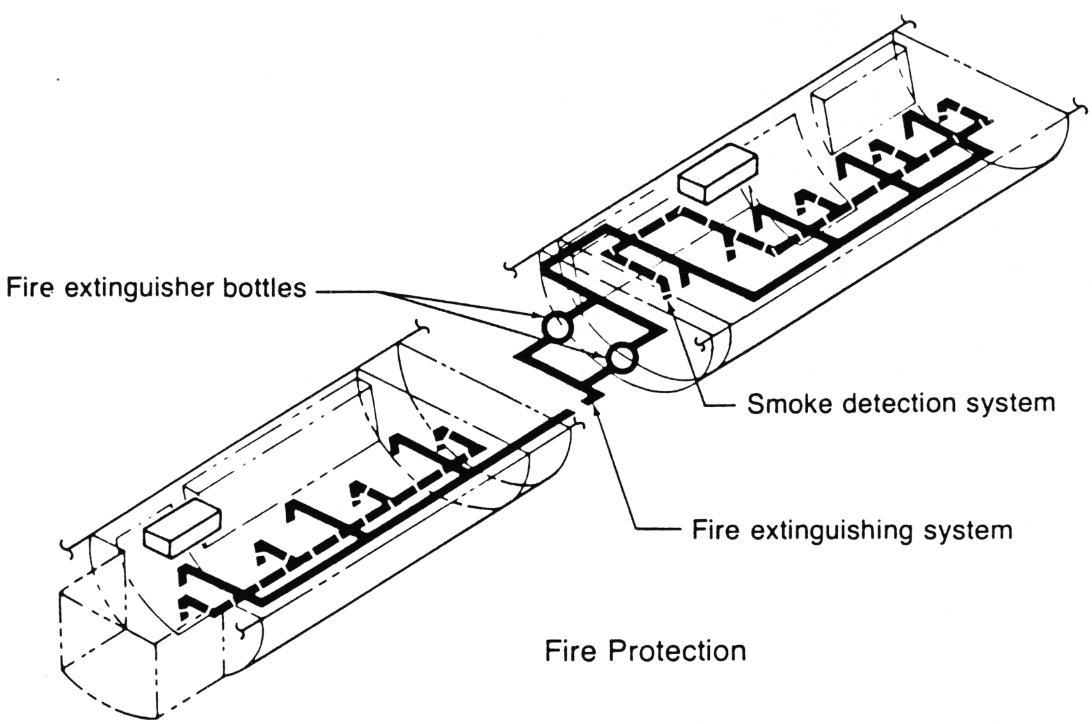


FIGURE 5-12. BOEING 757 EQUIPMENT COOLING, GALLEY AND LAVATORY VENTILATION, AND LEFT RECIRCULATION SYSTEMS

BOEING 757





Fire Protection

FIGURE 5-13. BOEING 757 CARGO COMPARTMENT HEATING

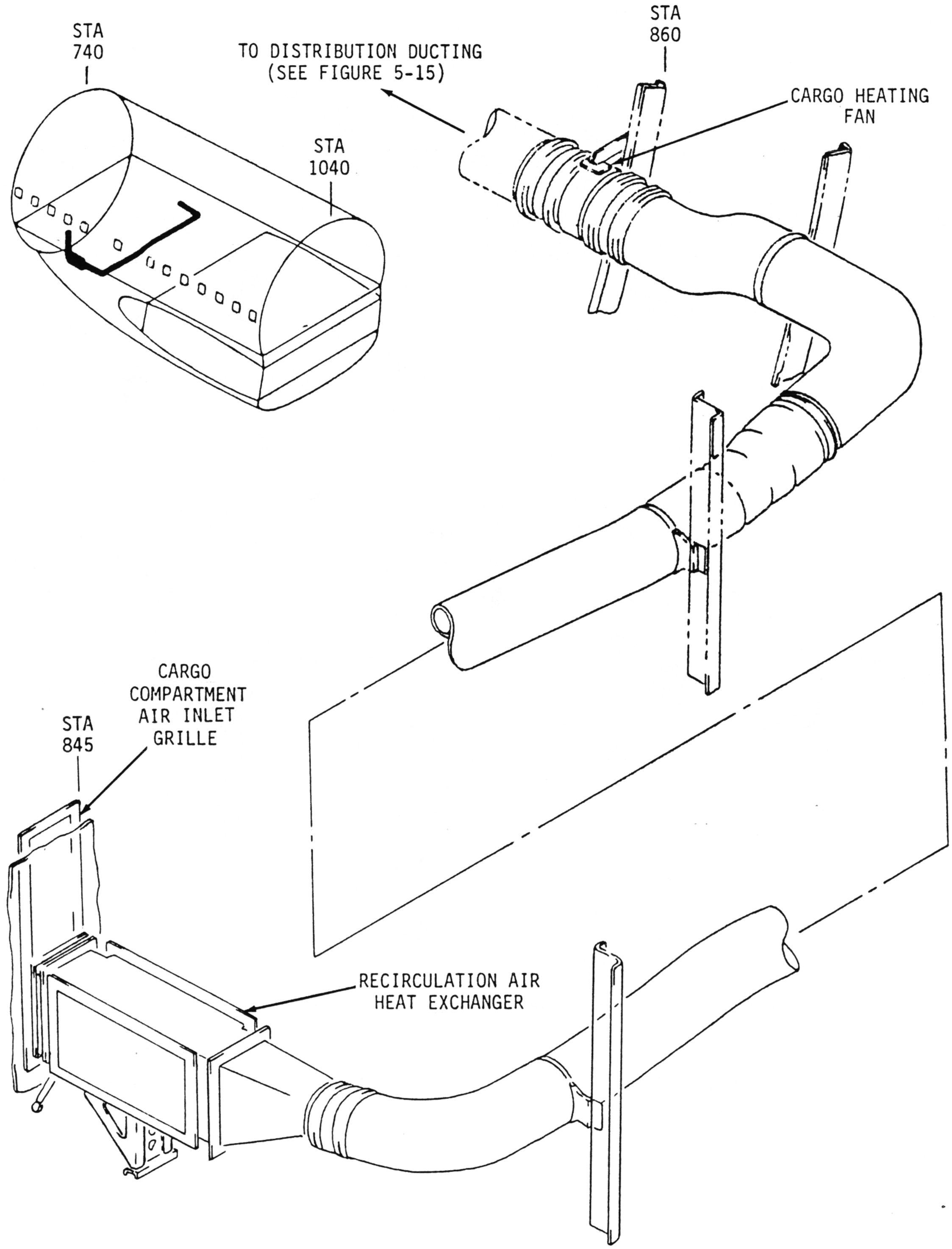


FIGURE 5-14. BOEING 757 FORWARD CARGO COMPARTMENT HEATING SYSTEM

BOEING 757

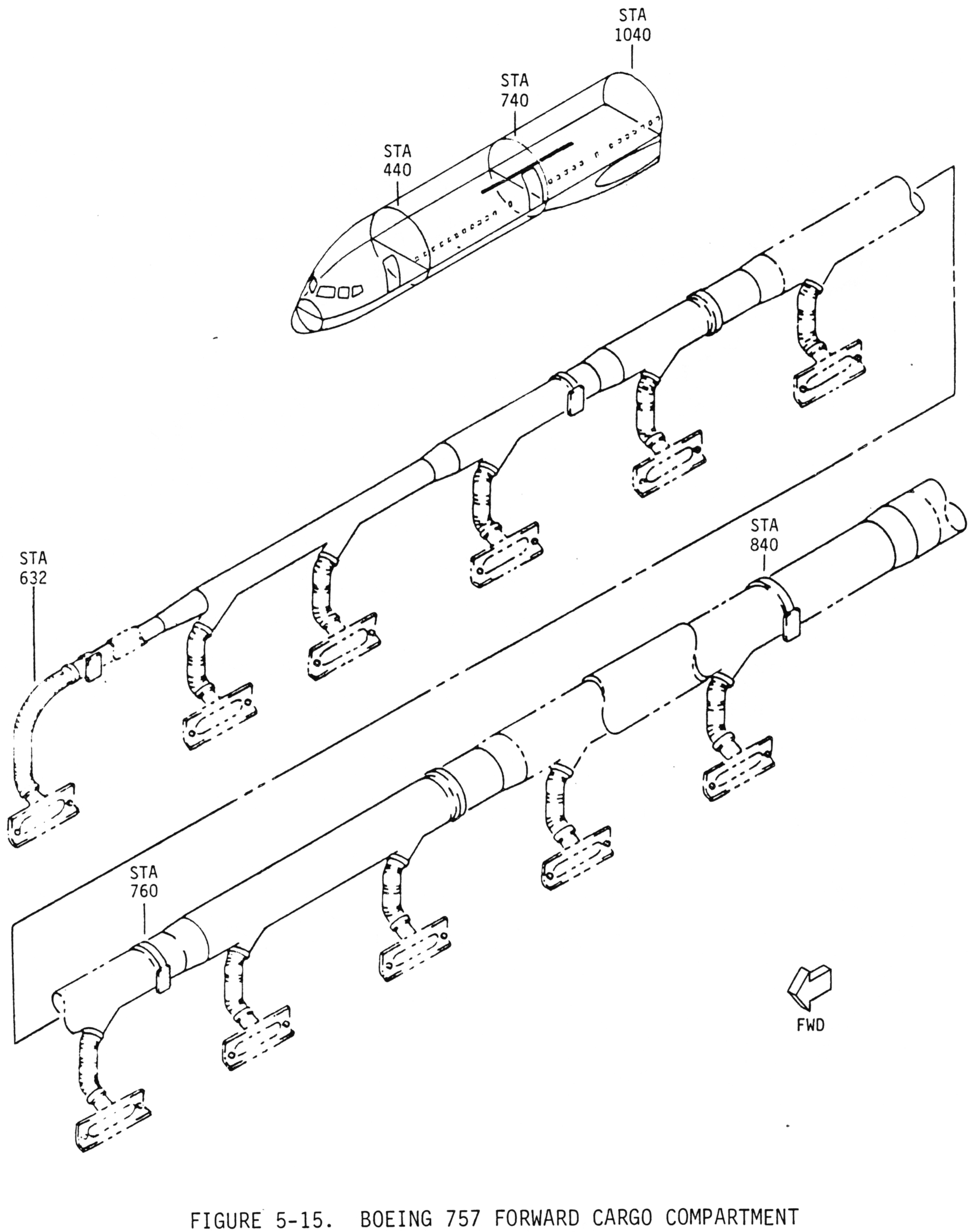


FIGURE 5-15. BOEING 757 FORWARD CARGO COMPARTMENT DISTRIBUTION DUCTING

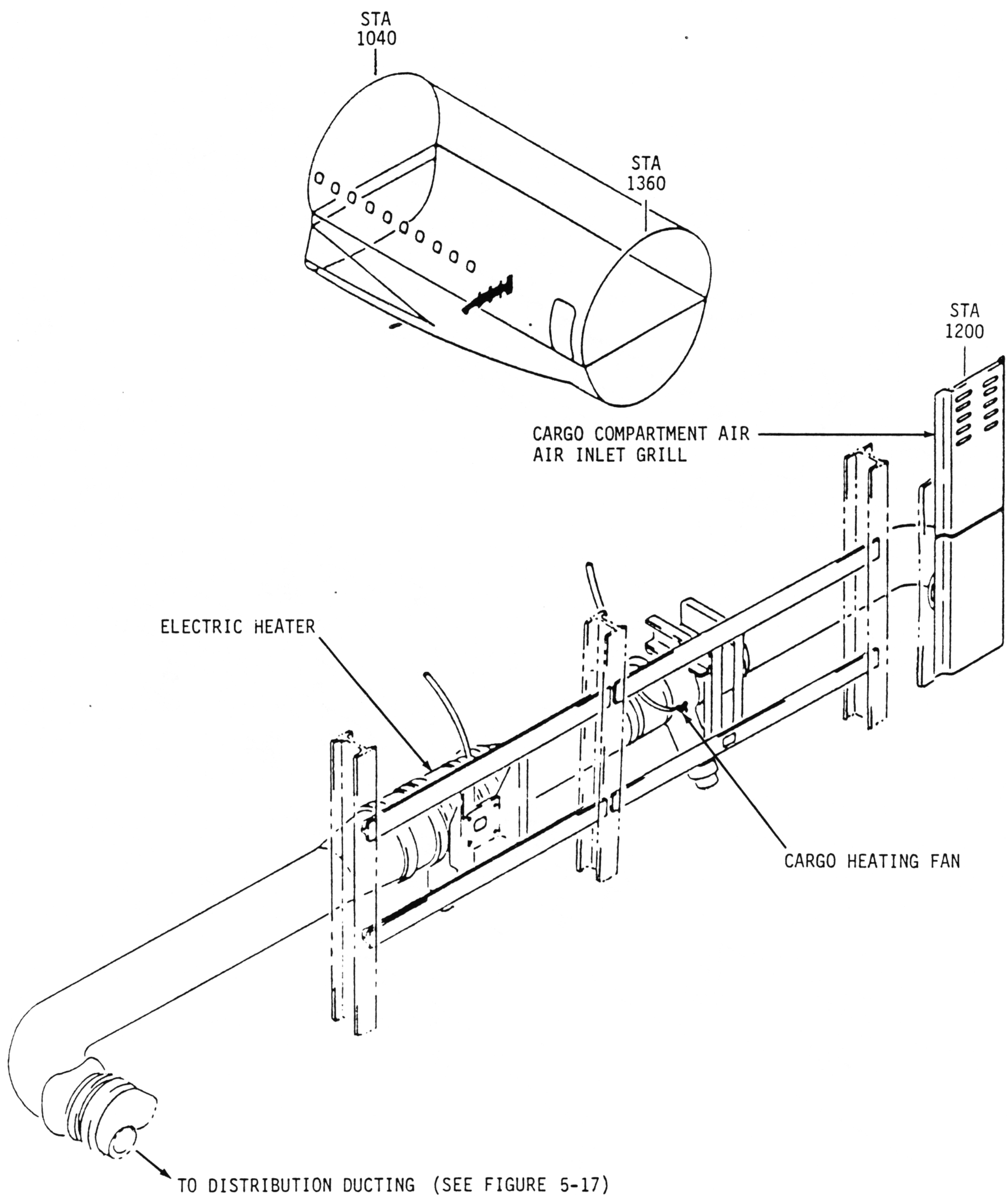


FIGURE 5-16. BOEING 757 AFT CARGO COMPARTMENT HEATING SYSTEM

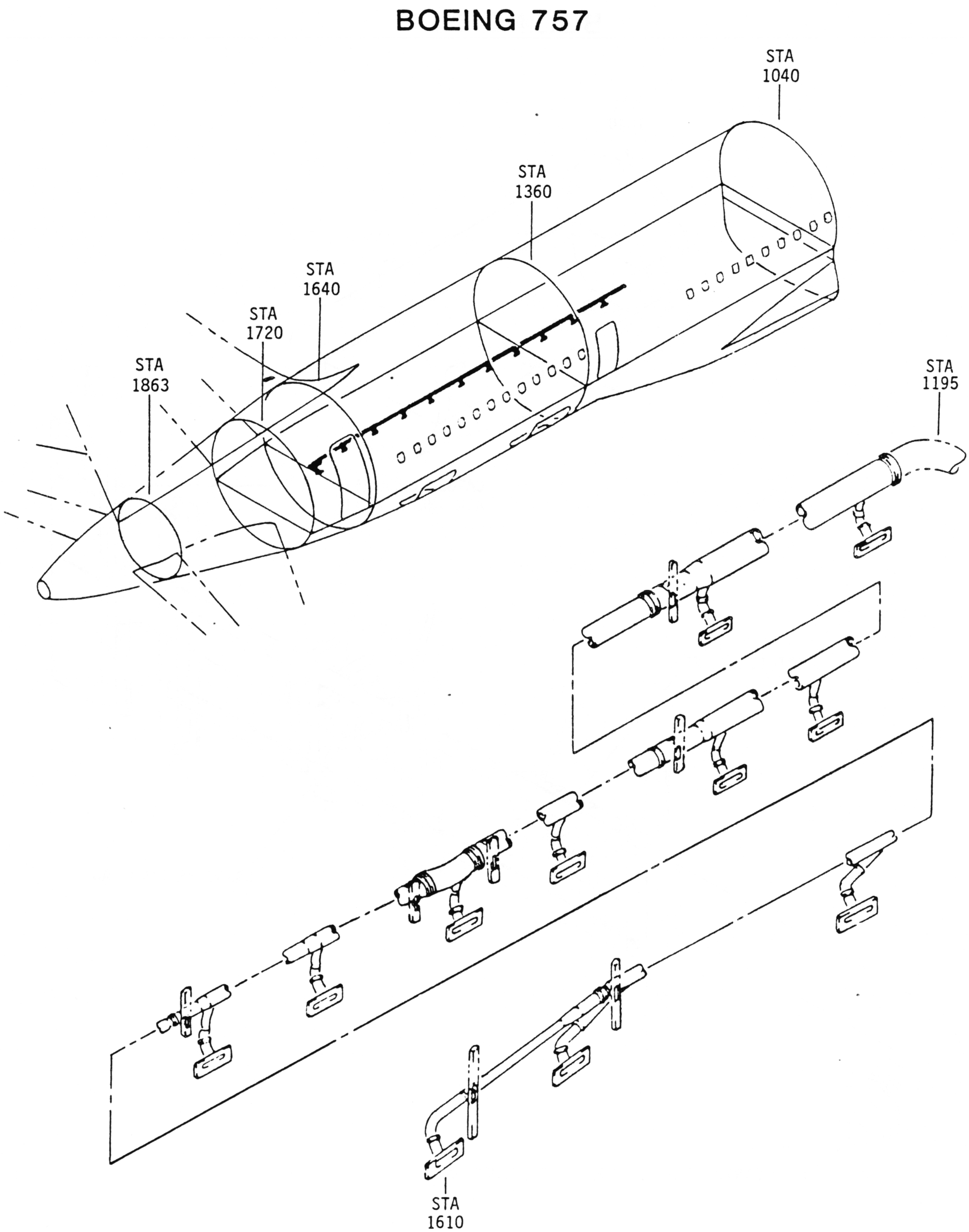


FIGURE 5-17. BOEING 757 AFT CARGO COMPARTMENT DISTRIBUTION DUCTING

BOEING 757

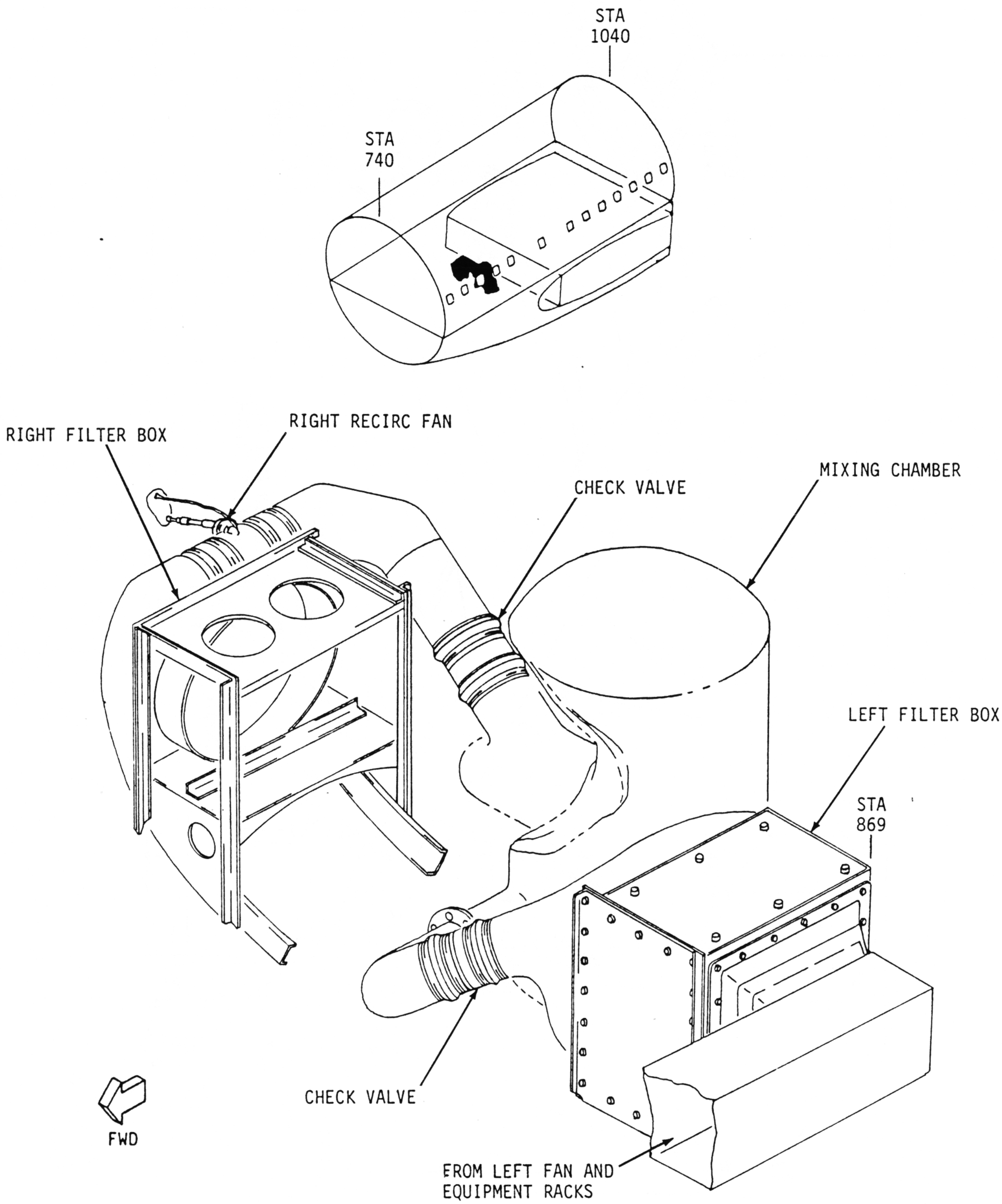


FIGURE 5-18. BOEING 757 RECIRCULATION SYSTEM

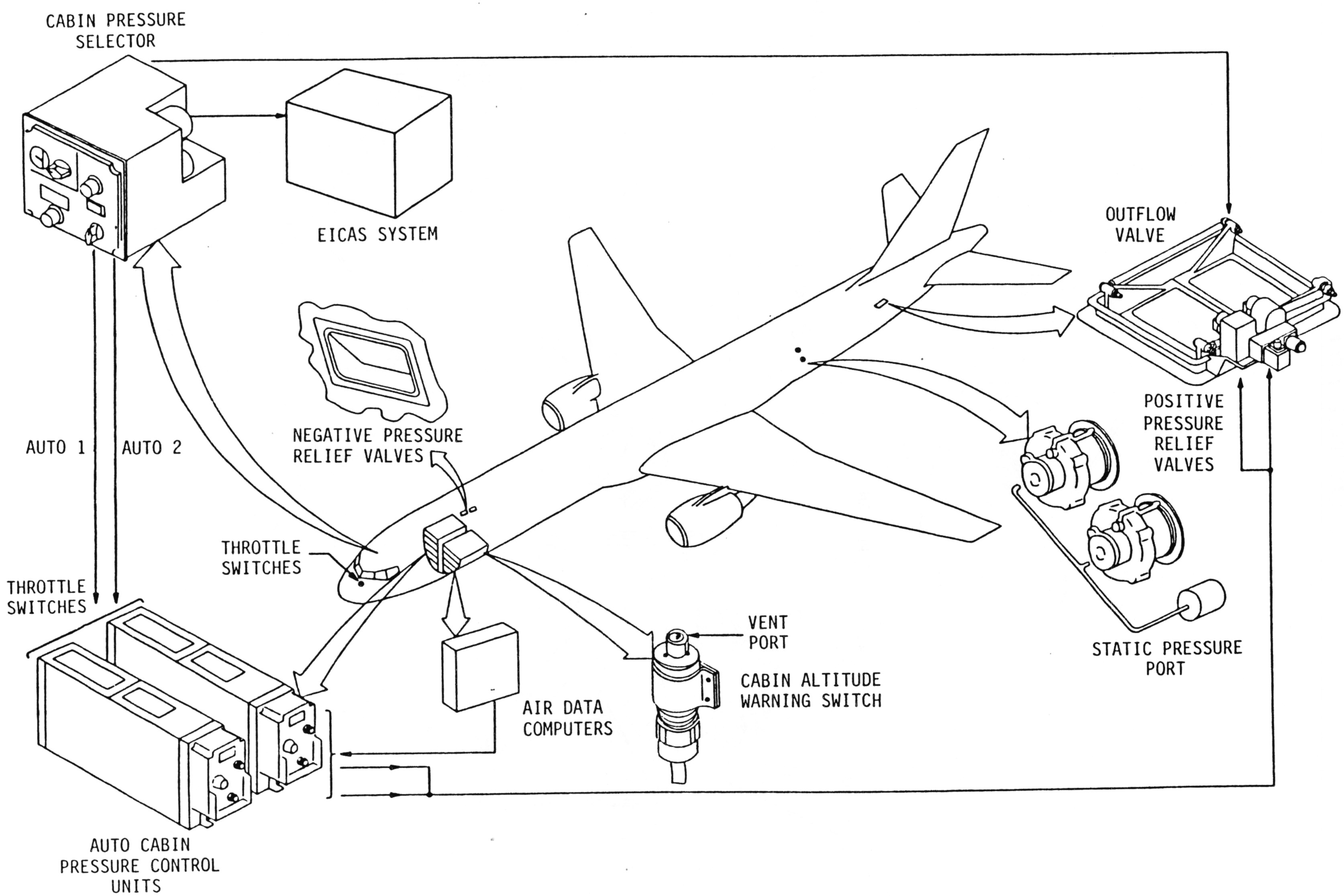


FIGURE 5-19. BOEING 757 PRESSURIZATION CONTROL EQUIPMENT LOCATION

BOEING 757

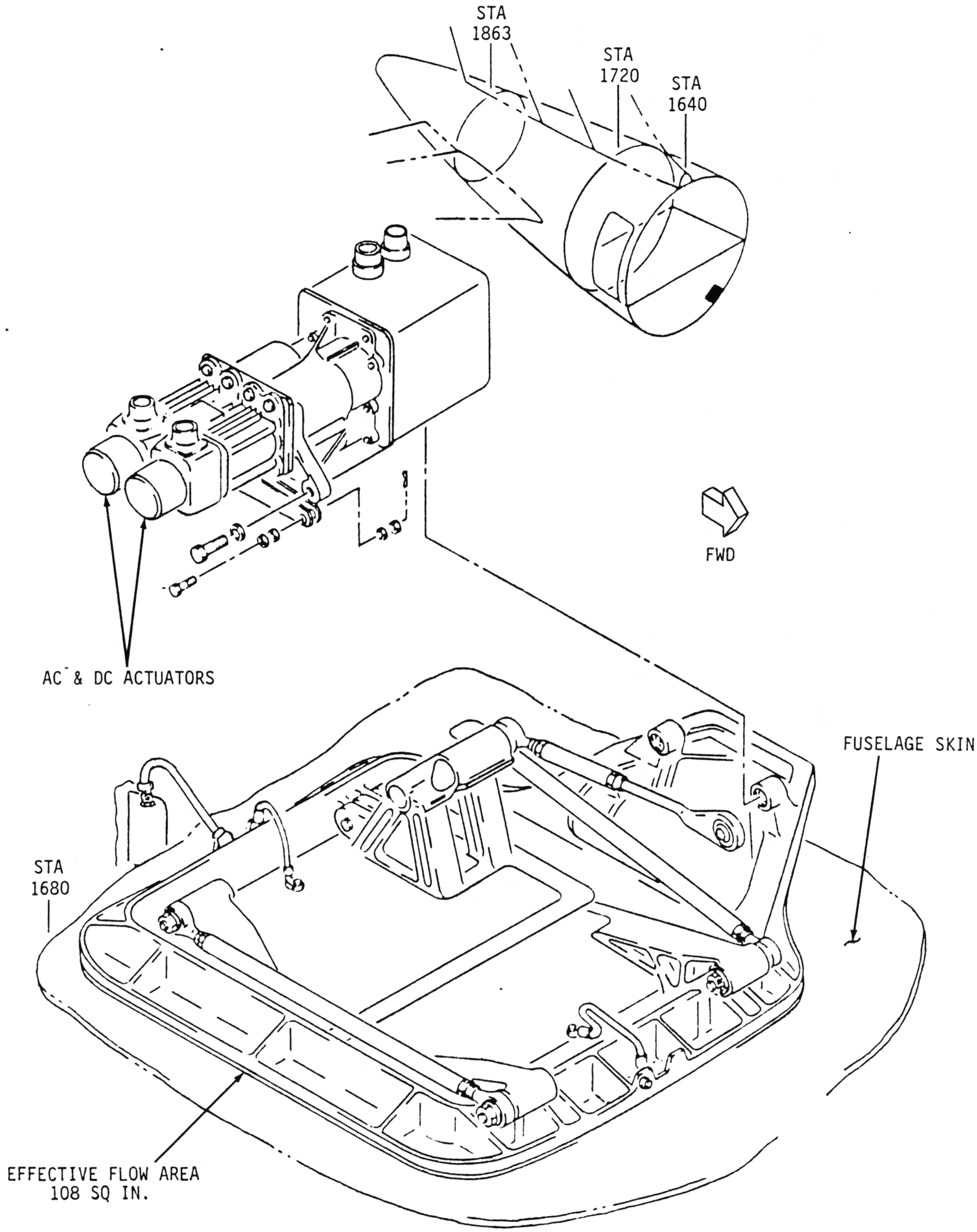


FIGURE 5-20. BOEING 757 AFT OUTFLOW VALVE

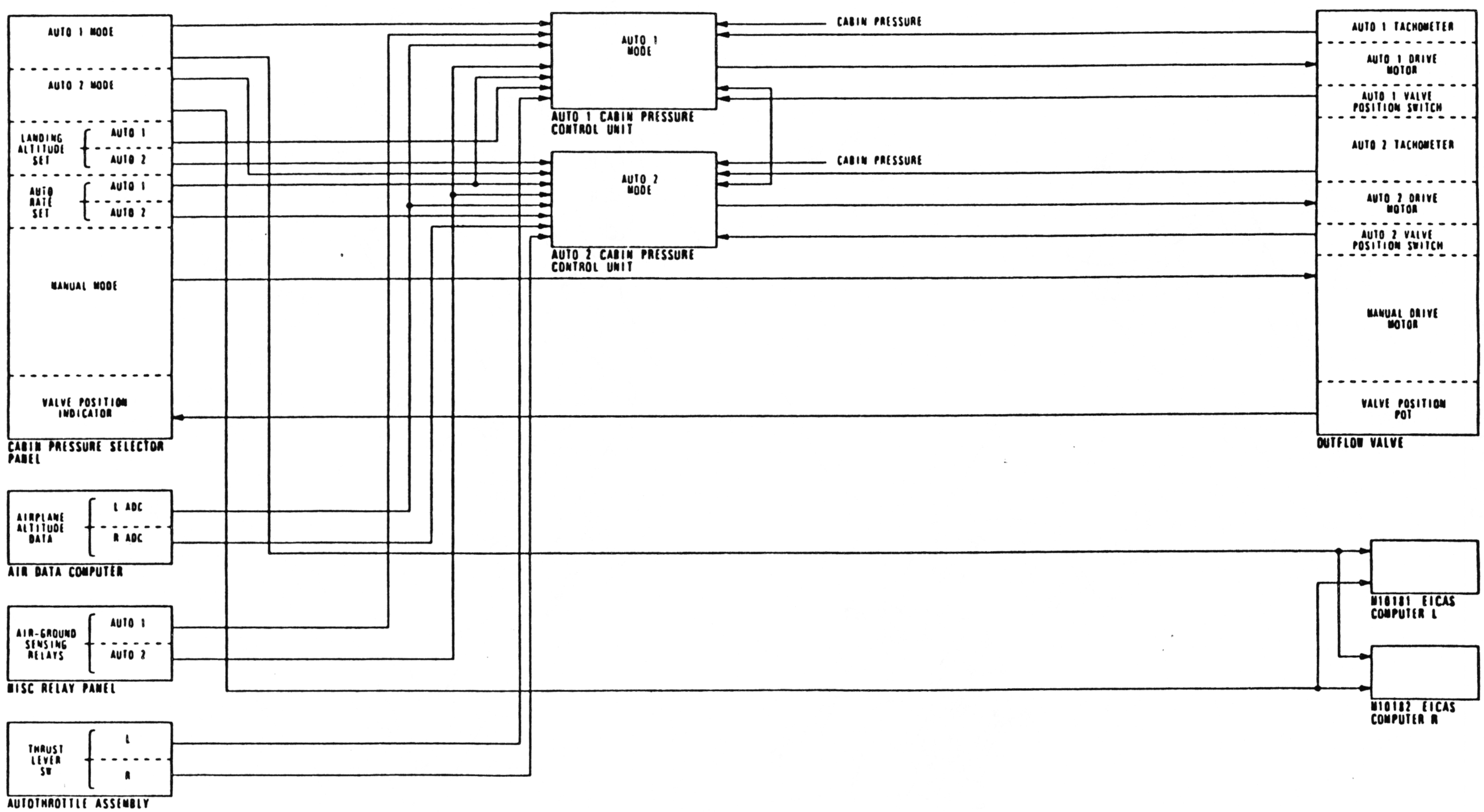


FIGURE 5-21. BOEING 757 PRESSURIZATION CONTROL SCHEMATIC

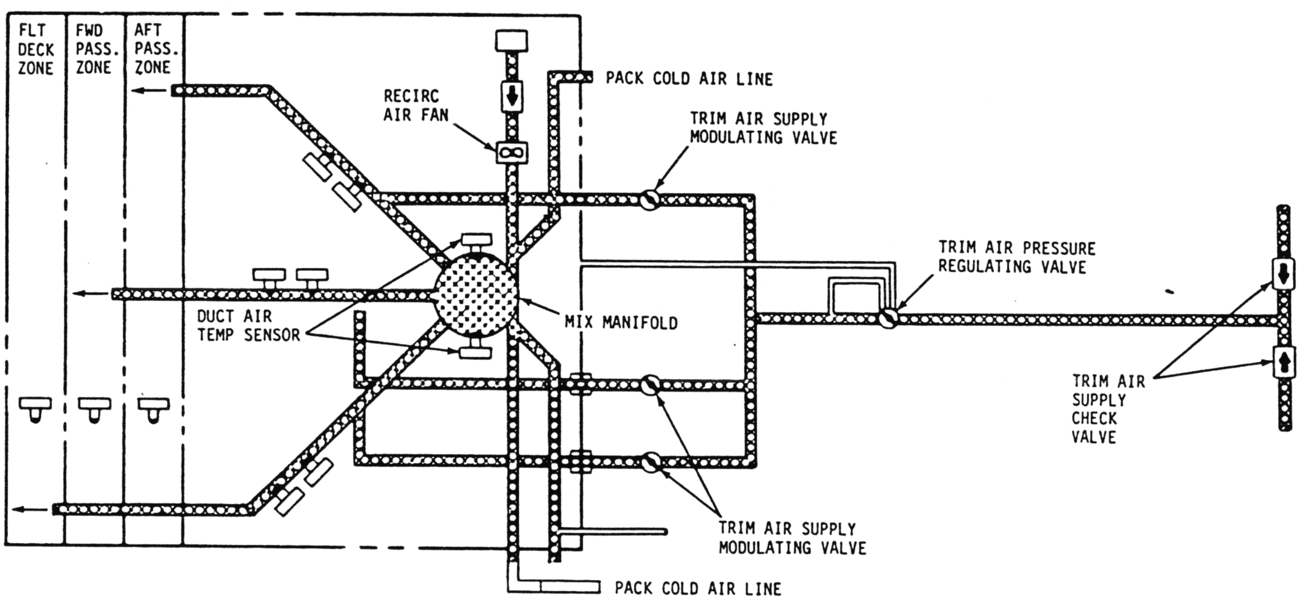
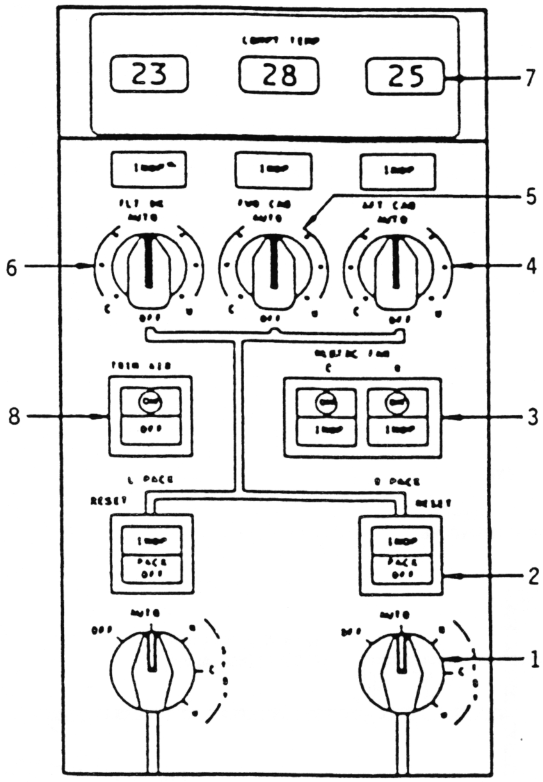
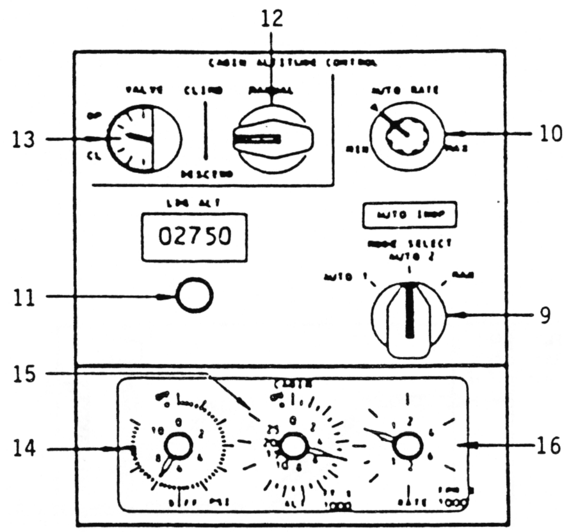


FIGURE 5-22. BOEING 757 ZONE TEMPERATURE CONTROL SCHEMATIC

BOEING 757



ECS CONTROLS



PRESSURIZATION CONTROLS

1 PACK MODE SELECTOR

2 PACK INDICATOR LIGHTS

3 RECIRCULATION FAN SWITCHES

4 AFT CABIN TEMPERATURE SELECTOR

5 MID CABIN TEMPERATURE SELECTOR

6 FLIGHT DECK TEMPERATURE SELECTOR

7 ZONE TEMPERATURE INDICATORS

8 TRIM AIR SWITCH

9 PRESSURE CONTROLLER SELECTOR

10 CABIN ALTITUDE RATE OF CHANGE SELECTOR

11 LANDING ALTITUDE SELECTOR

12 MANUAL PRESSURE CONTROL

13 OUTFLOW VALVE POSITION INDICATOR

14 DIFFERENTIAL PRESSURE GUAGE

15 CABIN ALTITUDE

16 CABIN ALTITUDE RATE OF CHANGE INDICATOR

FIGURE 5-23. BOEING 757 ECS AND PRESSURIZATION CONTROLS

SECTION 6

BOEING 767

Model Variation

The Boeing 767 was introduced in the early eighties as a medium range wide-body transport designed to fill a market not efficiently serviced by existing transports or their derivatives. The 767 incorporates advanced technology in aerodynamics, structures, materials, and most major systems

The 767 was first flown on 8-4-81, certified on 7-30-82 and placed into service by United Airlines on 9-8-82. Total program production as of 10-1-84 is 101 delivered, 80 on order, and 90 options. The 767 is available in two versions, the -200 and the -200 ER. The -200 ER is an extended range version of the -200, incorporating extra fuel in the wing center section.

The 767 series is soon to be joined by -300 and -300 ER versions. The new models will incorporate a 20 ft. body extension, revised ECS and strengthened structures.

767 Environmental Control System (ECS)

The 767 ECS is a two pack air cycle system that uses engine bleed-air as the air source. A block diagram is shown in Figure 6-1. The air conditioning packs are located below the wing in an unpressurized area of the fuselage, just forward of the wheel well. The air conditioning pack utilizes bleed-air from the compressor stages of both engines as an air source. During ground operation, the APU or a ground cart can be used as an air source. A schematic of the system is shown in Figure 6-2. The hot bleed-air temperature and pressure are regulated by the pneumatic system before being supplied to the flow-control and shut off valve.

The flow-control valve is an electrically controlled pneumatically operated valve that regulates flow through the system to minimize variation in volumetric flow rate. The flow-control valve has two operating modes, normal and high-flow modes. The high-flow mode allows the pack to be operated at 165% of normal flow schedule if certain conditions are satisfied (see ECS controls). The normal flow mode regulates the system flow rate from a preset schedule that is based upon the conditions of operation, and is contained in the pack controller logic.

After leaving the flow-control valve, hot air is routed to the trim air system, pack low-limit control valve, and primary heat exchanger. The trim air system is used to provide zone temperature control by adjusting the temperature of the appropriate distribution system, low-limit control air is used to control icing in the condenser, and prevent excessive compressor discharge temperature by limiting air flow through the compressor.

Most of the air flowing through the system is routed to the primary heat exchanger, where it is cooled by ram air, then routed to the air cycle machine (ACM) compressor. The ACM compresses the air to higher temperature and pressure. The air is then cooled by ram air in the secondary heat exchanger and directed through the water extraction components. After leaving the secondary heat exchanger water is partially removed in the secondary water extractor, then the air is cooled in the reheater, further cooled by turbine discharge air in the condenser, then water is extracted in the water extractor. Air leaving the water extractor is reheated in the reheater by air leaving the secondary heat exchanger before passing to the ACM turbine.

Air from the reheater is routed to the turbine and expands to produce cold air at the turbine outlet. The cold air then passes through the condenser and into the flight deck supply line and mixing manifold. The mixing manifold is shown in Figure 6-3. The temperature of the cabins is controlled by regulating the pack outlet temperature and by the trim air system. Pressures and temperatures at points shown in Figure 6-2 are shown in Table 6-1.

Distribution

Air leaving the pack condenser is routed to the mixing manifold where it is mixed with recirculated air before being routed to the distribution ducting.

The passenger cabin system is supplied from the mixing manifold by six risers located behind the sidewall (see Figure 6-4) on both sides of the cabin just forward of the wing. The risers are constructed from four ply Kevlar-epoxy materials, and supply air to the overhead distribution duct that is located above the ceiling, and runs the length of the passenger area (see Figure 6-5). The forward risers supply the forward cabin zone, and the mid and aft risers supply the aft cabin zone. Restrictors are installed in the risers to prevent uneven distribution within the cabin.

The overhead duct directs air to the passenger cabin through outlets at the bottom of the centerline stowage compartments. The stowage compartment outlets are connected to the overhead by dropper ducts spaced approximately every twenty inches along the overhead duct. The dropper ducts are connected to a plenum located below the stowage compartment that runs the length of the passenger cabin. The plenums exhaust air into the cabin through a thin opening that runs the length of the plenum. A cross section showing passenger cabin ducting locations is shown in Figure 6-6. Passenger cabin airflow patterns are shown in Figure 6-7.

The flight deck distribution system is shown in Figure 6-8. The distribution system is supplied from the main distribution manifold by a duct running forward below the left-hand floor. The distribution system consists of floor outlets, gasper outlets, windshield diffusers and overhead outlets.

The floor outlets are arranged along the lower edge of the compartment, three on each side, one at the back of the compartment, and two at the pilot and co-pilot's feet. The flight deck has six gasper outlets supplied from the flight deck distribution system. Outlet locations are shown in Figure 6-9.

The windshield diffusers exhaust conditioned air onto the window to prevent fogging. The side window diffusers are located below the window, and have an in-line electric heater for increasing the air temperature. The center window diffusers are located in the ceiling above the window. All diffusers are supplied from the air conditioning system.

Flight deck airflow patterns are shown in Figure 6-10.

Airflow rates entering the compartments are shown in Table 6-2 and air change rates in Table 6-3. Compartment volumes are shown in Table 6-4.

Individual (Gasper) Air

The 767 does not have gasper air available to the passengers. Gasper air is provided only for the crew, and in the lavatory and galley areas. All outlets are supplied from the conditioned air distribution system.

Equipment Cooling

The 767 equipment cooling system is shown in Figure 6-11. The equipment cooling system operates in one of four modes selected by the crew; auto, standby, override, and refrigeration. When using the auto mode, the equipment cooling controller chooses between one of the three auto modes available depending on atmospheric conditions, flight regime, and fire situation.

A schematic of the equipment cooling system showing airflow paths, status of valves and fans, control panel setting, and EICAS computer messages for each mode are shown in Figures 6-12 through 6-16. Once the mode is selected, the equipment cooling controller checks various inputs such as skin temperature, engine operation, and flight/ground relays, and activates the appropriate valves and fans to provide necessary cooling. The EICAS computer display screens alert the crew of the system status, equipment malfunctions, or inadequate cooling.

The auto mode can operate in one of three configurations, outboard open loop, inboard open loop, and closed loop.

The outboard open loop (OOL) configuration (see Figure 6-12) is used when the airplane is on the ground, the skin temperature is greater than 45 °F, and one or both engines off. During OOL operation, the supply fans draw outside air into system through the ground supply valve, and force it through the forward equipment racks and main panels. The exhaust fan draws air in through the overhead and side panels, and dumps the air overboard through the overboard exhaust valve.

The inboard open loop (IOL) mode (see Figure 6-13) requires that the airplane be on the ground with both engines operating. Operation in the IOL also occurs in flight if the skin temperature is greater than 45 °F. During IOL operation, air is drawn into the system by the supply fan through the inboard supply valve. The supply fan forces air through the forward equipment rack and main panels, and into the flight deck. The exhaust fans draw air from the flight deck through the overhead and side panels, and exhausts the air around the forward cargo compartment through the inboard exhaust valve.

The closed loop configuration (see Figure 6-14) requires that the airplane be in flight and the skin temperature be less than 45 °F. During closed loop operation, the supply fan draws air from the skin heat exchanger and blows it through the forward equipment rack and main panels into the flight deck. By drawing air from the skin heat exchanger, the supply fan causes air to be drawn into the overhead panels and side panels, into the exhaust ducting, then into the skin heat exchanger.

The refrigeration mode (see Figure 6-15) requires that the airplane be on the ground, the ambient temperature be greater than 70 °F, and one or no engines operating. If selected with both engines operating, the system switches to inboard open loop. During refrigeration mode, if the above conditions are met, the avionics cooling refrigeration unit (ACRU) operates. The ACRU is a small refrigerator that cools air supplied to the equipment cooling system by blowing air drawn from the flight deck exhaust system over the refrigerant evaporator. After exiting the evaporator, the cold air is blown through the forward equipment racks and into the flight deck through the main panels. The ACRU condenser fan draws air in through the ACRU supply valve, through the refrigerant condenser, and blows it overboard through the overboard exhaust valve.

Operation in the standby mode (see Figure 6-16) requires that it be selected on the equipment cooling control panel. It bypasses the equipment cooling controller and operates in flight or on the ground. During standby mode, the supply and exhaust fans operate to provide blow through and draw cooling as in the inboard open loop mode.

The override mode (see Figure 6-17) is used for smoke clearance. When the equipment cooling system detects smoke, the crew is alerted on the EICAS display screen and must select the OVRD mode on the control panel. When selected, the override mode bypasses the equipment controller and opens the override valve, and manifold interconnect valve. The manifold interconnect valve allows air from the flight deck conditioned air duct to blow through the main instrument panels into the flight deck. Cabin differential pressure drives flight deck air through overhead panels and side panels into the main and forward equipment racks, and overboard through the override valve.

The aft equipment rack is located at the right-hand side of the aft cargo compartment, and is cooled by the lavatory/galley ventilation system. The ventilation fans draw air from the equipment rack through the ventilation system ducting and exhaust this air in the vicinity of the out flow valve, to be exhausted overboard.

Cargo Heating

The 767 cargo compartments are classified as FAR Part 25 Class C compartments. As such, they are required to have the fire detection and suppression systems, adequate means to control ventilation and drafts within the compartment, and to exclude hazardous quantities of smoke from entering the passenger compartment. The 767 cargo compartments are heated by allowing hot air from the pneumatic manifold to be discharged below the cargo compartment and pass upward into the sides of the compartment area. The compartments are warmed by heat transfer to the cargo liner by the warm air circulating over it. The cargo heat system is shown in Figure 6-18.

The forward cargo heating system takes air from the pneumatic crossover manifold and exhausts it below the forward cargo compartment. Flow through the system is regulated by a flow-control valve, and compartment temperature is thermostatically controlled between 40-50 °F. The system is selected on or off from the overhead panel. Overheat protection and indication is provided if compartment temperature reaches 90 °F. If the fire bottle is armed, the shutoff valve will close.

The aft cargo compartment heating operates the same as the forward system.

The bulk cargo heating system operates the same as forward and aft systems, except that the heating has two levels; cargo and animal. With the selector switch in cargo, compartment temperature is regulated between 40-50 °F. In the animal position, the bulk cargo fan (see Figure 6-19) is actuated, and the temperature is regulated between 65 °F and 75 °F. The bulk cargo fan is mounted in the ceiling, and draws air from above the compartment into the compartment, to provide fresh air for live cargo. Air exits the compartment through a flapper valve in the left cargo lining. Overheat protection and indication is the same as the forward system.

Recirculation Systems

The 767 has two identical recirculation systems designated right and left. The recirculation system consists of a three stage filter, fan and check valve. The systems are mounted below the floor on either side of the mixing manifold, draw air from the surrounding areas through a three-stage filter, and exhaust into the mixing manifold (see Figure 6-20).

The recirculation filters are three stage fiberglass and charcoal pads rated at 1,200 cfm airflow. The first stage is a fiberglass prefilter that removes approximately 60% of the large particles. The second stage is a high-efficiency particulate filter that has a minimum arrestance of 95% of all particles 0.3 microns or larger. The third stage consists of granulated charcoal sandwiched between corrugated steel sheets, and removes odors and gases from the airflow.

The fans operate on 115 volt 400 Hz three phase power. The fans are protected against overheat by thermal sensors in the motor, that stop the fan when the temperature reaches 350°F. Fan operation is controlled by switches located on the overhead panel.

Ventilation

Air is vented overboard by two systems, galley and lavatory venting and pressurization outflow valves. The galley and lavatory vent system uses a fan to draw air from the galley and lavatory areas into a system of ducting, and exhausts the air near the pressurization outflow valve. The 767 generally carries two to four galleys, one located at the right front door, and the rest placed at the very back of the cabin.

The ventilation system connects all the lavatories and galleys through a system of ducts located above the ceiling panels. The galleys have openings in the ceiling panels that draw air from the top of the galley through a filter into the ventilation ducting. The lavatory inlets are located beneath the toilet shroud. The ventilation system fans also provide airflow for cooling the aft equipment rack. The fans are located below the floor aft of the bulk cargo compartment, and exhaust air through the aft outflow valve. The fans run on 115 volt 400 Hz 3-phase AC power and are protected against overheat by a 275 F thermal switch. The fans are rated at 670 cfm.

The pressurization outflow valves are the primary method of venting air overboard. The 767 outflow valve is mounted on the lower right-hand fuselage just aft of the bulk cargo compartment.

The outflow valves respond to signals generated by the pressure controller to vary the size of the opening to maintain cabin pressure as requested. The outflow valve is shown in Figure 6-21.

Pressurization Control

The 767 has an electrically operated electronically controlled pressurization control system (PCS). The pressurization control system maintains a low cabin altitude during flight, and controls the cabin altitude rate of change by modulating the outflow valve opening. The 767 PCS has three operating modes, auto 1, auto 2, and manual.

Normal operation is on one of the auto modes, with the other auto mode acting as a standby. The manual mode further backs up the auto modes. A schematic of the pressurization control system is shown in Figure 6-22 and its limits of operation are shown in Table 6-4.

The auto modes consist of two identical electronic pressure controllers that accept inputs from the control panel, air data computer, and other control interfaces. The control panel is shown in Figure 6-23. Normally, one controller operates the outflow valve and the other remains in standby, monitoring system operation. To use the auto mode, the crew selects auto 1 or auto 2, and sets the landing altitude and the cabin altitude rate of change. The controller then modulates the outflow valve to maintain cabin pressure. Gauges are provided to monitor cabin altitude, differential pressure, and cabin altitude rate of change.

The manual mode can be used in case both auto controllers fail. The manual mode must be selected using the selector knob. When using the manual mode, the crew can only choose to have the cabin descend, climb or remain unchanged. A switch on the control panel signals the outflow valve to open or close. The crew must monitor the gauges to maintain cabin conditions within desired limits. A gauge is also provided to show the outflow valve position.

Environmental Control System (ECS)

The ECS control panel is shown in Figure 6-23. The ECS controls consist of switches to control the pack mode of operation, bleed-air source, recirculation fan operation, and compartment temperatures.

The pack control has two modes, auto and standby. The standby mode has three choices - N, W, or C.

The pack is started by putting the selector in auto or one of the standby modes. The flow of the pack is not adjustable by the crew, but the pack does have a high-flow mode. High-flow mode occurs automatically when the system is operating on 1 pack, or the recirculation fan on the same side as the pack has failed or is off. Additionally, high-flow mode is prevented when any one of the following conditions exist: during take-off or approach; when one engine is off, the aft cargo fire bottles are armed, or if using only one engine air source with wing thermal anti-ice in operation. When using auto mode, the temperature of the pack outlet is limited between 145 and 35 °F (0 °F above 31,000 feet) by automatic control systems. The standby modes are used when the auto mode is inoperative, or the heating or cooling demands are high.

The bleed-air source is the compressor stages of both engines while in flight, or the APU or a ground cart during ground operation of the packs. The switches permit shutdown of bleed-air sources when not needed.

Recirculation fan switches allow the crew to shut off the recirculation fans when less airflow is desired, or to force one pack into high-flow mode. The recirculation fans should also be shut off during a fire situation to avoid dispersing smoke from the lower areas into the passenger cabin.

The 767 temperature control uses a three zone control system; the flight deck, the forward passenger cabin, and the aft passenger cabin. A schematic of the zone temperature control system is shown in Figure 6-2. The zone temperature control system mixes hot pneumatic air with cold pack discharge air to provide temperature controlled air to all cabins.

To operate the zone temperature system, the crew first turns the trim air switch to on. This enables hot air to flow to the zone temperature control valves. The temperature-control valves respond to the temperature selector and compartment temperature sensor to mix the correct amounts of hot and cold air to achieve the desired temperature. The temperature is selected between 63-85 °F by the crew, and thermostatically maintained by the zone temperature control system. Gauges to monitor zone temperature are also provided.

Electrical energy requirements for ECS components and control systems are shown in Tables 6-5 and 6-6. The loads presented represent the connected load when the equipment is operating. It should be noted that not all equipment operates continuously through the flight.

TABLE 6-1. BOEING 767-200 SYSTEM TEMPERATURES & PRESSURES (REF 7)

(°F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		PACK OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	55	386	39	386	15	15	14.7	54	14.7	54	14.7	75	14.7	99
5,000 FT CLIMB	52	385	39	385	15.2	-2	14.7	39	14.7	39	14.7	75	12.2	81
10,000 FT CLIMB	50	384	38	384	15.2	1	14.7	38	14.7	38	14.7	75	10.1	64
25,000 FT CRUISE	DATA NOT AVAILABLE													
30,000 FT CRUISE	38	383	28	383	13.2	1	12.9	35	12.9	35	12.9	75	4.4	-8
35,000 FT CRUISE	30	382	30	382	12.3	-4	12.1	35	12.1	35	12.1	75	3.5	-26
43,000 FT CRUISE	33	379	25	379	11.2	50	11.0	77	11.0	68	11.0	75	2.4	-70
20,000 FT DESCENT	43	372	31	372	15.0	37	14.7	68	14.7	62	14.7	75	6.8	-12
15,000 FT DESCENT	44	372	31	372	15.0	31	14.7	65	14.7	69	14.7	75	8.3	6

MAXIMUM SUPPLY TEMP 145°F

MINIMUM SUPPLY TEMP 0°F

TABLE 6-2. BOEING 767-200 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN/PACK)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	90.5	4,071	53	528	53
5,000 FT CLIMB	90.5	3,780	49	488	49
10,000 FT CLIMB	90.5	4,616	45	490	45
25,000 FT CRUISE	DATA NOT AVAILABLE				
30,000 FT CRUISE	81	4,081	52	525	52
35,000 FT CRUISE	76	4,075	52	523	52
43,000 FT CRUISE	72	4,183	51	545	51
20,000 FT DESCENT	91	4,084	52	532	52
15,000 FT DESCENT	91	4,087	52	533	52

TABLE 6-3. BOEING 767-200 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK (FRESH & RECIRC)	FLIGHT DECK (ALL FRESH)
SEA LEVEL TAKEOFF	10.2	21.7	66.3	31.1
5,000 FT CLIMB	10.3	20.1	61.3	31.3
10,000 FT CLIMB	13.51	24.6	61.5	27.7
25,000 FT CRUISE	N/A*	N/A*	N/A*	N/A*
30,000 FT CRUISE	10.4	21.7	65.9	31.6
35,000 FT CRUISE	10.4	21.7	65.6	31.5
43,000 FT CRUISE	10.9	22.3	68.4	33.5
20,000 FT DESCENT	10.4	21.7	66.7	32.0
15,000 FT DESCENT	10.4	21.8	66.9	32.1

*NOT AVAILABLE

TABLE 6-4. BOEING 767-200 VENTILATION PARAMETERS

VOLUMES (CU FT)		767-200	
TOTAL PRESSURIZED		24,178	
PASSENGER CABIN		11,266	
CONTROL CABIN		478	
FWD CARGO		1,470	
AFT CARGO		1,225	
BULK CARGO		430	
PRESSURIZATION			
MAX △P			
CONTROLLER		8.6 PSI	
SAFETY VALVE		8.95 - 9.42	2 STAGE
CABIN ALTITUDE CHANGE RATES		CLIMB	DESCENT
CONTOLLER	MAX (FT/MIN)	2,000	1,200
CONTOLLER	MIN (FT/MIN)	50	30

MAXIMUM CABIN ALTITUDE-MANNUAL LIMITS TO 11,500 (FT)

AUTO MODE ALLOWS LANDING FIELD ALTITUDE OF 14,000 (FT)

TABLE 6-5. BOEING 767-200 AC ELECTRICAL ENERGY REQUIREMENTS (REF 16)

EQUIPMENT	POWER REQD	WATTS	VARS	SOURCE
Aft Equipment Cooling Fan #1	115V 400 Hz 3Ø	1.33 KW	2.37 KVAR	AC Ground Service
Pressure Controller Auto 1	115V 400 Hz 1Ø	.235 KW	.176 KVAR	AC Left Sec 1 ØB
R Pack Standby Power	115V 400 Hz 1Ø	.207 KW	.100 KVAR	AC Left Sec 1 ØB
L Pack Auto Power	115V 400 Hz 1Ø	.062 KW	.030 KVAR	AC Left Sec 1 ØB
Equip Cool Inboard Valves	115V 400 Hz 1Ø	.178 KW	.086 KVAR	AC Left Sec 1 ØB
Equip Cool Outboard Valves	115V 400 Hz 1Ø	.189KW	.092 KVAR	AC Left Sec 1 ØB
Pack Flow Indication	115V 400 Hz 1Ø	.01 KW		AC Left Sec 1 ØB
Cabin Zone Control	115V 400 Hz 1Ø	.061 KW	.030 KVAR	AC Left Sec 1 ØC
Equip Cooling Supply Fan 1	115V 400 Hz 3Ø	3.20 KW	1.55 KVAR	AC Left Sec 3
Aft Equip Cooling Fan 2	115V 400 Hz 3Ø	1.33 KW	2.37 KVAR	AC Left Sec 4
Aft Cargo Heat Valve	115V 400 Hz 1Ø	.207 KW	.100 KVAR	AC Left Sec 4 ØC
Fwd Cargo Heat Valve	115V 400 Hz 1Ø	.207 KW	.100 KVAR	AC Left Sec 4 ØC
Equip Cooling Stdby Power	115V 400 Hz 3Ø	.18 KW	.087 KVAR	AC Standby
Cabin Altimeter	115V 400 Hz 1Ø	5 W		AC Standby
Cabin Pressure Indicator	115V 400 Hz 1Ø	2 W		AC Standby
Left Recirc Fan	115V 400 Hz 1Ø	4 KW	2.79 KVAR	AC Utility Left
Capt Aux Heater, High	115V 400 Hz 1Ø	.385 KW		AC Utility Left ØA
Capt Aux Heater, Low	115V 400 Hz 1Ø	.385 KW		AC Utility Left ØB
L Pack Standby Power	115V 400 Hz 1Ø	.207 KW	.100 KVAR	AC Right Sec 1 ØA
R Pack Auto Power	115V 400 Hz 1Ø	.062 KW	.03 KVAR	AC Right Sec 1 ØA
Pressure Controller Auto 1	115V 400 Hz 1Ø	.235 KW	.176 KVAR	AC Right Sec 1 ØB
Fwd Cargo Ht Ovrd	115V 400 Hz 1Ø	.207 KW	.100 KVAR	AC Right Sec 1 ØB
Aft Cargo Ht Ovrd	115V 400 Hz 1Ø	.207 KW	.100 KVAR	AC Right Sec 1 ØB
Flt DK Temp Man Cont	115V 400 Hz 1Ø	.032 KW	.015 KVAR	AC Right Sec 1 ØB
Fwd Temp Control Valve Control	115V 400 Hz 1Ø	.032 KW	.015 KVAR	AC Right Sec 1 ØB
Aft Temp Control Valve Control	115V 400 Hz 1Ø	.032 KW	.015 KVAR	AC Right Sec 1 ØB
Equip Cool Sply Fan 2	115V 400 Hz 3Ø	3.2 KW	1.55 KVAR	AC Right Sec 3
Equip Cool Exhaust Fan	115V 400 Hz 3Ø	3.2 KW	1.55 KVAR	AC Right Sec 3
Right Recirc Fan	115V 400 Hz 3Ø	4 KW	2.79 KVAR	AC Utility Right
First Officer Aux Heater Low	115V 400 Hz 1Ø	.385 KW		AC Utility Right ØB
First Officer Aux Heater High	115V 400 Hz 1Ø	.385 KW		AC Utility Right ØC

TABLE 6-6. BOEING 767-200 DC ELECTRICAL ENERGY REQUIREMENTS (REF 16)

POWER REQD	EQUIPMENT	LOAD	SOURCE
Aft Equip Cooling Fan #1	28 VDC	.60 A	28 V Ground Handling
Left Recirc Fan	28 VDC	.60 A	DC Left Section 1
Aft Equip Cooling Fan #2	28 VDC	.60 A	DC Left Section 1
R Pack Standby Control	28 VDC	.65 A	DC Left Section 1
L Pack Auto Control	28 VDC	.24 A	DC Left Section 1
L Pack Flow Control	28 VDC	.40 A	DC Left Section 1
Equip Cooling Supply Fan #1	28 VDC	.60 A	DC Left Section 1
Equip Cooling Control	28 VDC	.8 A	DC Left Section 1
Trim Air	28 VDC	1.85 A	DC Left Section 1
Zone Temp Indication	28 VDC	.09 A	DC Left Section 1
Right Recirc Fan	28 VDC	.60 A	DC Right Section 1
Aft Equip Cooling Fan #1	28 VDC	.60 A	DC Right Section 1
Equip Cooling Exhaust Fan	28 VDC	.60 A	DC Right Section 1
Aft Cargo Heat Control	28 VDC	.25 A	DC Right Section 1
Fwd Cargo Heat Control	28 VDC	.25 A	DC Right Section 1
L Pack Standby Control	28 VDC	.65 A	DC Right Section 1
R Pack Auto Control	28 VDC	.24 A	DC Right Section 1
R Pack Flow Control	28 VDC	.40 A	DC Right Section 1
Equip Cooling Supply Fan #2	28 VDC	.60 A	DC Right Section 1
Ovht-Smoke Value Indication	28 VDC	1.37 A	DC Right Section 1
Fwd Zone Duct Ovht	28 VDC	.12 A	DC Right Section 1
Aft Zone Duct Ovht	28 VDC	.12 A	DC Right Section 1
Equip Cooling Override	28 VDC	1.40 A	Battery Bus
Cabin Alt Control Selector	28 VDC	.18 A	DC Standby Bus
Cabin Alt Control Manual	28 VDC	1.60 A	DC Standby
Equip Cooling Bnd Warning	28 VDC	.51 A	Hot Battery Bus

BOEING 767-200

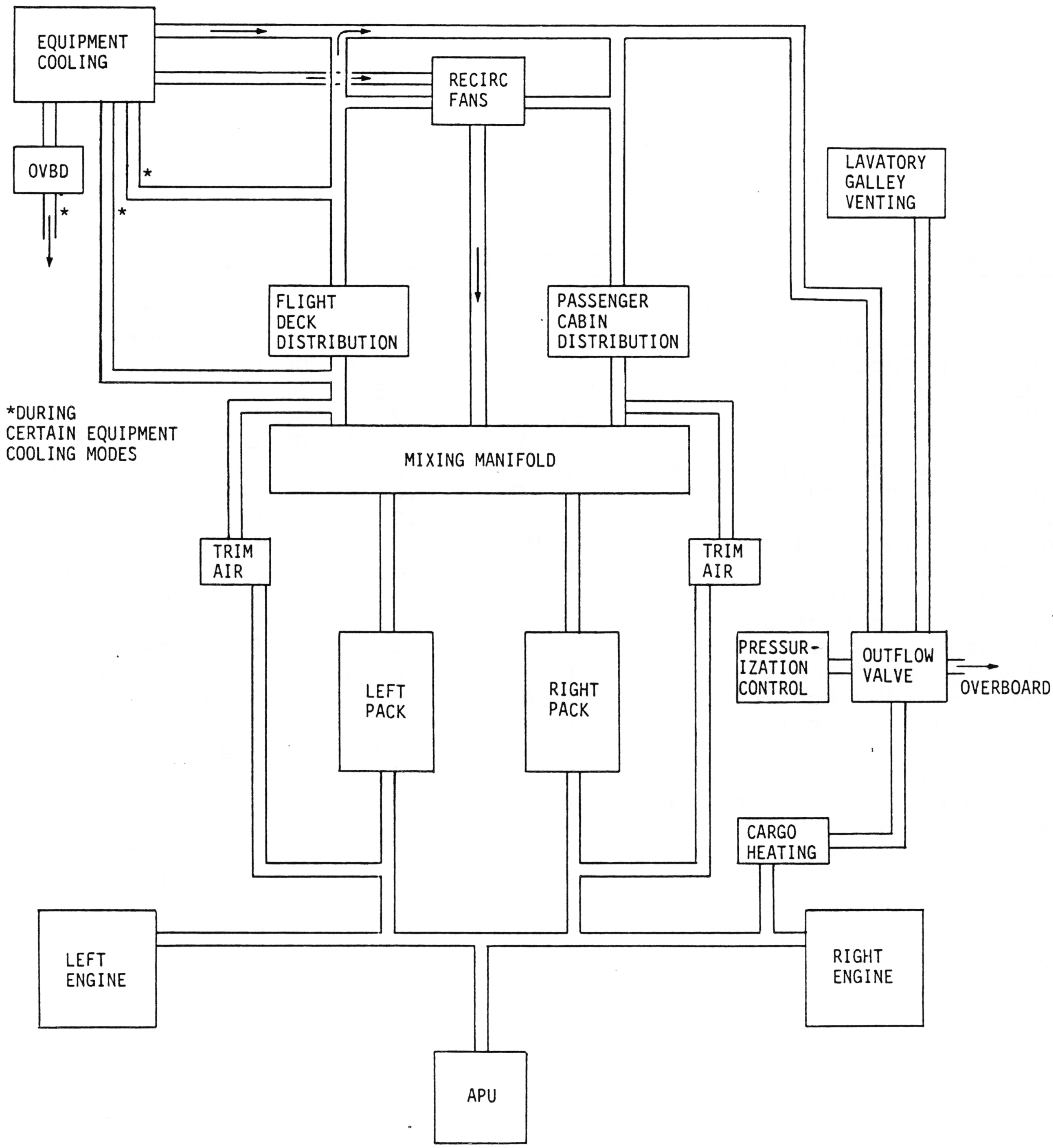


FIGURE 6-1. BOEING 767-200 AIR CONDITIONING SYSTEM BLOCK DIAGRAM

BOEING 767-200

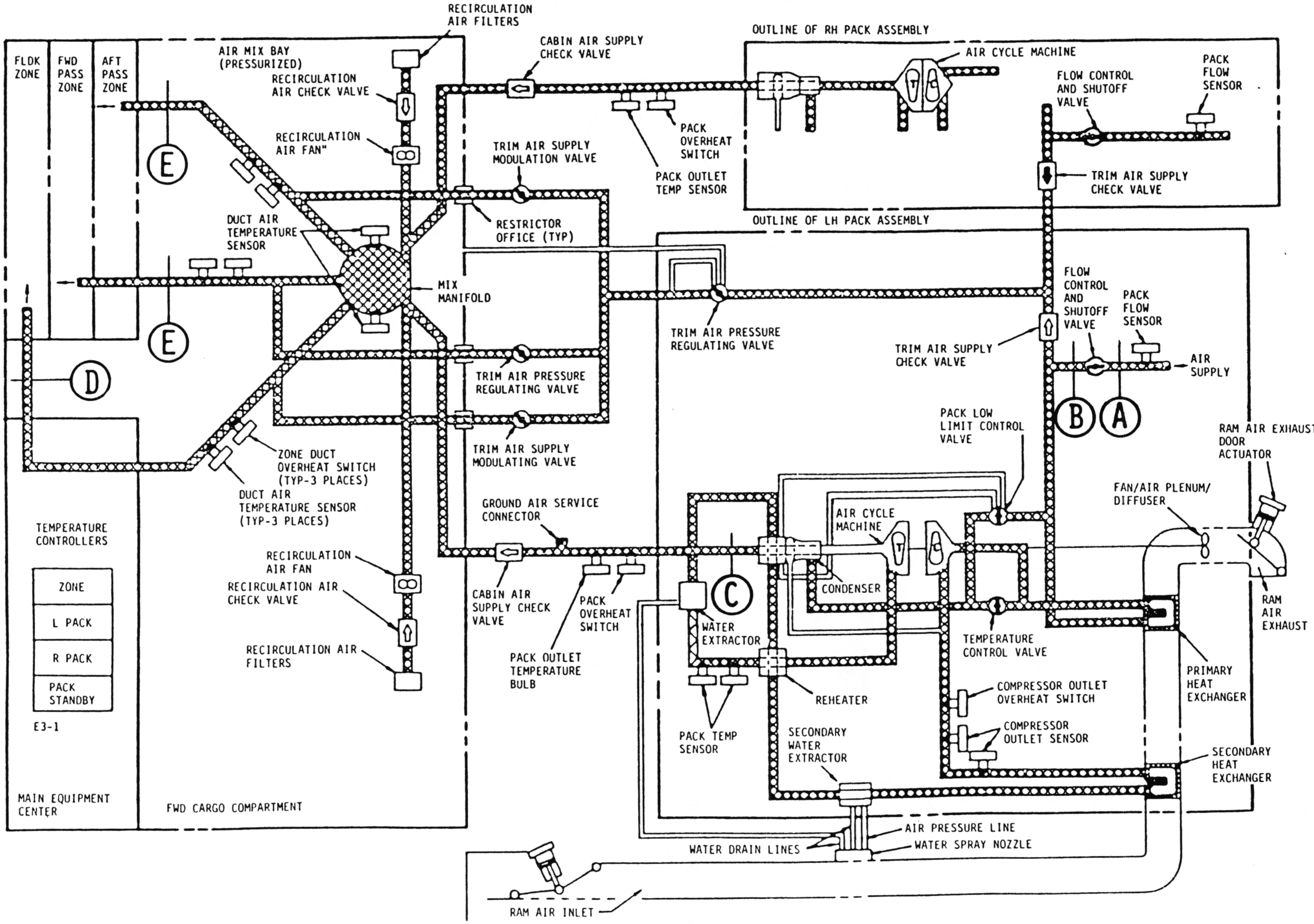


FIGURE 6-2. BOEING 767-200 AIR CONDITIONING SYSTEM SCHEMATIC

BOEING 767-200

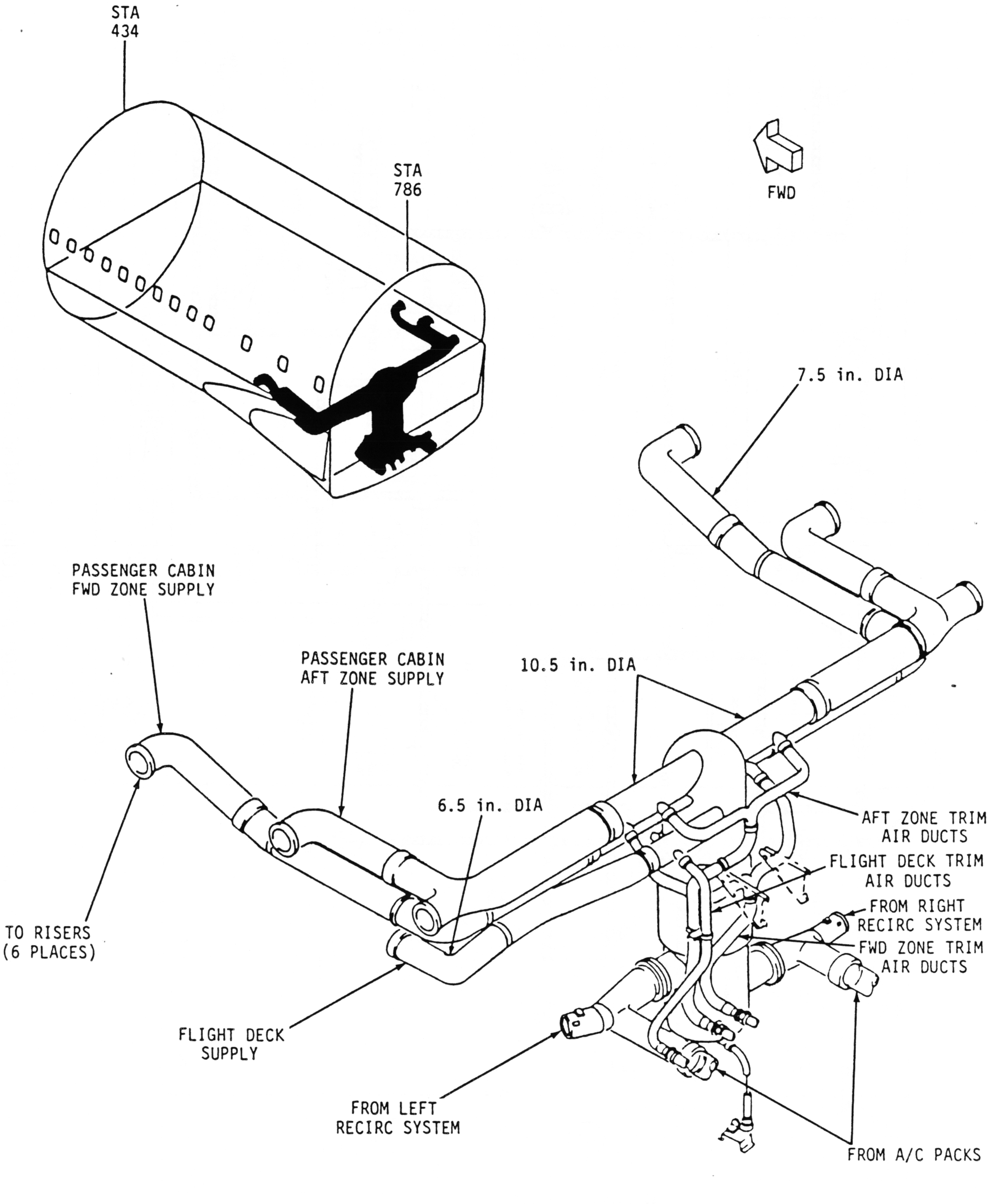


FIGURE 6-3. BOEING 767-200 MIXING AND DISTRIBUTION MANIFOLD

BOEING 767-200

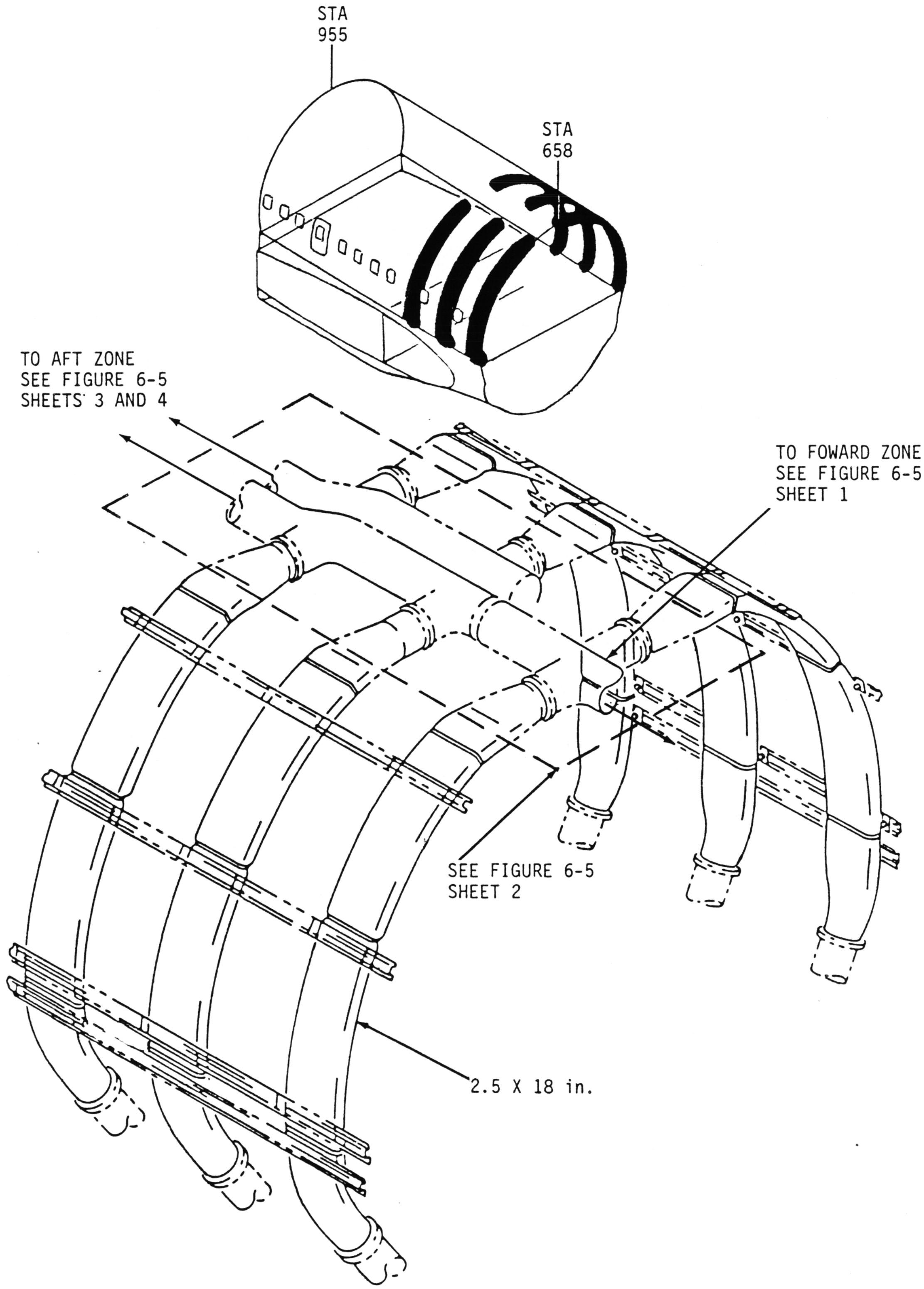


FIGURE 6-4. BOEING 767-200 PASSENGER CABIN AIR CONDITIONING RISERS

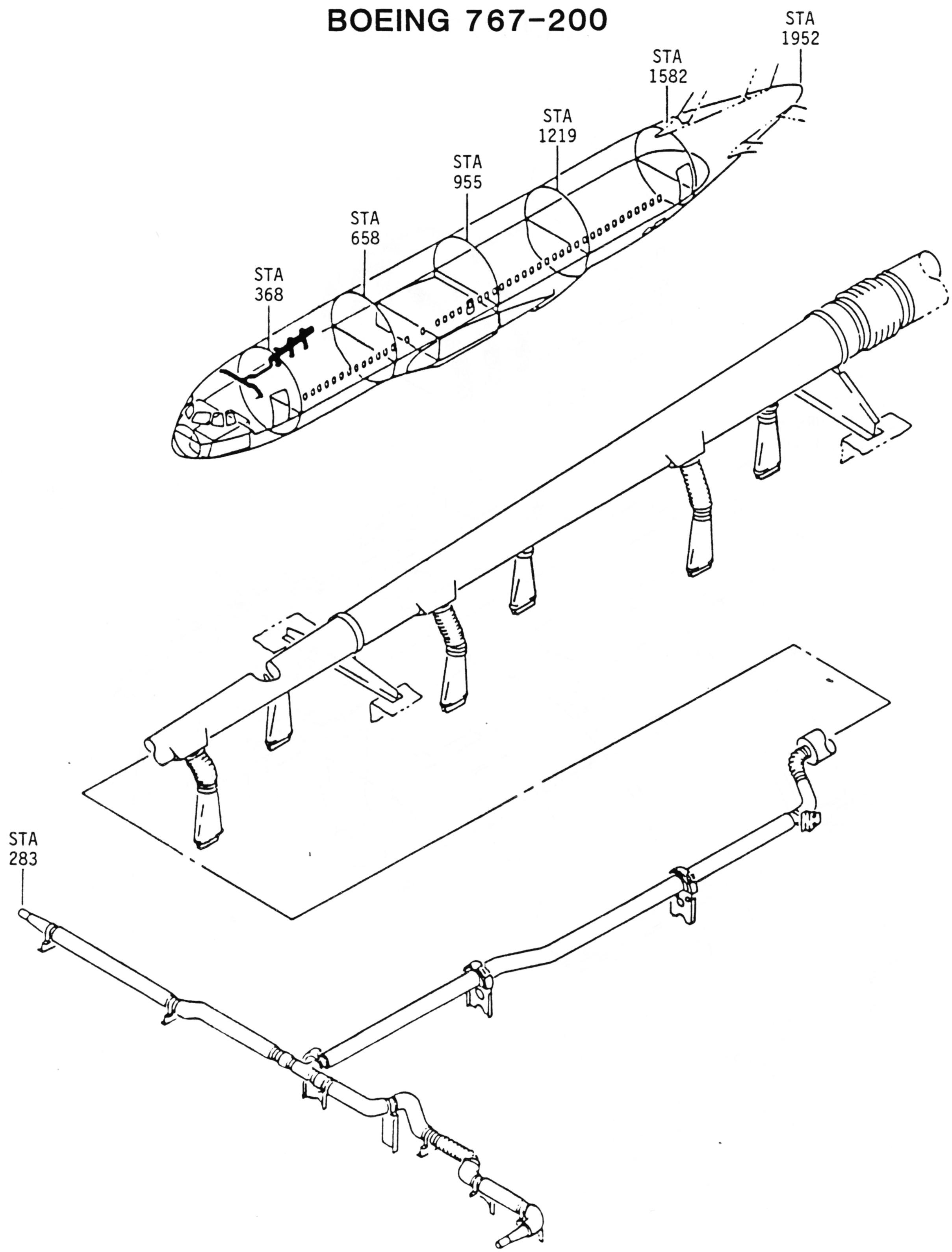


FIGURE 6-5. BOEING 767-200 PASSENGER CABIN DISTRIBUTION SYSTEM (SHEET 1 OF 4)

BOEING 767-200

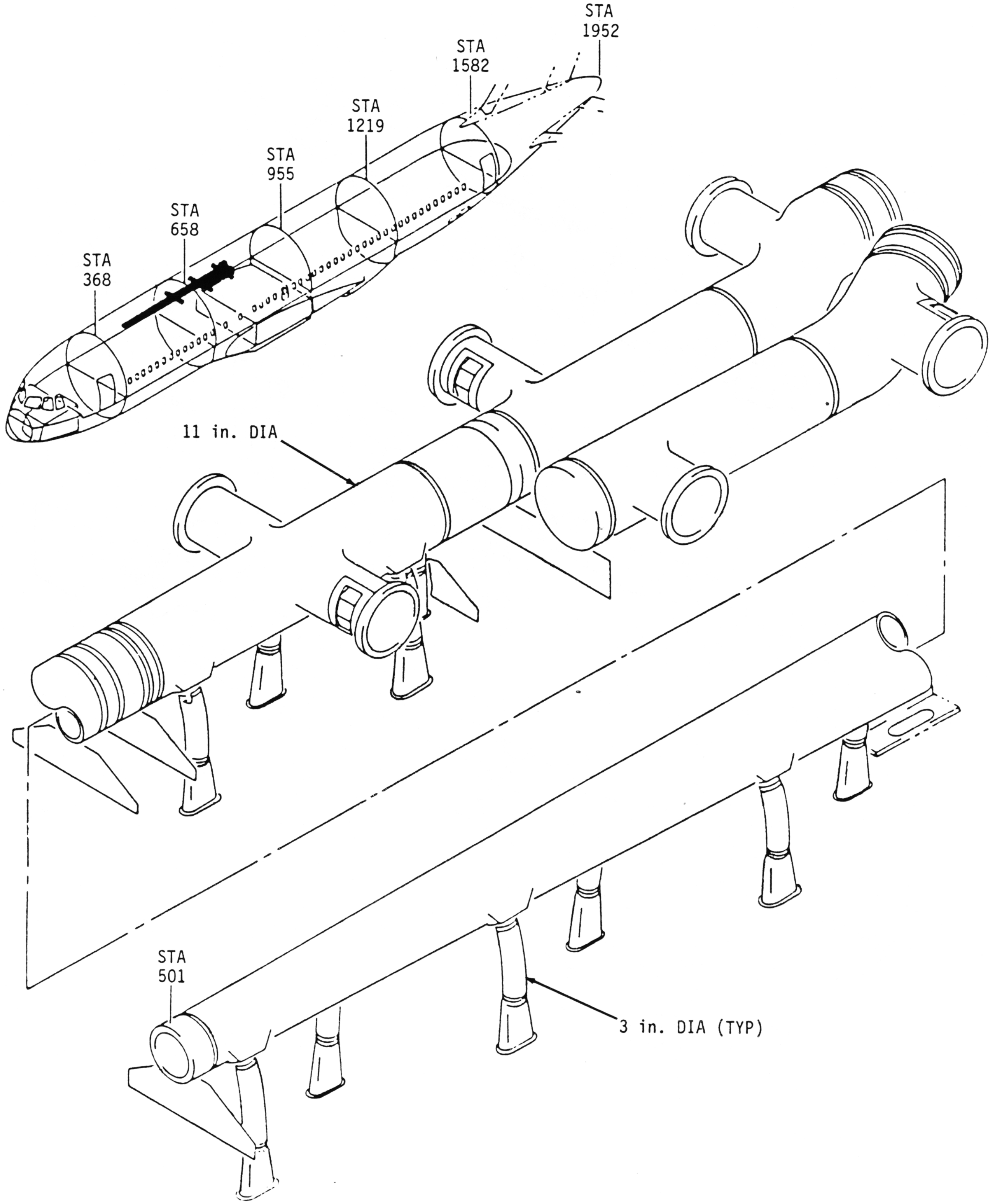


FIGURE 6-5. BOEING 767-200 PASSENGER CABIN DISTRIBUTION SYSTEM (SHEET 2 OF 4)

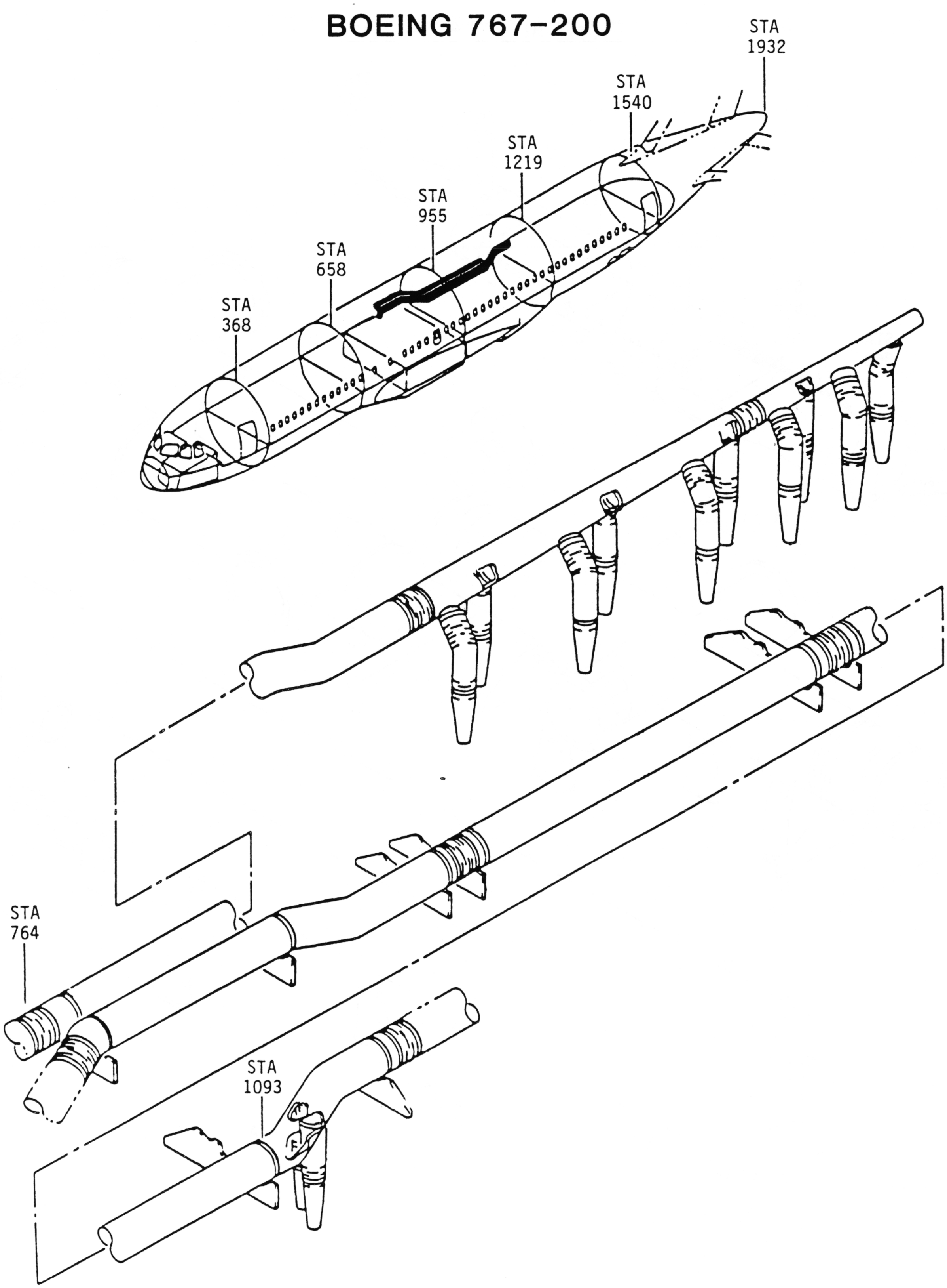


FIGURE 6-5. BOEING 767-200 PASSENGER CABIN DISTRIBUTION SYSTEM (SHEET 3 OF 4)

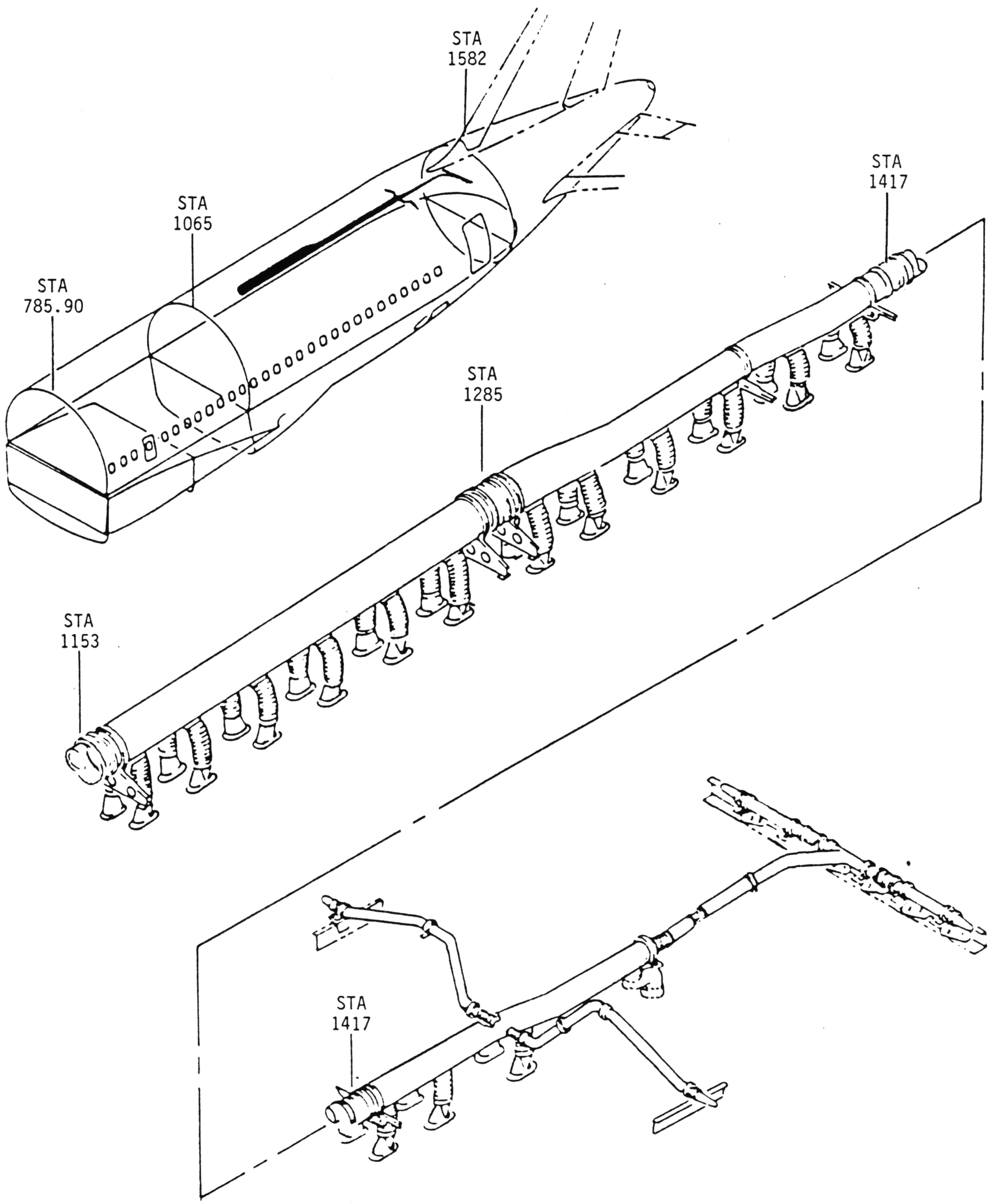


FIGURE 6-5. BOEING 767-200 PASSENGER CABIN DISTRIBUTION SYSTEM (SHEET 4 OF 4)

BOEING 767-200

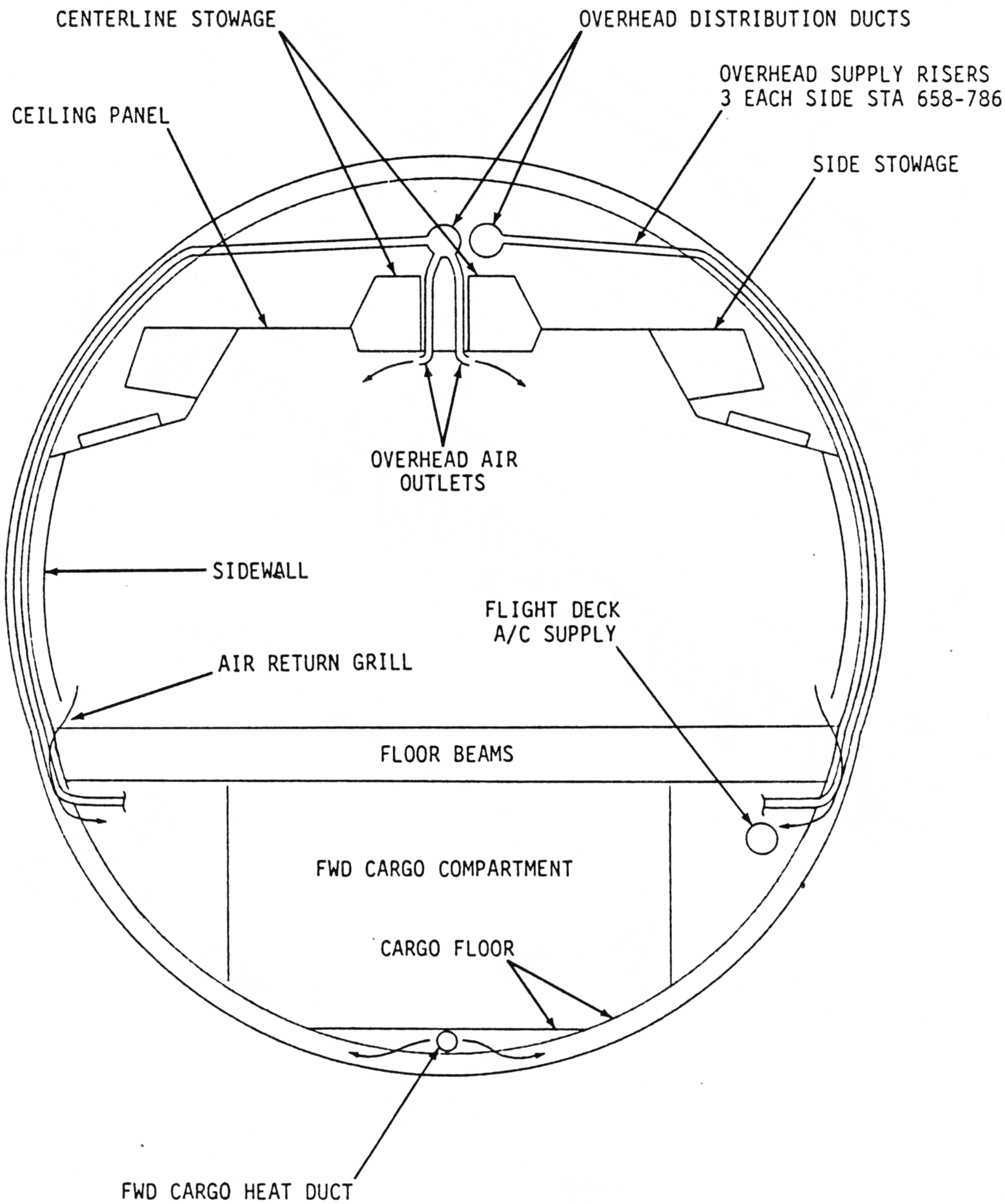


FIGURE 6-6. BOEING 767-200 PASSENGER CABIN CROSS SECTION

BOEING 767-200

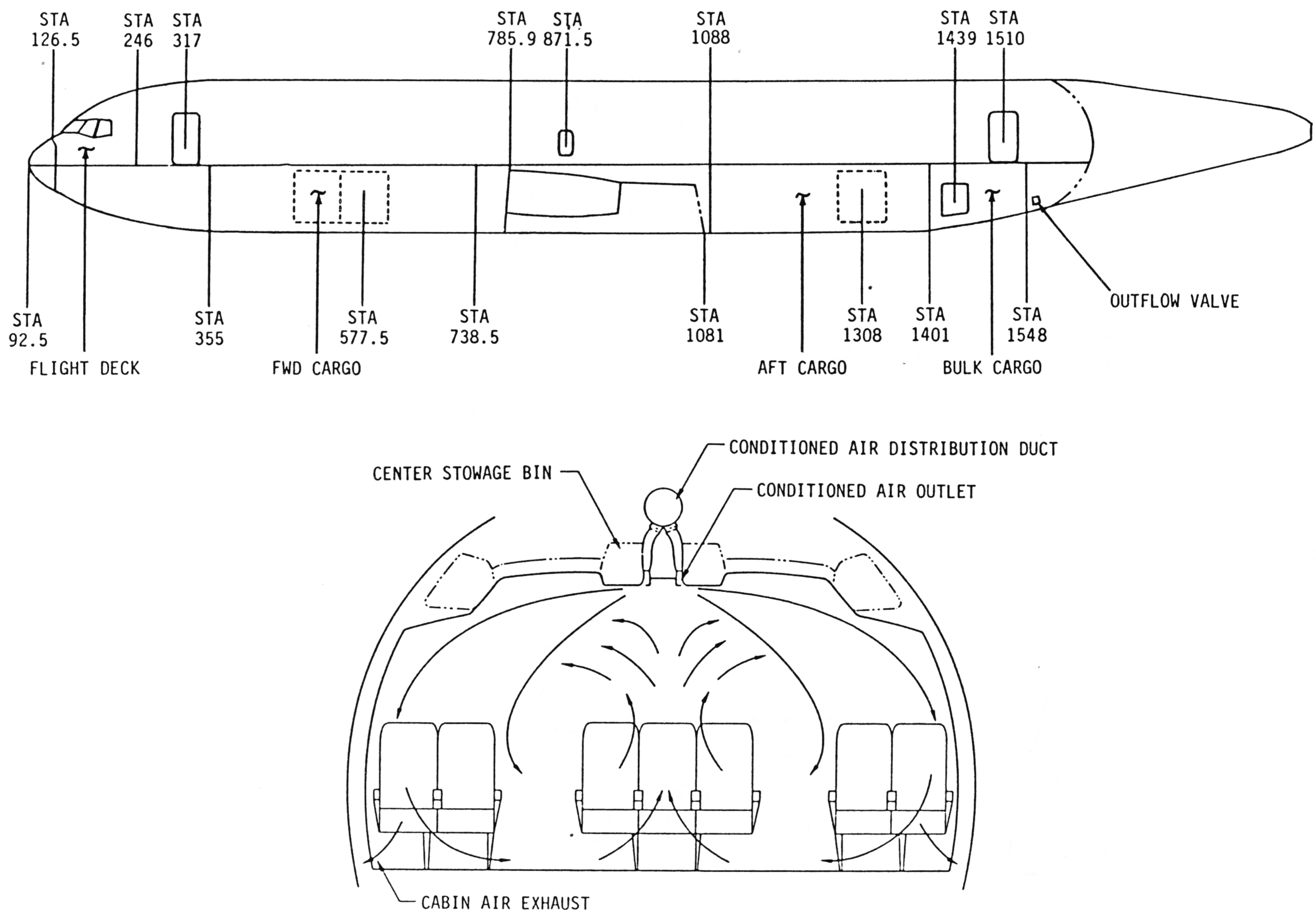


FIGURE 6-7. BOEING 767-200 PASSENGER CABIN AIR FLOW PATTERNS

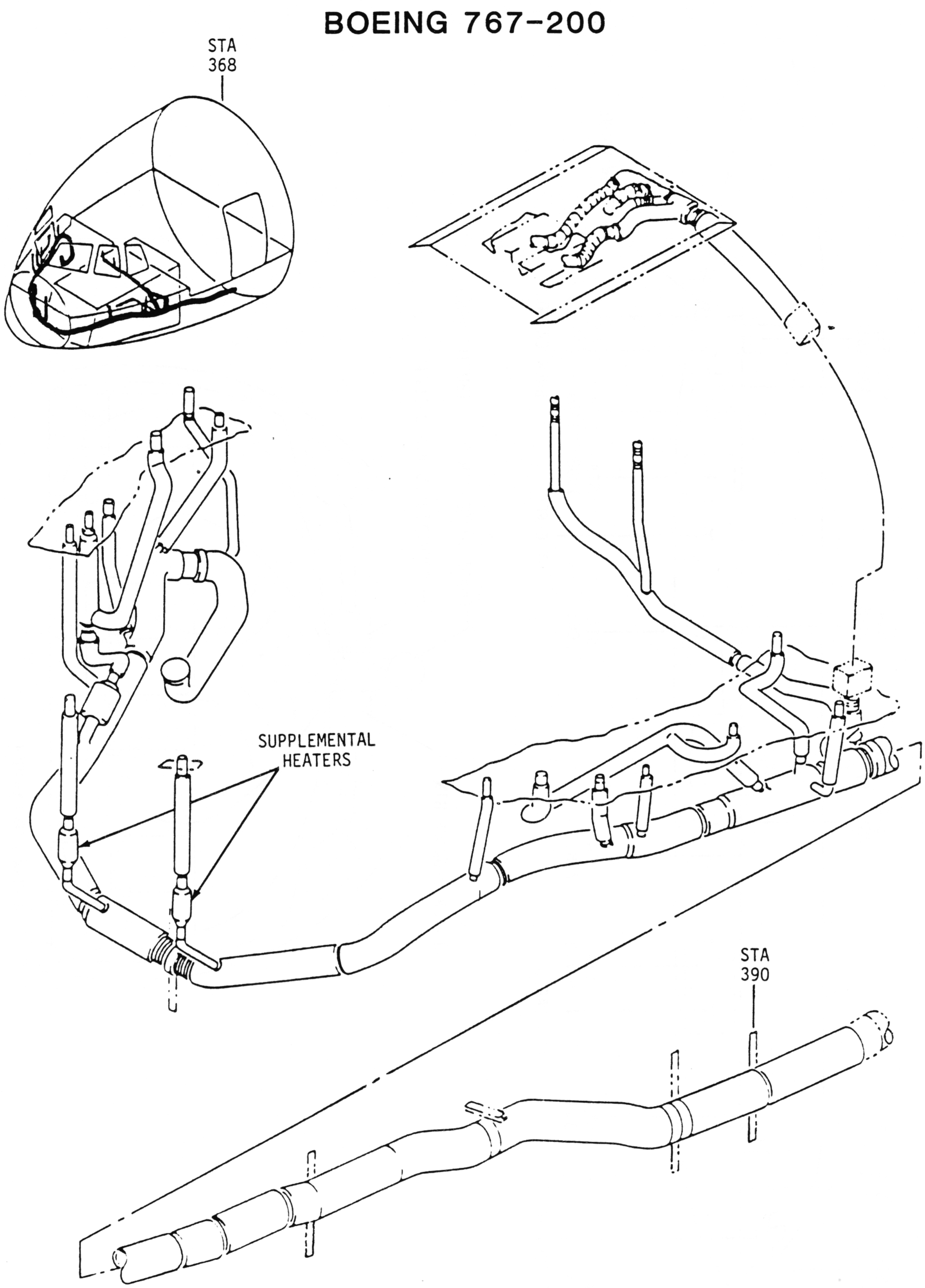


FIGURE 6-8. BOEING 767-200 FLIGHT DECK SUPPLY DUCTING

BOEING 767-200

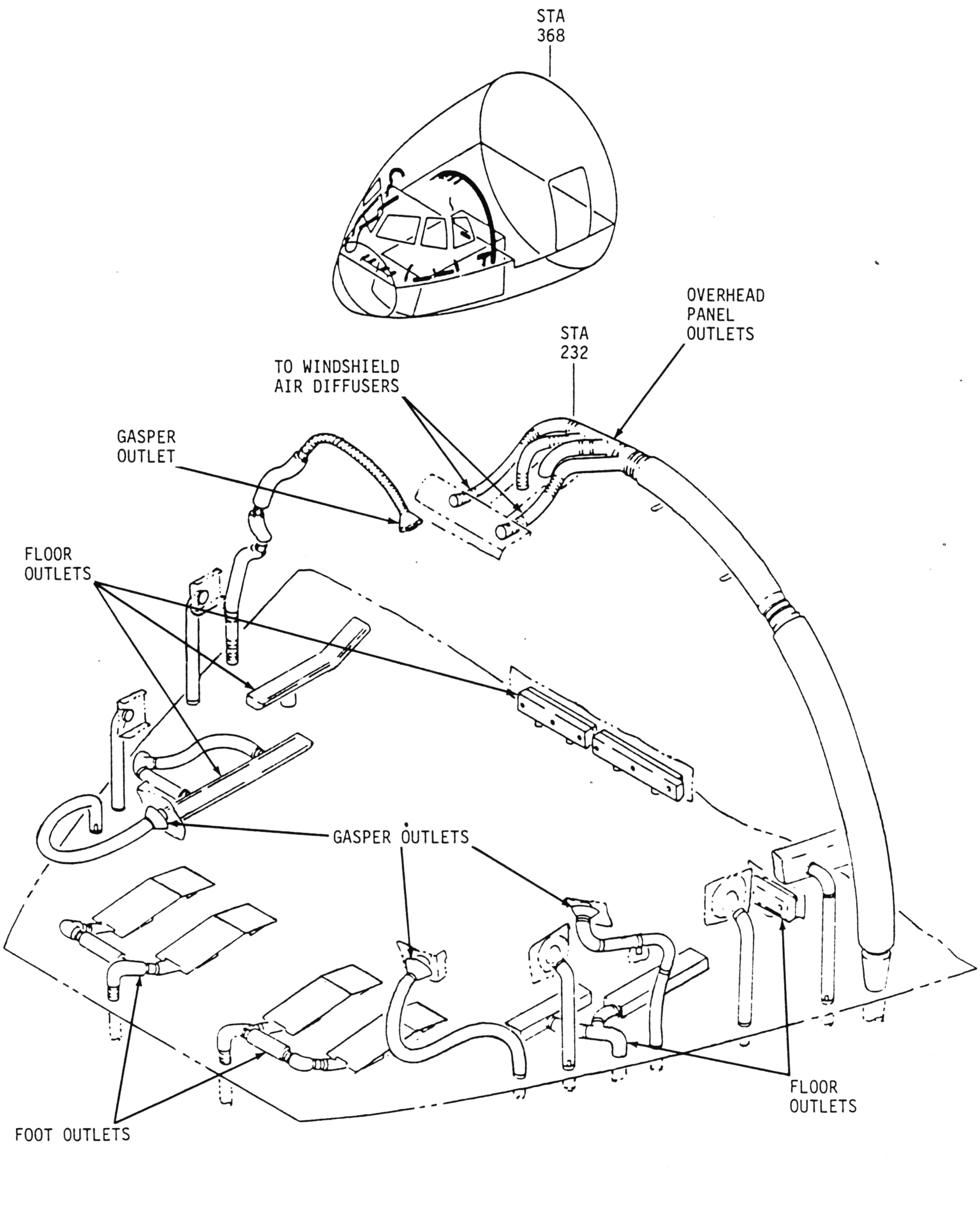


FIGURE 6-9. BOEING 767-200 FLIGHT DECK OUTLETS

BOEING 767-200

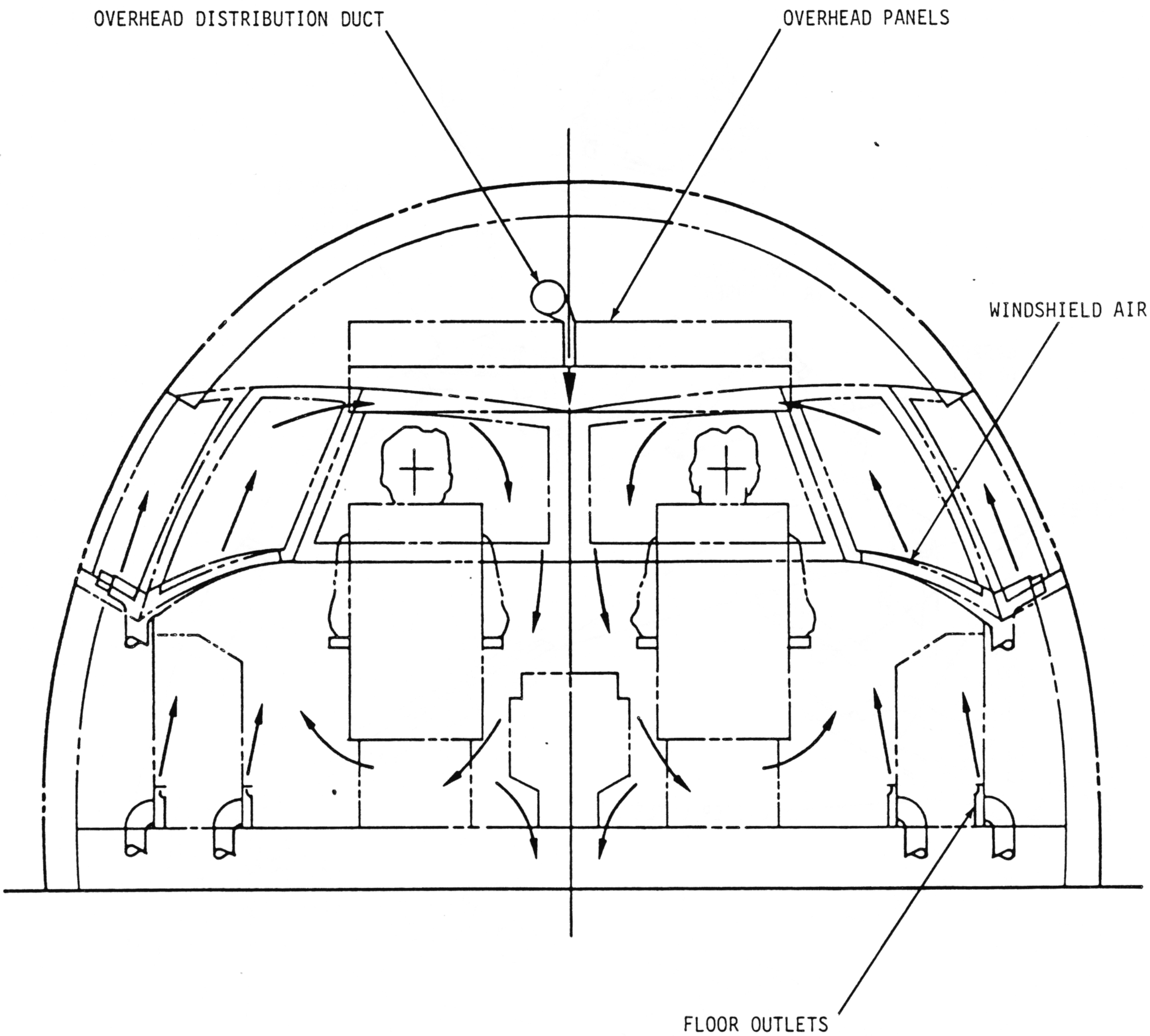


FIGURE 6-10. BOEING 767-200 FLIGHT DECK AIR FLOW PATTERNS

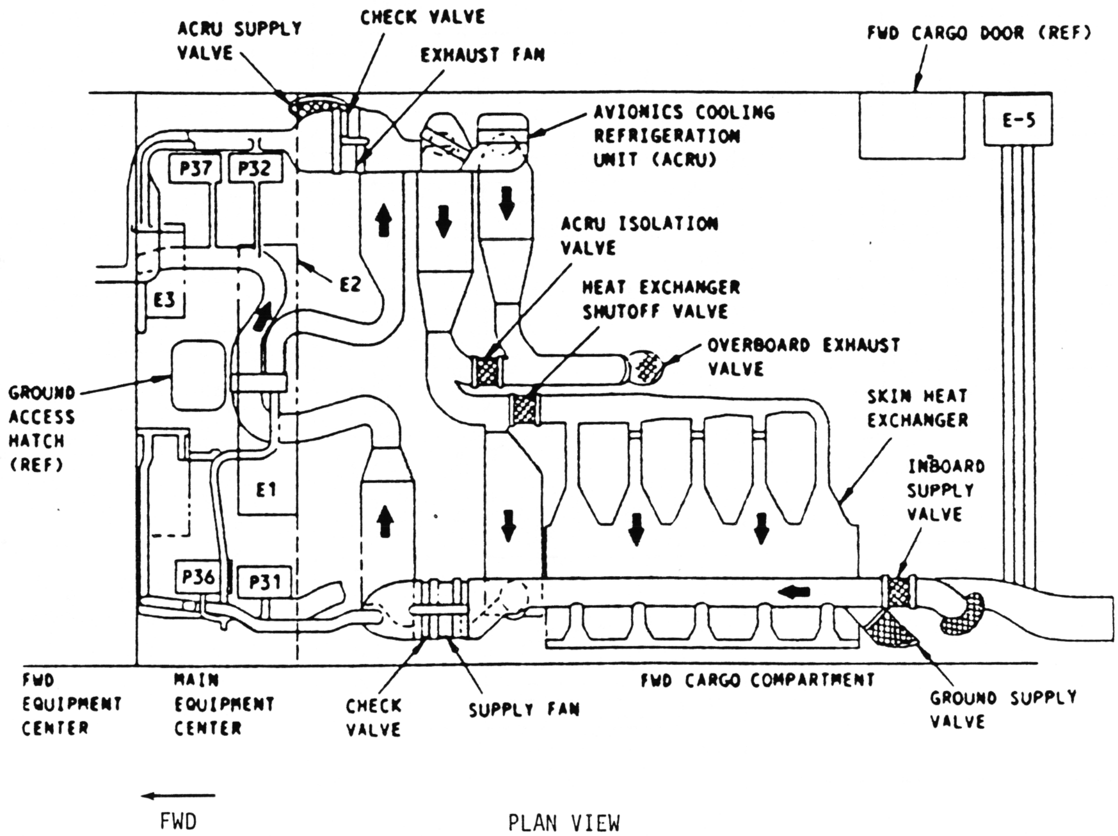
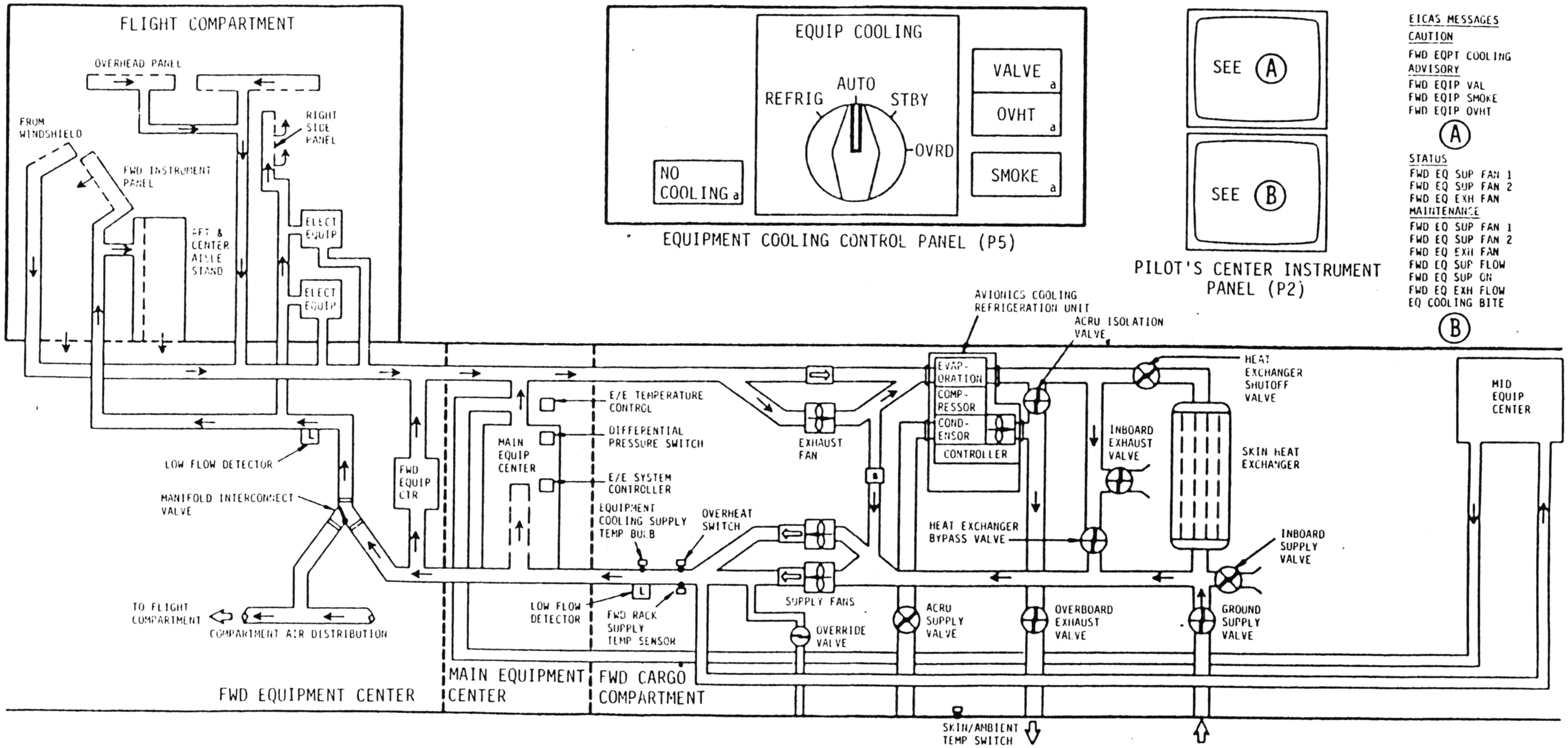
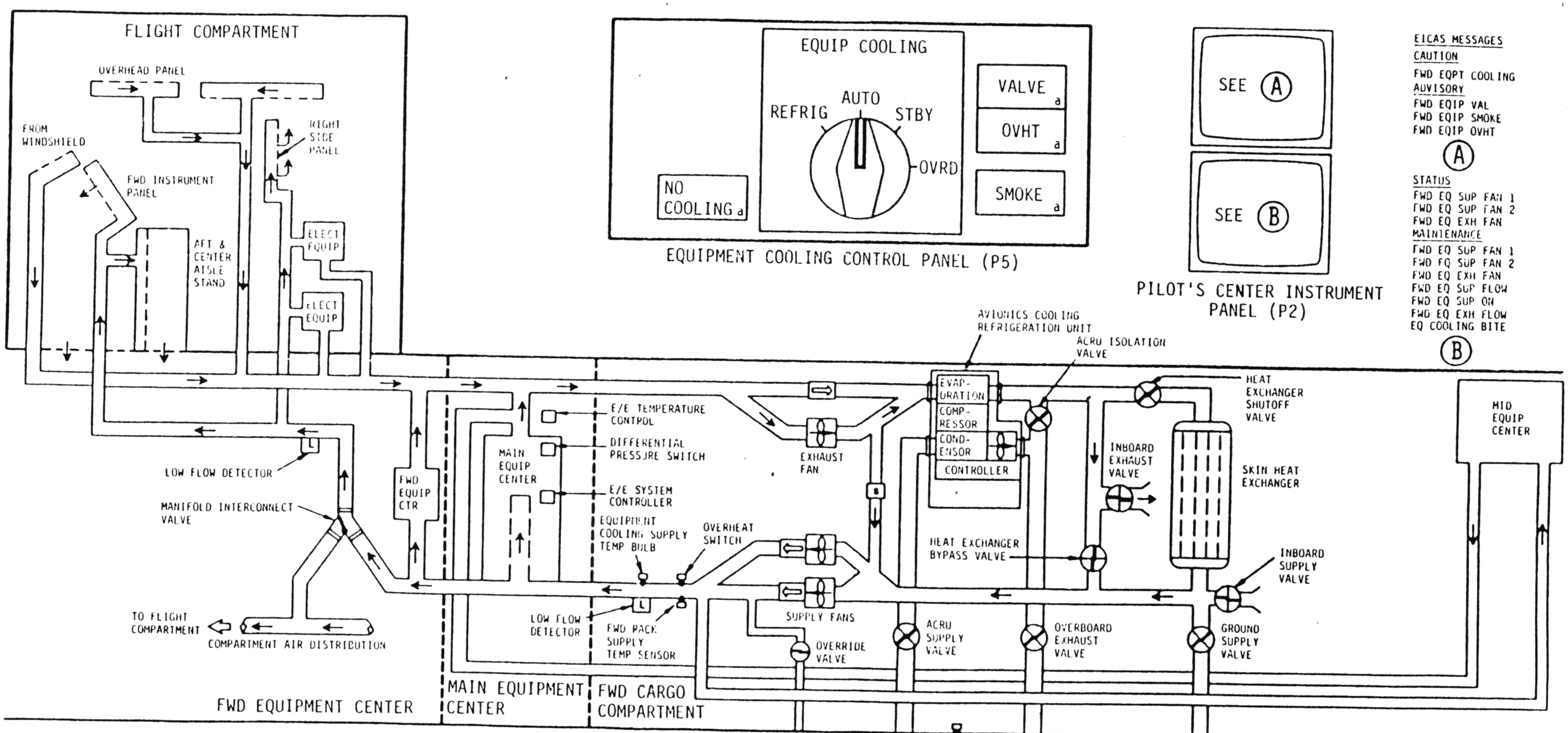


FIGURE 6-11. BOEING 767-200 EQUIPMENT COOLING SYSTEM



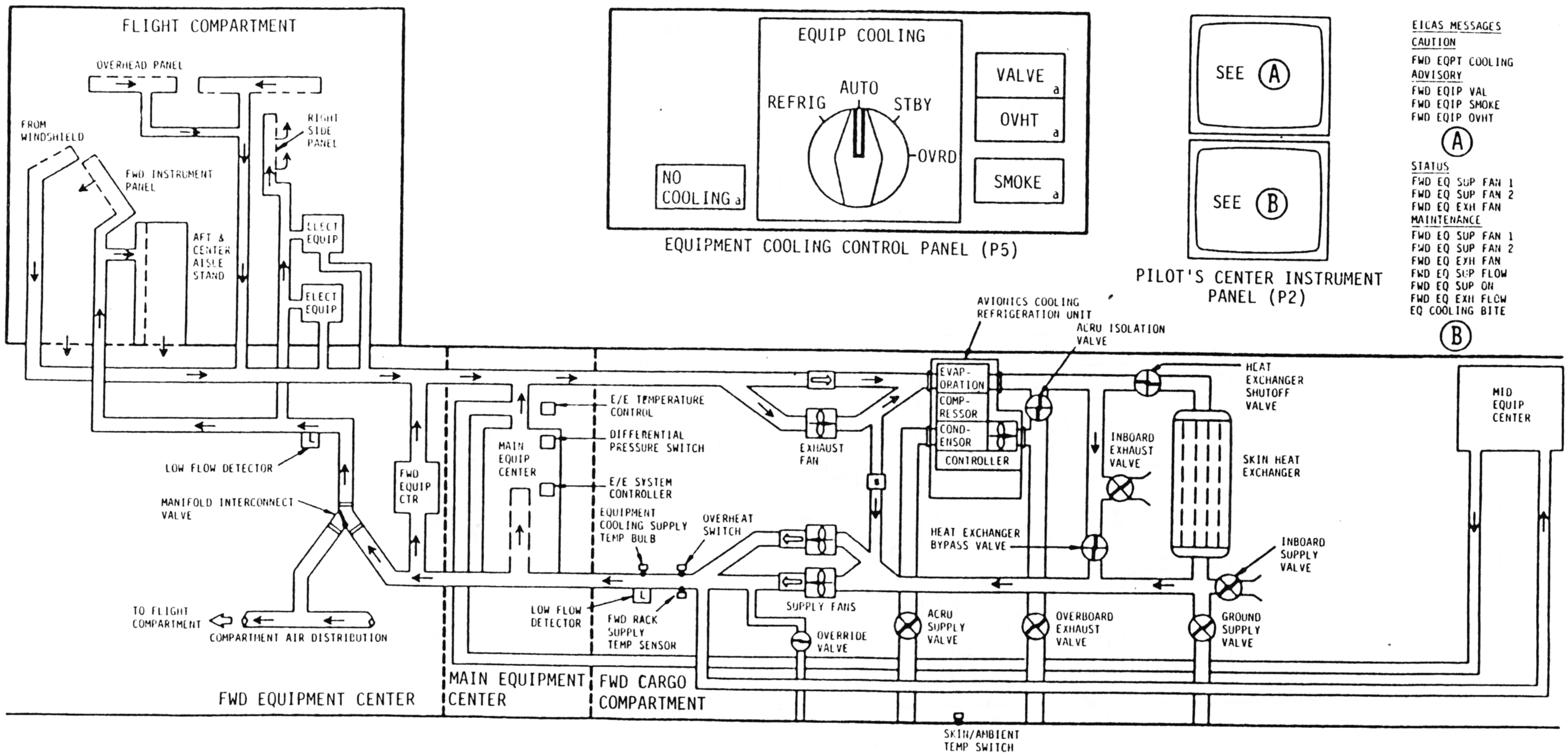
MODE	INBD SUP VALVE	INBD EX VALVE	GND SUP VALVE	OVBD EX VALVE	OVER RIDE VALVE	MAN INT VALVE	HT EX S O VALVE	HT EX BYP VALVE	ACRU SUP VALVE	ACRU ISO VALVE	SUP FAN	EX FAN
AUTO-OUTBOARD OPEN LOOP	C	C	O	O	C	C	C	M	C	O	ON	ON
AUTO-INBOARD OPEN LOOP												
AUTO-CLOSED LOOP												
REFRIGERATION												
STANDBY												
OVERBOARD (SMOKE CLEARANCE)												

FIGURE 6-12. BOEING 767-200 EQUIPMENT COOLING - AUTO OUTBOARD OPEN LOOP MODE



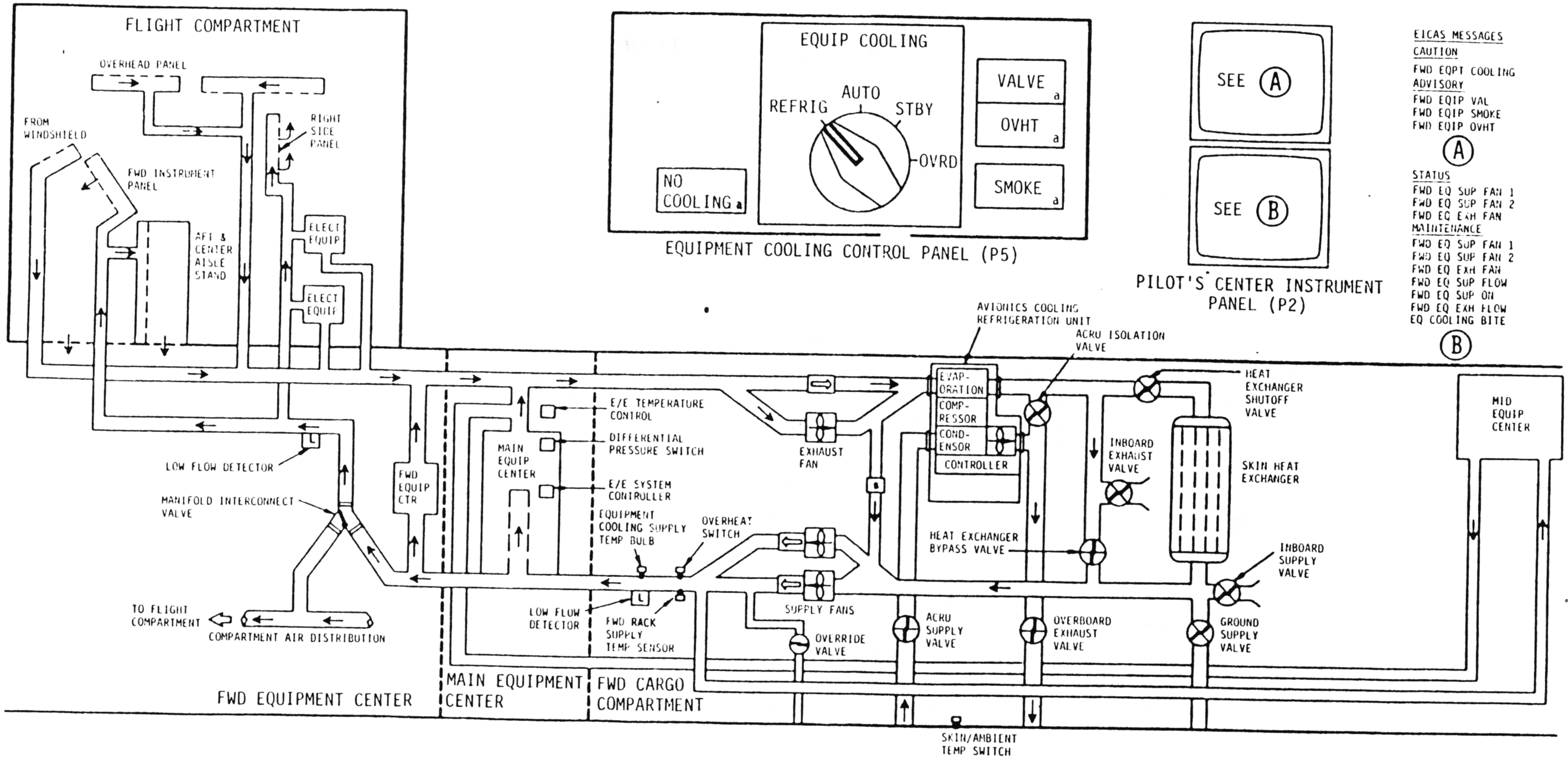
MODE	INBD SUP VALVE	INBD EX VALVE	GND SUP VALVE	OVBD EX VALVE	OVER RIDE VALVE	MAN INT VALVE	HT EX S O VALVE	HT EX BYP VALVE	ACRU SUP VALVE	ACRU ISO VALVE	SUP FAN	EX FAN
AUTO-OUTBOARD OPEN LOOP												
AUTO-INBOARD OPEN LOOP	O	O	C	C	C	C	C	M	C	O	ON	ON
AUTO-CLOSED LOOP												
REFRIGERATION												
STANDBY												
OVERBOARD (SMOKE CLEARANCE)												

FIGURE 6-13. BOEING 767-200 EQUIPMENT COOLING - AUTO INBOARD OPEN LOOP MODE



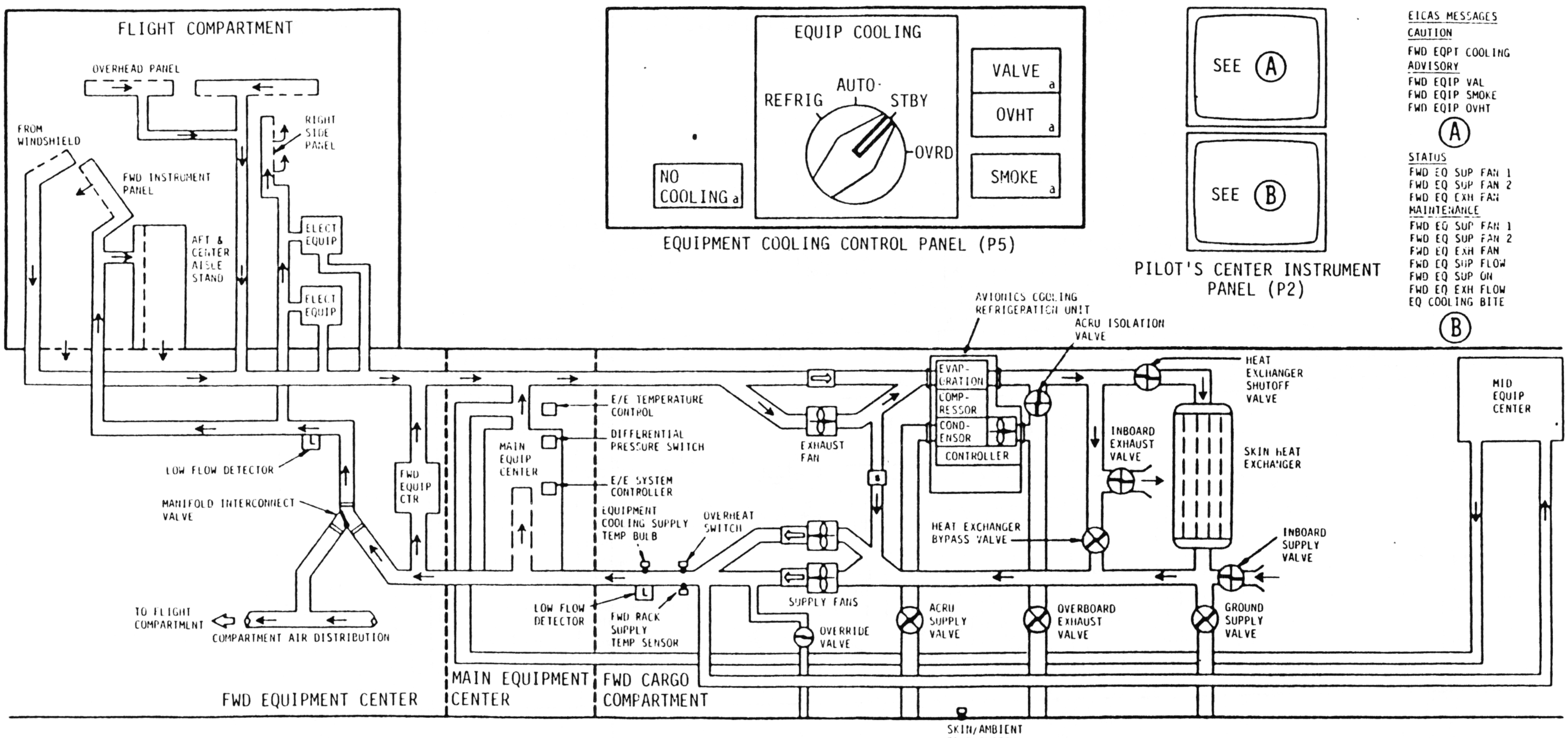
MODE	INBD SUP VALVE	INBD EX VALVE	GND SUP VALVE	OVBD EX VALVE	OVER RIDE VALVE	MAN INT VALVE	HT EX S O VALVE	HT EX BYP VALVE	ACRU SUP VALVE	ACRU ISO VALVE	SUP FAN	EX FAN
AUTO-OUTBOARD OPEN LOOP												
AUTO-INBOARD OPEN LOOP												
AUTO-CLOSED LOOP	C	C	C	C	C	C	O	M	C	O	ON	OFF
REFRIGERATION												
STANDBY												
OVERBOARD (SMOKE CLEARANCE)												

FIGURE 6-14 BOEING 767-200 EQUIPMENT COOLING - AUTO CLOSED LOOP MODE



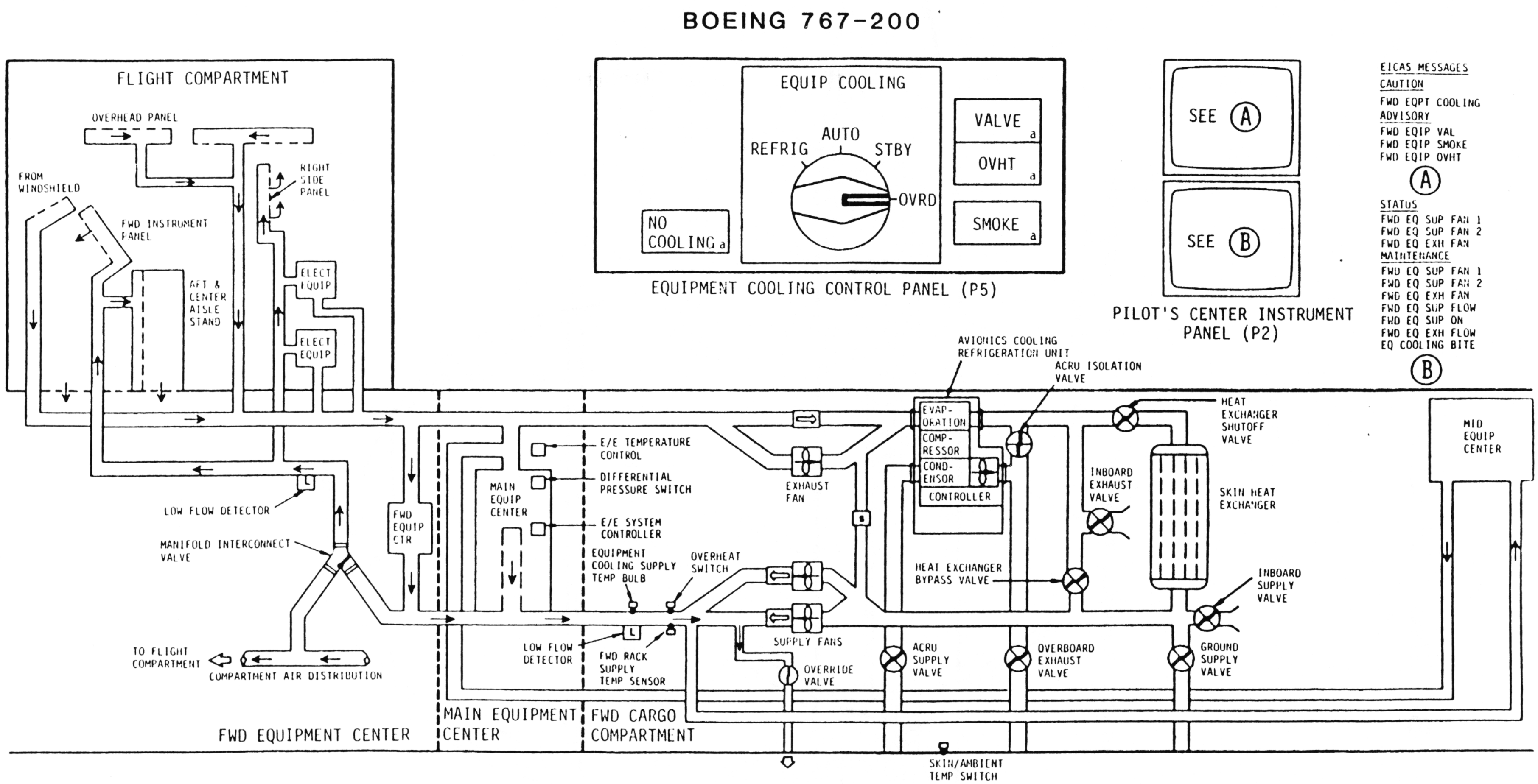
MODE	INBD SUP VALVE	INBD EX VALVE	GND SUP VALVE	OVBD EX VALVE	OVER RIDE VALVE	MAN INT VALVE	HT EX S O VALVE	HT EX BYP VALVE	ACRU SUP VALVE	ACRU ISO VALVE	SUP FAN	EX FAN
AUTO-OUTBOARD OPEN LOOP												
AUTO-INBOARD OPEN LOOP												
AUTO-CLOSED LOOP												
REFRIGERATION	C	C	C	O	C	C	C	O	O	C	OFF	ON
STANDBY												
OVERBOARD (SMOKE CLEARANCE)												

FIGURE 6-15. BOEING 767-200 EQUIPMENT COOLING - REFRIGERATION MODE



MODE	INBD SUP VALVE	INBD EX VALVE	GND SUP VALVE	OVBD EX VALVE	OVER RIDE VALVE	MAN INT VALVE	HT EX S O VALVE	HT EX BYP VALVE	ACRU SUP VALVE	ACRU ISO VALVE	SUP FAN	EX FAN
AUTO-OUTBOARD OPEN LOOP												
AUTO-INBOARD OPEN LOOP												
AUTO-CLOSED LOOP												
REFRIGERATION												
STANDBY	O	O	C	C	C	C	O	C	C	O	ON	ON
OVERBOARD (SMOKE CLEARANCE)												

FIGURE 6-16. BOEING 767-200 EQUIPMENT COOLING - STANDBY MODE



MODE	INBD SUP VALVE	INBD EX VALVE	GND SUP VALVE	OVBD EX VALVE	OVER RIDE VALVE	MAN INT VALVE	HT EX S O VALVE	HT EX BYP VALVE	ACRU SUP VALVE	ACRU ISO VALVE	SUP FAN	EX FAN
AUTO-OUTBOARD OPEN LOOP												
AUTO-INBOARD OPEN LOOP												
AUTO-CLOSED LOOP												
REFRIGERATION												
STANDBY												
OVERBOARD (SMOKE CLEARANCE)	C	C	C	C	O	O	C	C	C	O	OFF	OFF

FIGURE 6-17. BOEING 767-200 EQUIPMENT COOLING - OVERBOARD (SMOKE CLEARANCE MODE)

BOEING 767-200

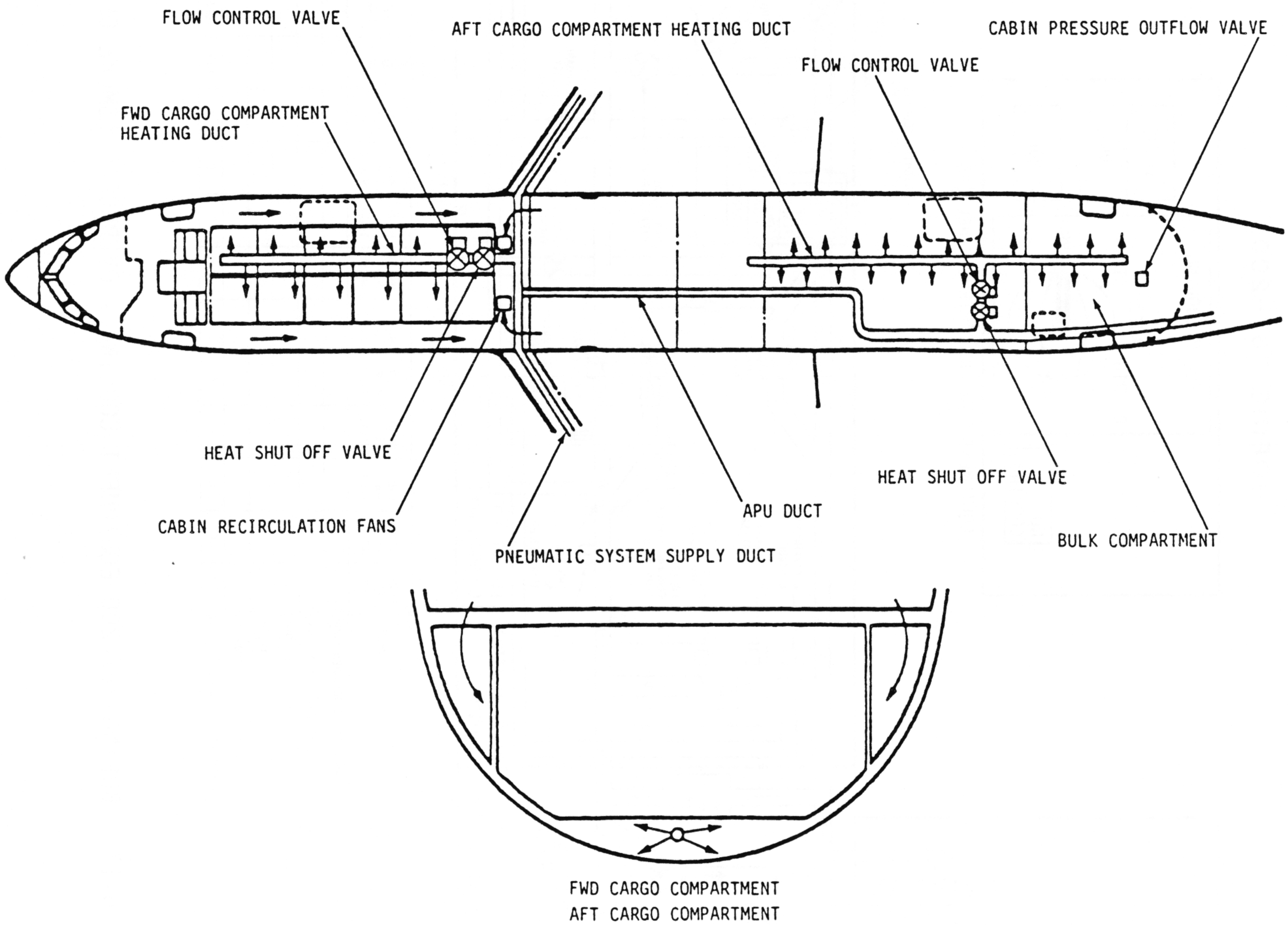


FIGURE 6-18. BOEING 767-200 CARGO COMPARTMENT HEATING SYSTEMS

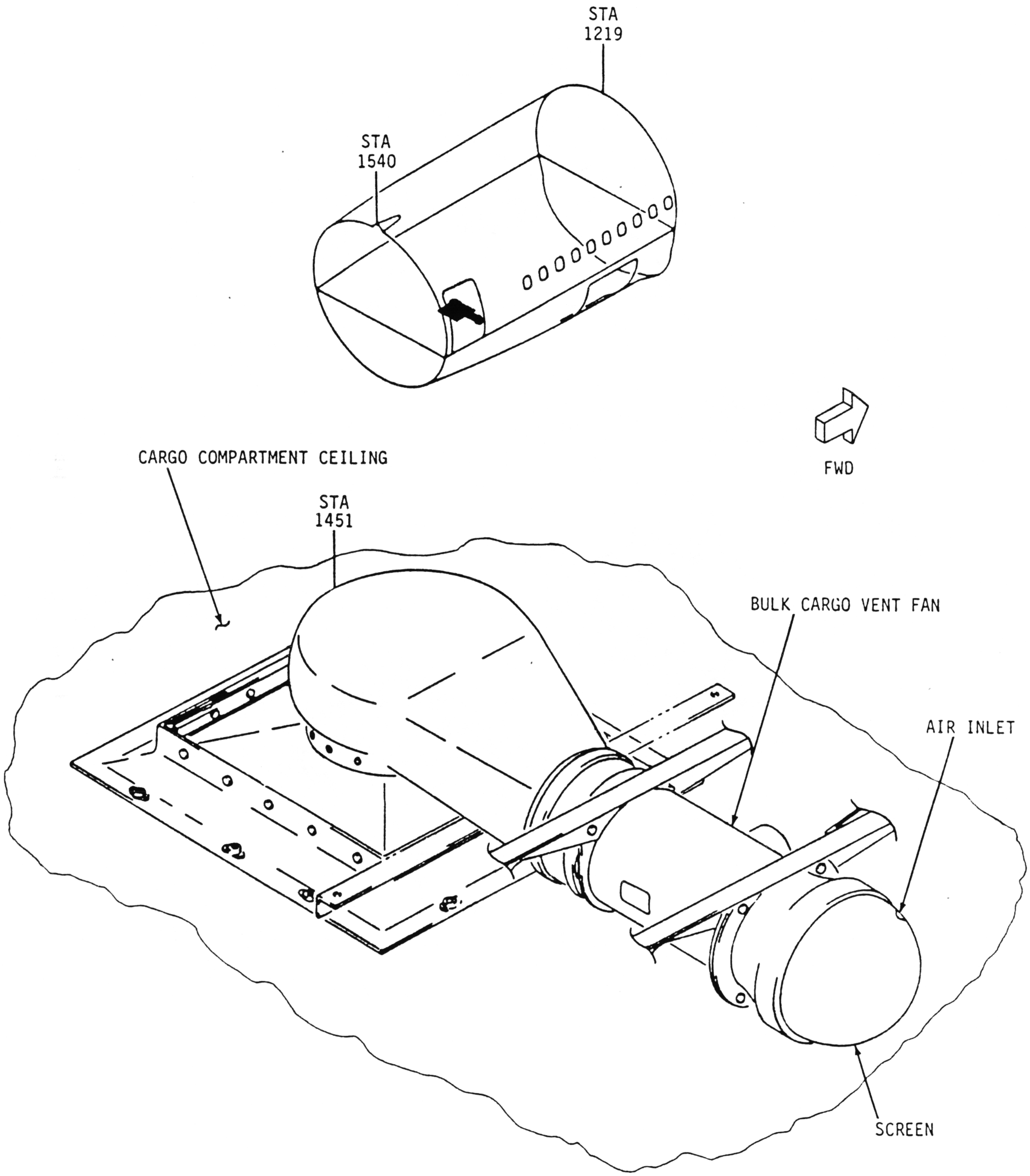


FIGURE 6-19. BOEING 767-200 BULK CARGO VENT FAN

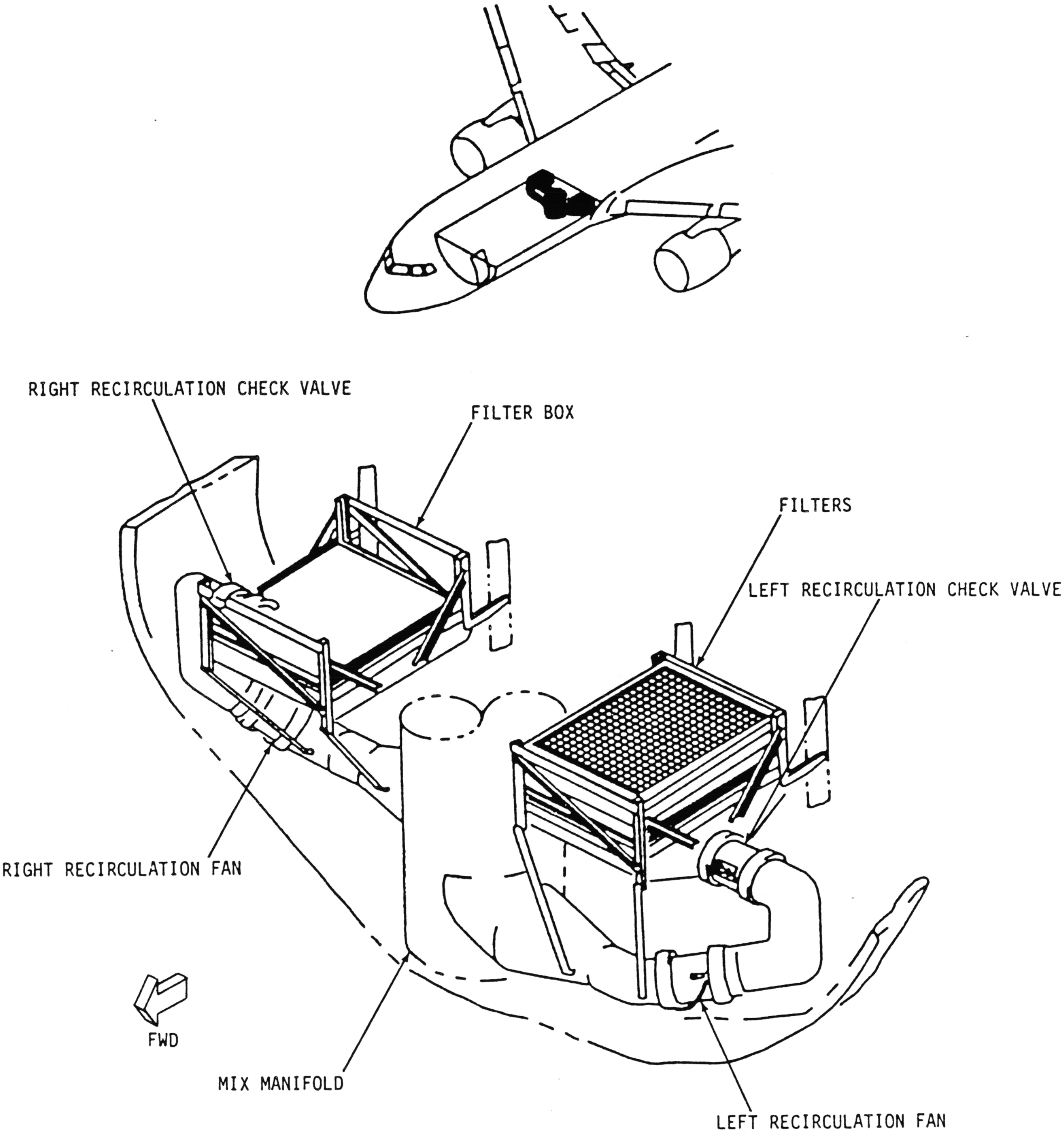


FIGURE 6-20. BOEING 767-200 RECIRCULATION SYSTEMS

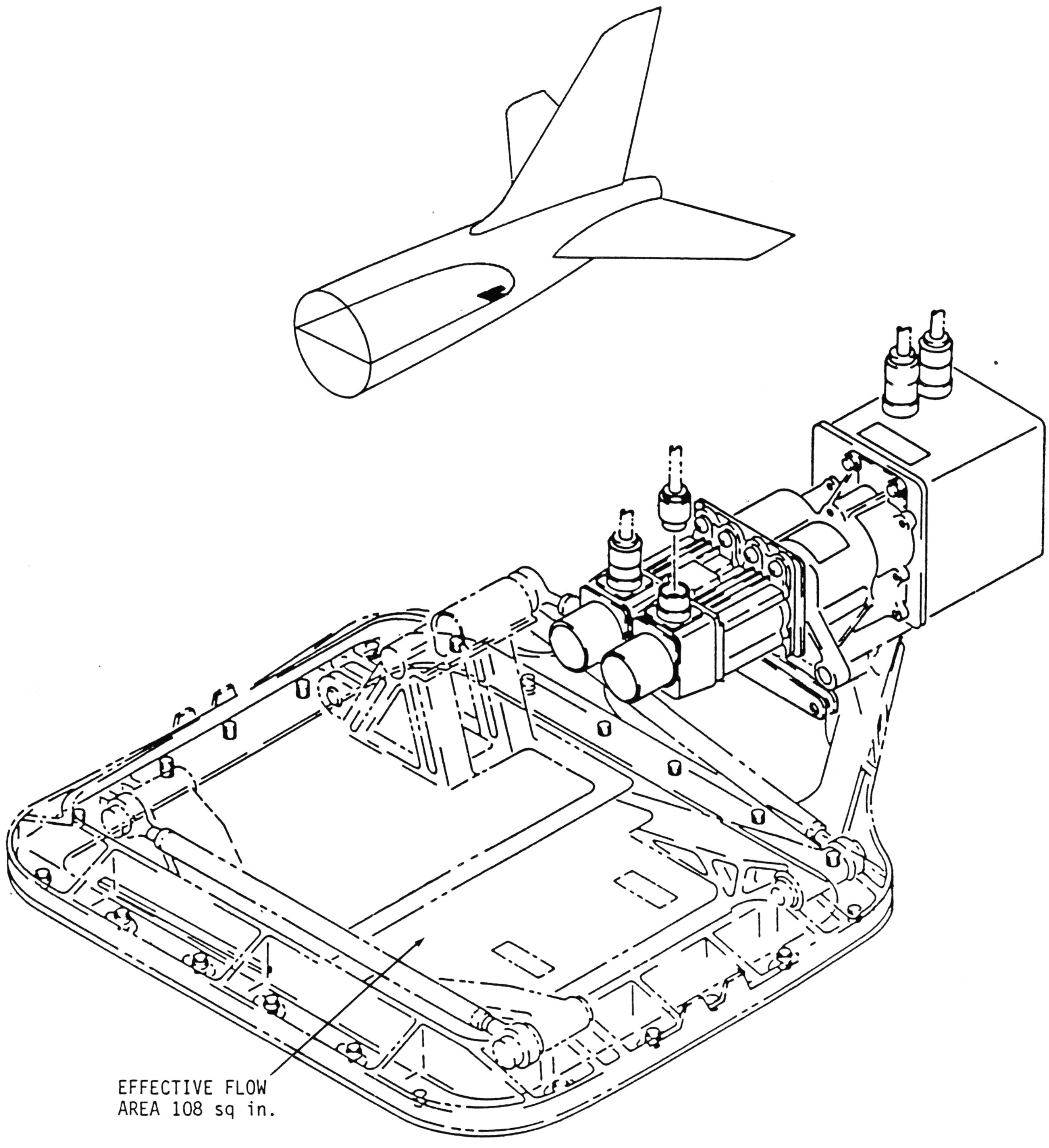


FIGURE 6-21. BOEING 767-200 OUTFLOW VALVE

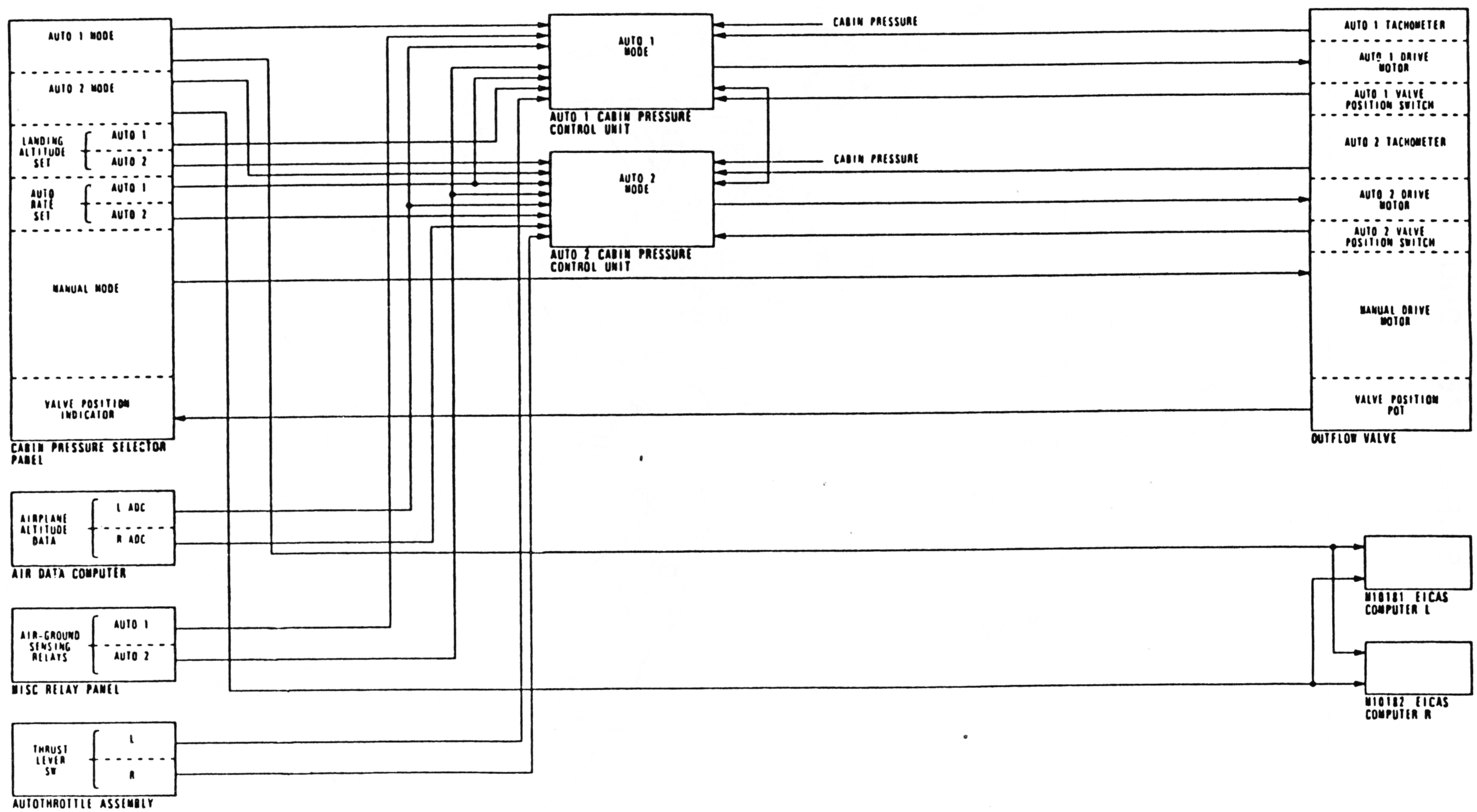
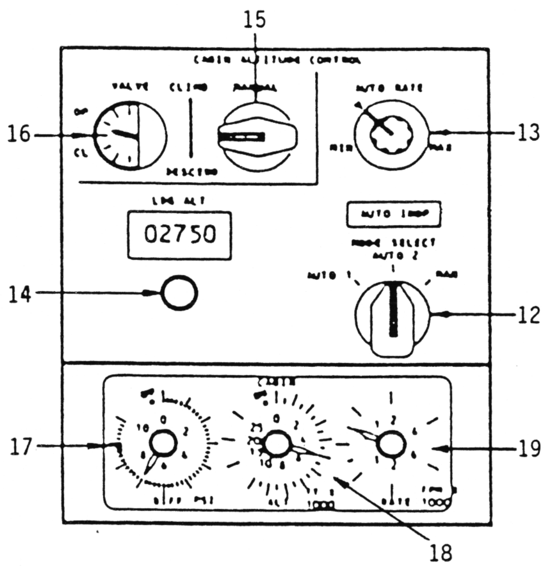
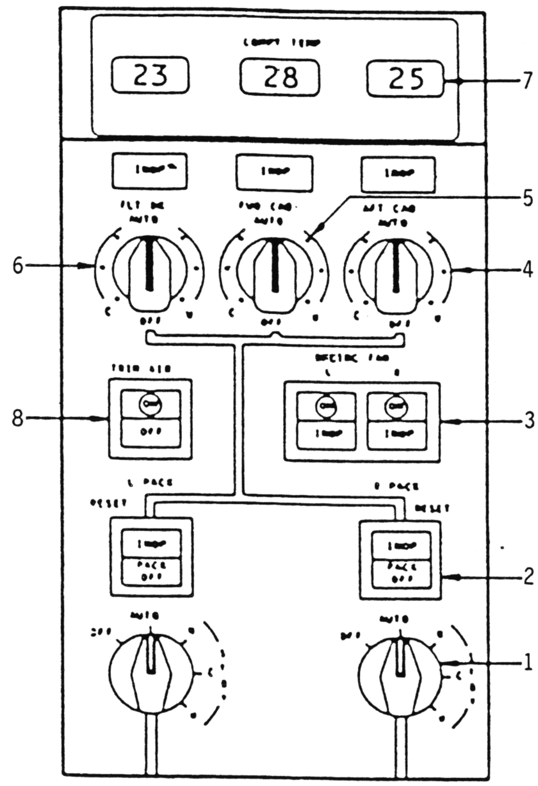


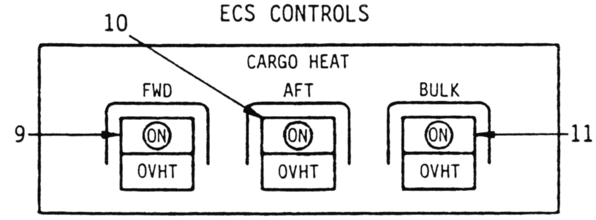
FIGURE 6-22. BOEING 767-200 PRESSURIZATION CONTROL SCHEMATIC



PRESSURIZATION CONTROLS



ECS CONTROLS



CARGO HEATING SWITCHLIGHTS

PRESSURIZATION CONTROLS

12 PRESSURE CONTOLLER SELECTOR
13 CABIN ALTITUDE RATE OF CHANGE SELECTOR
14 LANDING ALTITUDE SELECTOR
15 MANUAL PRESSURE CONTROL
16 OUTFLOW VALVE POSITION INDICATOR
17 DIFFERENTIAL PRESSURE GUAGE
18 CABIN ALTITUDE
19 CABIN ALTITUDE RATE OF CHANGE INDICATOR

ECS CONTROLS

1 PACK MODE SELECTOR
2 PACK INDICATION LIGHTS
3 RECIRCULATION FAN SWITCHES
4 AFT CABIN TEMPERATURE SELECTOR
5 MID CABIN TEMPERATURE SELECTOR
6 FLIGHT DECK TEMPERATURE SELECTOR
7 ZONE TEMPERATURE INDICATORS
8 TRIM AIR SWITCH
9 FWD CARGO HEAT SWITCH
10 AFT CARGO HEAT SWITCH
11 BULK CARGO HEAT SWITCH

FIGURE 6-23. BOEING 767-200 ECS AND PRESSURIZATION CONTROLS

SECTION 7

DOUGLAS DC-8

Model Variation

The DC-8 was introduced in the late fifties as a long range jet transport to compete with the Boeing 707. The series was initiated with the -10 model that was put into service by United Airlines on September 18, 1959. The series was joined by -20, -30, -40, and -50 models during the late fifties and early sixties. These models featured higher thrust engines, and increased payload and range capability. The sixty series was introduced in the mid-sixties as stretched versions of the early models. The -61/-63 models incorporated a fuselage extension of approximately 37 feet, which increased passenger capacity by approximately sixty passengers. The -62 model was stretched 7 feet, and outfitted to be a long-range model with a range of over 7,300 nautical miles. A summary of first flight, certification date, and number produced is shown in Table 7-1.

The DC-8 production was terminated in November of 1969, and the last delivery was made in March of 1970. The DC-8 continues in operation today, but its operators have been impacted by Federal and international noise reduction legislation. The DC-8 is now illegal to fly in the United States unless the operator has received an exemption from compliance, or has installed a re-engine or hush kit. The re-engine kit is available for the -61, -62, and -63 models, and replaces the JT3D-3B engine with the CFM 56 engine. The CFM engine is a new-generation high-bypass design that allows the DC-8 to meet noise reduction standards. The re-engined models are designated as the -71, -72, and -73.

In addition to the engine retrofit, AiResearch Manufacturing Company offers an air-conditioning pack retrofit available to seventy series operators. The modifications include removal of the freon system and cabin compressor system, and replacement with an air cycle system. The distribution ducting is only slightly affected in the area of the mixing valve and main distribution manifolds. The performance data herein includes both systems. Peculiarities arising from the air pack retrofit are clearly identified.

DC-8 Environmental Control System (ECS)

The original DC-8 ECS is a two-pack vapor cycle system that uses auxiliary compressors as an air source. Some -60 series models also had provisions to allow use of engine bleed-air as the air source. A block diagram of the system is shown in Figure 7-1. The air-conditioning packs are located below the flight deck in an unpressurized area of the fuselage. The air-conditioning pack can be divided into two subsystems, air supply and cooling. The air supply and cooling pack is shown in Figures 7-2 and 7-3.

The air supply system consists of four auxiliary compressors that supply hot air to the cooling system. The compressors utilize bleed-air from the engine compressor, expanding in a centrifugal turbine to drive a centrifugal compressor. The centrifugal compressor draws ambient air in through the scoops mounted at the lower sides of the radome, and compresses it to higher pressure and temperature. Hot air leaving the compressors is divided into two streams. A portion of the hot air is routed to the hot air port of the mixing valve, and the rest flows to the air-conditioning heat exchanger. The hot air is cooled in the heat exchanger by ram air to form warm air. The warm air is further subdivided into two streams. A portion of the warm air is routed to the warm air port of the mixing valve and the rest flows to the freon evaporator. Warm air passing through the evaporator is cooled by liquid freon expanding to gaseous freon in the other side of the evaporator. After flowing through the evaporator, the cold air is routed to the cold air distribution system and cold air port of the mixing valve. The mixing valve then mixes the three air sources in the correct proportions according to cabin heating or cooling demand, and routes the air to the cabin distribution systems.

Air cooling is provided by a vapor cycle refrigeration system that uses freon as the working fluid. A schematic of the refrigeration system is shown in Figure 7-4. The refrigeration cycle starts in the refrigerant compressor. The compressor takes gaseous refrigerant from the evaporator, and compresses it to higher temperature and pressure. The high-pressure gas is routed to the condenser, where it is cooled to form high-pressure liquid freon. The condenser is cooled by ram air in flight, or by ambient air drawn through it by the condenser fan when on the ground. High-pressure liquid is then routed to the receiver/drier. The receiver/drier separates the high-pressure liquid from the high-pressure gas, and also removes any water contained in the freon with desiccant beads. High-pressure liquid freon is removed from the receiver and passes through the evaporator. As it passes through the evaporator the high-pressure liquid expands to produce low pressure gas. During this expansion process, heat is extracted from the air stream passing over the other side of the evaporator. The air is cooled and routed to the distribution ducting. The refrigeration system controls regulate the flow of freon to maintain a 50 F air temperature on the discharge side of the evaporator. The freon system performance parameters are shown in Table 7-12.

DC-8 airplanes that have been upgraded to seventy series by the engine retrofit, have the option of having the vapor-cycle air-conditioning system replaced with an air cycle system. When using this system the cabin compressor, freon system and associated ducting are removed and replaced with a conventional air cycle system. As of this writing, all operators who have ordered the engine retrofit have also ordered the pack retrofit. A total of 110 shipsets have been sold.

The air cycle system uses bleed-air from the 5th and 9th engine compressor stages as an air source. The bleed-air is routed to the pack flow-control valve by the pneumatic system. A schematic of the air cycle system is shown in Figure 7-5.

The flow-control valve is electronically controlled and pneumatically operated. The valve maintains a constant volumetric flow of air to the cabin in response to variations in bleed-air conditions and cabin pressures. Air leaving the flow-control valve is routed to the primary heat exchanger and hot air port of the mixing valve. The primary heat exchanger uses ram air passing over the heat exchanger to cool the pneumatic air. Air is routed from the primary heat exchanger to the ACM compressor and compressor-bypass check valve. The compressor-bypass check valve allows air to bypass the compressor into the secondary heat exchanger when cooling demands are low. The ACM compressor raises air temperature and pressure, and routes it to the secondary heat exchanger. Air is cooled in the secondary heat exchanger by ram air, then routed to the ACM turbine or warm air port of the mixing valve. Air expands in the turbine to drive the compressor, and exits the turbine at low temperature. Air leaving the turbine is routed to the water separator, then to the cold air port of the mixing valve and gasper system regulator valve.

The mixing valve mixes hot, warm, and cold air in correct proportions according to the cabin heating and cooling demands. The right valve is controlled by the passenger cabin temperature selector, and the left valve by the flight deck temperature selector. Only a part of the air from the left valve is directed to the flight deck, the rest passes to the passenger cabin distribution system.

If the temperature demanded by the flight deck differs from that demanded by the passenger cabin, the temperature sensors and control system will adjust the passenger cabin valve to compensate for the difference.

Pressures and temperatures at points designated on Figure 7-5 are shown in Table 7-13 for the air cycle system. Note that the minimum supply temperature is limited by the water separator anti-ice control and the maximum supply temperature is limited by the duct overheat sensors.

Distribution

Air leaving the mixing valves is routed to the passenger cabin distribution system by risers located behind the right cabin sidewall at approximately station 250 (See Figure 7-6). The riser supplies an overhead duct that is located above the ceiling panels and runs the length of the passenger cabin. The overhead duct (Figures 7-7 and 7-8) has dropper ducts, spaced approximately every 160 inches, that supply air to the sidewall radiant heat panels. The overhead ducting is the same for all models; cross-sectional area and sidewall dropper spacing was not changed for the sixty series, only the length of the duct was increased. The sidewall panel is a double-skin panel (see Figure 7-9) with an air outlet at the top edge. The dropper duct supplies air to the lower edge of the sidewall panel. As the air rises between the sidewall panel sides, it warms the panel and then enters the passenger area through the outlet at the top edge of the panel.

The flight deck distribution system is shown in Figure 7-10. The distribution system is supplied from the left pack just downstream of the mixing valve. The supply duct is divided, and runs forward and under each side of the floor (See Figure 7-6). The supply duct feeds four or six outlets (depending on model) in the flight deck. Two outlets are located in the ceiling just aft of the pilot and co-pilot's stations, one outlet is located at the pilot and co-pilot's feet, and one outlet is at each outboard side of the control panel. If the left pack becomes inoperative, air is supplied to the flight deck from the distribution manifold, down stream of the right pack outlet duct by closing the temperature diverter valve (See Figure 7-3).

Volume flow rates entering the compartments are shown in Tables 7-4 and 7-5 for vapor cycle airplanes, and Table 7-6 for 70 series (air cycle) airplanes. Air change rates for the flight deck and passenger cabin are shown in Tables 7-7 through 7-11. Compartment volumes are listed in Table 7-12.

A cross section of the passenger cabin showing ducting placement is shown in Figure 7-11. Airflow patterns are shown in Figure 7-12.

Individual (Gasper) Air

A separate supply of cold air is also available to each passenger. The gasper system is supplied from the discharge side of the evaporator of the left air-conditioning pack. The supply duct branches into three ducts, one for each side of the passenger cabin and one for the flight deck (See Figures 7-2, 7-3 and 7-5).

The passenger cabin supply ducts run aft below the floor, then up behind the sidewall, to above the ceiling. The ducts above the ceiling run aft to the back of the passenger cabin. These ducts have droppers that supply a duct, that runs the length of the passenger cabin, next to the sidewall, at about arm rest level. This duct supplies the gasper air outlets that are located in the back of the seats (See Figure 7-13). The gasper air system is shown in Figure 7-14.

Some airplanes have the cold air outlets located below the hatracks. In this configuration, the overhead gasper distribution duct is located at the outboard side of the hatrack (see Figure 7-15) and the seat level ducting is removed. The supply ducts and risers are the same for all models.

The flight deck gasper supply ducting runs forward and up behind the left side of the flight deck panels. The system supplies five outlets, two in the ceiling above the pilot and co-pilot and one at the flight engineer's station. The flight deck gasper system is shown in Figure 7-16.

Equipment Cooling

The equipment cooling system provides cooling for the electronic equipment located in the flight deck, and warm air for forward cargo compartment heating. The equipment cooling system is shown in Figure 7-17.

The equipment racks are cooled by drawing flight-deck conditioned air through the instrument panels, and circulating it around the instruments. Flow through the system is normally driven by the radio rack exhaust blower during flight or on the ground. The blower exhausts air overboard, or to the forward cargo compartment depending on flight regime, recirculation fan mode, or condition of the pneumatic system. If the power fails, the airflow is driven overboard by cabin pressure through either the radio rack discharge venturi, or the venturi bypass valve.

Cargo Heating

The DC-8 cargo compartments are classified as FAR Part 25, Class D compartments. As such, they are limited in their ventilation rates to 1500 cubic feet per hour. There are no provisions for directly ventilating the cargo compartments.

The forward cargo compartment is heated by circulating radio-rack-cooling-discharge air between the cargo compartment lining and fuselage skin. Air is distributed by a duct located in the left utility tunnel. The duct receives air from the radio-rack-fan outlet, and passes air below the cargo compartment through diffusers located along its length.

The aft cargo compartment is heated by circulating passenger cabin exhaust air between the cargo lining and fuselage skin. A fan, mounted at the forward left-hand side of the cargo compartment, draws air into a duct that runs the length of the cargo compartment. Diffusers located along this duct distribute the air along the length of the cargo compartment. The fan motor is a three phase 200-volt motor, protected against overheat by a 300 °F switch. The cargo compartment heating systems are shown in Figure 7-18.

Recirculation Systems

The DC-8 recirculation system (-60 series only) returns cabin exhaust air from the air conditioning compartment to the evaporator inlet duct, to be cooled before returning to the distribution systems.

The system consists of three fans mounted on the aft surface of the nose wheel well. The fans are controlled from the flight engineer's panel, and can be operated on the ground or in-flight. Usually, the outboard fans are used for ground operations, and the center fan is used during flight. The fans will automatically stop if the temperature of the motorcase reaches 450 °F. If the fan trips off, it cannot be reset by the crew.

During ground operations, if the refrigeration system is off, the recirculation fans draw in ambient air from the nose wheel well to ventilate the cabin. If the refrigeration system is on, the recirculation fans draw air from the air conditioning accessories bay.

Ventilation

Air is vented overboard by three systems; galley and lavatory venting, equipment cooling, and pressurization outflow valves. The galley and lavatory venting, and equipment cooling systems are fixed-flow; the crew has no control over the amount of air being vented. The pressurization outflow valves are variable flow, and can be adjusted from the flight engineer's panel. The outflow valves are shown in Figure 7-19, and a typical galley and lavatory vent in Figures 7-20 and 7-21. Equipment ventilation is covered under equipment cooling.

The galley vent system removes air from the top of the galley and from the oven compartment, and vents it overboard through a flow limiting venturi. The flow is driven by the cabin to atmospheric pressure differential, and is not adjustable. There are generally two to four galleys on a DC-8, and they are placed in the forward and aft cabins.

The lavatory vent system removes air from the toilet bowl and below the shroud, and vents it overboard through a flow limiting venturi. The flow is driven by the cabin-to-atmospheric pressure differential, and is not adjustable by the crew. At the aft end of the airplane, the galley(s) and lavatories vent through a common port, with a venturi installed in the line from each lavatory so that the flow rate from each unit is approximately equal.

The pressurization outflow valves are the primary method of ventilating the cabin. The DC-8 has two outflow valves located on the underside of the fuselage, aft of the aft-baggage compartment. One valve is a butterfly type and the other is a nozzle type. The valves are connected to a system of linkages that sequence the opening and closing, and allow for automatic or manual control.

When the airplane is on the ground, both valves are full open. As the airplane climbs and the differential pressure increases to 1 psi, the butterfly valve closes, and the nozzle valve continues to vent all the air overboard. As the climb continues, the nozzle valve modulates in response to the pressure controller to maintain adequate pressure in the cabin.

Pressurization Control

The DC-8 pressurization control system is an electrically operated and electronically controlled system that regulates the amount of air passing through the outflow valves. The system has two operating modes, automatic and manual. The auto mode uses the pressure controller to regulate the outflow valve opening, and the manual mode operates the outflow valves through a system of cables and pulleys.

Gauges are provided at the first officer's and flight engineer's stations to monitor cabin altitude, cabin altitude rate of change, and differential pressure.

When using the auto mode, the flight engineer sets the flight altitude, desired cabin altitude change rate, and the barometric correction factor for take-off field elevation. The pressure control system then modulates the outflow valves to maintain the cabin conditions within desired limits. The system is not automatic in that the flight engineer must calculate the rate of change required to insure that system limits are not exceeded.

To use the manual mode the automatic system is disengauged by a lever on the control pedestal. The position of the outflow valve is then controlled through cables by a thumbwheel on the control pedestal (see Figure 7-22). An indicator is provided to show relative position of the outflow valve. The indication gauges must be monitored to prevent excessive cabin altitude or altitude change rate. The differential pressure gauge must be monitored to prevent exceeding the capabilities of the safety relief valves.

Pressurization system limits are shown in Table 7-1.

ECS Controls

The DC-8 vapor cycle ECS controls can be considered as two systems, air supply and cooling. The controls are located on the flight engineer's left-hand panels and are shown in Figures 7-23 and 7-24.

The air supply controls consist of switches and gauges, to control and monitor the operation of the compressor system. Four on-off switches, one for each compressor, to control compressor operation, are located on the flight engineer's panel. The switches control the turbine on-off valve which regulates the flow of pneumatic air to drive the turbine and compressor. Flow through the system is non-adjustable, except for selection of the number of turbo compressors operating, but automatic control systems attempt to maintain a constant volumetric flow rate. Indication lights are provided to alert the crew to compressor overheat and low flow. Gauges are provided to monitor compressor rpm.

The cooling system controls consist of refrigeration system controls and cabin temperature controls. The refrigeration system is started by starting the refrigerant compressor using a switch on the flight engineer's panel (See Figure 7-23). Once started, the system is self-modulating, via the refrigeration controller, to maintain an evaporator discharge of approximately 50 °F.

Compartment temperature control can be automatic or manual. The flight deck temperature is controlled by the position of the left system mixing valves. To use the auto system, the crew sets the desired cabin temperature on the control panel; the temperature controller then adjusts the mixing valve according to the demanded temperature and actual sensed temperature. To use the manual system, the automatic system is disengauged by rotating the knob on the appropriate manual control lever (See Figure 7-22). The temperature is adjusted by moving the lever to increase or decrease. When using this mode, the compartment temperature must be monitored on the gauges provided.

The air cycle system controls are shown in Figure 7-24. The air cycle controls consist of bleed-air controls, pack controls, temperature controls and temperature indicators. The control panel is located in the place vacated by the freon system controls.

The bleed-air switches are located at lower portion of the panel and control the flow of bleed-air to the pack flow-control valves. The bleed-air system operates in either auto or high mode. In the auto mode, the bleed-air system selects between 5th and 9th stage air as required to maintain 38 psig pneumatic pressure. In the high position, 9th stage air is delivered continuously.

The pack controls consist of on-off switches, flow adjustment controls, and heat-exchanger cooling-duct door controls.

The pack on-off switches control the flow of bleed-air to the flow-control valve. The flow adjustment knobs allow the crew to vary the flow of air through the pack. The flow adjustment knobs have five positions. Numbers in Table 7-6 correspond to the maximum flow schedule. For each position towards minimum, the flow is reduced approximately 10%. This can be used to reduce bleed-air flow from the engines when passenger loading is light to increase fuel economy.

The ram air door controls allow the crew to adjust the flow of ram air through the pack heat exchangers in response to varying atmospheric conditions, and heating or cooling demands.

The temperature controls allow the crew to select flight deck and passenger cabin temperatures separately. Control can be either automatic or manual. In the auto mode, the crew selects the desired temperature; the sensing and control systems then adjust the mixing valve to maintain a constant temperature. The temperatures are selectable between 65-85 °F. In the manual mode, the control knob controls the mix valve position directly; the crew can only select cooler or warmer. Compartment temperature must be monitored on the gauge provided. Gauges are also provided to show the mixing valve position and compressor discharge temperature.

A multi-purpose gauge is also provided to show pack discharge temperatures, cabin supply temperature, and cargo compartment temperature. A selector knob determines which temperature is displayed.

Electrical energy requirements for the ECS components and control systems for the vapor and air cycle systems are shown in Table 7-13 through 7-16. The loads presented are the connected load when the equipment is operating. During actual flight some equipment will, operate intermittently, at a load less than the connected load, only during emergency, or in certain system configurations.

TABLE 7-1. DC-8 PRODUCTION DATA

SERIES	FIRST FLIGHT (REF 17)	CERTIFICATION (REF 18)	NO. PRODUCED* (REF 3)
DC8-10	5-30-58	8-31-59	28
-20	11-29-58	1-19-60	34
-30	2-20-59	2-1-60	57
-40	7-23-59	3-23-60	32
-50	12-20-60	4-28-61	143
-61	3-14-66	9-1-66	88
-62	8-29-66	4-27-67	67
-63	4-10-67	6-29-67	107
-71	8-15-81	4-13-82	43*
-72	12-5-81	9-17-82	5*
-73	3-4-82	6-23-82	35*

*-71,-72,-73 CONVERTED FROM -61,-62,-63 BY RE-ENGINE WITH CFM 56-1B

TABLE 7-2. DC-8 VAPOR CYCLE SYSTEM FREON SUBSYSTEM PERFORMANCE (PER SYSTEM) (REF 20)

COOLING CAPACITY	13.7 TONS
REFRIGERANT	FREON 12
FREON COMPRESSOR INLET PRESSURE	51.67 PSIA (40° F SAT PRESSURE)
FREON COMPRESSOR DISCHARGE PRESSURE	230 PSIA (143° F SAT PRESSURE)
REFRIGERANT FLOW RATE	53.3 CFM
COMPRESSOR TURBINE INLET TEMPERATURE	425° F
COMPRESSOR TURBINE INLET PRESSURE	44.7 PSIA
COMPRESSOR TURBINE BLEED AIR FLOW RATE	30 LB PER MIN
COMPRESSOR SHAFT HORSEPOWER	28 HP
COMPRESSOR RPM	89,000 RPM

TABLE 7-3. DC-8-71,-72,-73 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(^{o}F DRY BULB AND PSIA)

FLIGHT REGIME	A FLOW CONTROL VALVE INLET		B FLOW CONTROL VALVE OUTLET		C WATER SEPARATOR OUTLET		D FLIGHT DECK SUPPLY		E PASS. CABIN SUPPLY		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	52	332	48	332	15.9	35	14.7	34	14.7	49	14.7	75	14.7	103
5,000 FT CLIMB	48	334	43	334	15.9	35	14.7	35	14.7	46	14.7	75	12.2	84
10,000 FT CLIMB	46	332	40	332	15.8	35	14.7	34	14.7	46	14.7	75	10.1	64
25,000 FT CRUISE	42	328	36	328	15.3	35	14.3	35	14.3	53	14.3	75	5.4	6
30,000 FT CRUISE	41	322	32	322	14.0	36	13.1	61	13.1	64	13.1	75	4.36	-12
35,000 FT CRUISE	40	321	25	321	13.0	35	12.2	35	12.2	49	12.2	75	3.46	-30
43,000 FT CRUISE	DATA NOT AVAILABLE													
20,000 FT DESCENT	43	352	33	352	15.7	35	14.7	35	14.7	53	14.7	75	6.7	25
15,000 FT DESCENT	30	348	29	348	15.4	35	14.7	34	14.7	56	14.7	75	8.3	45

MAXIMUM SUPPLY TEMP 190^{o} F

MINIMUM SUPPLY TEMP 35^{o} F

TABLE 7-4. DC-8-10 THRU -50,-62 VOLUME FLOW (CFM) VAPOR CYCLE SYSTEM (REF 19)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF 5,000 FT CLIMB 10,000 FT CLIMB 25,000 FT CRUISE 30,000 FT CRUISE 35,000 FT CRUISE 40,000 FT CRUISE 18,500 FT DESCENT 10,000 FT DESCENT		2,924	0	260	0

TABLE 7-5. DC-8-61,-63 VOLUME FLOW (CFM) VAPOR CYCLE SYSTEM (REF 19)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF 5,000 FT CLIMB 10,000 FT CLIMB 25,000 FT CRUISE 30,000 FT CRUISE 35,000 FT CRUISE 40,000 FT CRUISE 18,500 FT DESCENT 10,000 FT DESCENT		4,817	35	422	40

TABLE 7-6. DC-8-71,-72,-73 VOLUME FLOW AIR CYCLE SYSTEM (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	120	4,661	41	382	0
5,000 FT CLIMB	120	4,129	34	380	0
10,000 FT CLIMB	120	4,126	34	377	0
25,000 FT CRUISE	118	4,697	41	384	0
30,000 FT CRUISE	110	4,782	40	406	0
35,000 FT CRUISE	104	4,543	37	394	0
43,000 FT CRUISE	DATA NOT AVAILABLE				
20,000 FT DESCENT	119	4,647	41	376	0
15,000 FT DESCENT	89	4,045	49	285	0

TABLE 7-7. DC-8-10 THRU -50 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF		
5,000 FT CLIMB		
10,000 FT CLIMB		
25,000 FT CRUISE		
30,000 FT CRUISE		
35,000 FT CRUISE	20.32	22.8
40,000 FT CRUISE		
18,500 FT DESCENT		
10,000 FT DESCENT		

TABLE 7-8. DC-8-61,-63 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK (ALL FRESH)	FLIGHT DECK (FRESH & RECIRC)
SEA LEVEL TAKEOFF				
5,000 FT CLIMB				
10,000 FT CLIMB				
25,000 FT CRUISE				
30,000 FT CRUISE				
35,000 FT CRUISE	16.2	24.9	22.2	37.0
40,000 FT CRUISE				
18,500 FT DESCENT				
10,000 FT DESCENT				

TABLE 7-9. DC-8-62 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF		
5,000 FT CLIMB		
10,000 FT CLIMB		
25,000 FT CRUISE		
30,000 FT CRUISE		
35,000 FT CRUISE	19.2	22.8
40,000 FT CRUISE		
18,500 FT DESCENT		
10,000 FT DESCENT		

TABLE 7-10. DC-8-71,-73 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	18.1	30.6	33.6
5,000 FT CLIMB	18.0	27.2	33.4
10,000 FT CLIMB	18.0	27.2	33.1
25,000 FT CRUISE	18.2	30.9	33.7
30,000 FT CRUISE	18.9	31.5	35.7
35,000 FT CRUISE	18.8	29.9	34.6
43,000 FT CRUISE	N/A*	N/A*	N/A*
20,000 FT DESCENT	18.1	30.6	33.0
15,000 FT DESCENT	13.6	26.6	25.0

*NOT AVAILABLE

TABLE 7-11. DC-8-72 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	14.2	24.0	33.6
5,000 FT CLIMB	14.0	21.3	33.4
10,000 FT CLIMB	14.0	21.3	33.1
25,000 FT CRUISE	14.3	24.2	33.7
30,000 FT CRUISE	14.8	24.7	35.7
35,000 FT CRUISE	14.8	23.5	34.6
43,000 FT CRUISE	N/A*	N/A*	N/A*
20,000 FT DESCENT	14.2	24.0	33.0
15,000 FT DESCENT	10.7	20.9	25.0

*NOT AVAILABLE

TABLE 7-12. DC-8 VENTILATION PARAMETERS

	DC-8-10,-20,-30,-40, -50,-54,-55	DC-8-61,-63	DC-8,-62
VOLUMES (CU FT)			
TOTAL PRESSURIZED	12,950	18,579*	14,650*
PASSENGER CABIN	8,633	11,622	9,115
FLIGHT DECK	683	683	683
FWD CARGO	690	1,290	800
AFT CARGO	700	1,210	815
PRESSURIZATION			
MAX ΔP (PSI)			
CONTROLLER LIMITED	8.77		
SAFETY VALVE LIMITED	8.82 - 9.18		
CABIN ALTITUDE CHANGE RATES (FT/MIN)			
CONTROLLER SELECTED — MAX	975		
CONTROLLER SELECTED — MIN	0		

*ESTIMATED

TABLE 7-13. DC-8-10 THRU -50,-61,-62,-63 AC ELECTRICAL ENERGY REQUIREMENTS (REF 21,22)

EQUIPMENT	POWER REQD	LOAD WATTS	LOAD VARS	SOURCE
Mix Valve Control, Left	115V 400 Hz 1Ø	5	4	AC Bus 1 ØB
A/C Mix Valve Motor, Left	115V 400 Hz 1Ø	64	64	AC Bus 1 ØB
A/C Mix Valve Clutch, Left	115V 400 Hz 1Ø	8	6	AC Bus 1 ØB
Aft Cargo Blower	200V 400 Hz 3Ø	1,280	960	AC Bus 1
Radio Rack Blower	200V 400 Hz 3Ø	1,280	960	AC Bus 1
Recirc Fan, Left	200V 400 Hz 3Ø	13,330	8,610	AC Bus 1
Freon Compressor Oil Pump, Left	115V 400 Hz 1Ø	46	33	AC Bus 1 ØB
Cold Air Bypass Valve	115V 400 Hz 1Ø	46	33	AC Bus 1 ØB
Recirc Fan Power, Relay Left	115V 400 Hz 1Ø	21	9	AC Bus 1 ØA
Recirc Fan Check Relay Valve, Left	115V 400 Hz 1Ø	8		AC Bus 1 ØA
Heat Exchanger Control, Left	115V 400 Hz 1Ø	5	4	AC Bus 2 ØB
Freon System Control, Left	115V 400 Hz 1Ø	21	9	AC Bus 2 ØB
Heat Exchanger, A/C Motor, Left	115V 400 Hz 1Ø	72	72	AC Bus 2 ØB
Freon Exhaust Flap Motor, Left	115V 400 Hz 1Ø	169	148	AC Bus 2 ØB
Fan and Ram Air Flap, Left	115V 400 Hz 1Ø	55	15	AC Bus 2 ØB
Recirc Fan, Center	200V 400 Hz 3Ø	13,330	8,610	AC Bus 2
Freon Band Control Relay, Left	115V 400 Hz 1Ø	23	9	AC Bus 2 ØB
Recirc Fan Check Valve Relay, Center	115V 400 Hz 1Ø	8		AC Bus 2 ØA
Recirc Fan Power Relay, Center	115V 400 Hz 1Ø	21	9	AC Bus 2 ØA
Recirc Fan Control Relay, Center	115V 400 Hz 1Ø	8		AC Bus 2 ØA
Heat Exchanger Control, Right	115V 400 Hz 1Ø	5	4	AC Bus 3 ØC
Freon System Control, Right	115V 400 Hz 1Ø	21	9	AC Bus 3 ØB
Fan and Ram Air Flap, Right	115V 400 Hz 1Ø	55	15	AC Bus 3 ØB
Heat Exchanger, A/C Motor, Right	115V 400 Hz 1Ø	72	72	AC Bus 3 ØC
Freon Exhaust Flap Motor, Right	115V 400 Hz 1Ø	169	148	AC Bus 3 ØB
Recirc Fan, Right	200V 400 Hz 3Ø	13,330	8,610	AC Bus 3
Freon Band Control Relay, Right	115V 400 Hz 1Ø	23	9	AC Bus 3 ØB
Recirc Fan Power Relay, Right	115V 400 Hz 1Ø	21	9	AC Bus 3 ØA
Recirc Fan Check Valve Relay	115V 400 Hz 1Ø	8	-	AC Bus 3 ØA
Cabin Press Control	115V 400 Hz 1Ø	7	7	AC Bus 4 ØC
Mix Valve Control, Right	115V 400 Hz 1Ø	5	4	AC Bus 4 ØA
A/C Mix Valve Motor, Right	115V 400 Hz 1Ø	64	64	AC Bus 4 ØA
A/C Mix Valve Clutch, Right	115V 400 Hz 1Ø	8	6	AC Bus 4 ØA
Cabin Press Control Valve Motor	115V 400 Hz 1Ø	26	30	AC Bus 4 ØC
Recirc Fan Unloader Valve Actuator	115V 400 Hz 1Ø	138	102	AC Bus 4 ØB
Freon Compressor Oil Pump, Right	115V 400 Hz 1Ø	160	120	AC Bus 4 ØB

TABLE 7-14. DC-8-10 THRU -50,-61,-62,-63 DC ELECTRICAL ENERGY REQUIREMENTS (REF 21)

EQUIPMENT	POWER REQD	LOAD	SOURCE
Freon System Control - Left	28V	1.00 A	DC Bus 1
Saturation/Superheat Temp Indicators	28V	.20 A	DC Bus 1
Recirc Fan - Left	28V	.20 A	DC Bus 1
Recirc Fan - Center	28V	.20 A	DC Bus 1
Freon Flight Position Relay - Left	28V	.35 A	DC Bus 1
Freon Oil Pump Delay Relay - Left	28V	3.00 A	DC Bus 1
Freon Oil Pump - Left	28V	.25 A	DC Bus 1
Cabin Compressor Shutoff Soilenoids - L	28V	1.30 A	DC Bus 1
Freon Turbine On/Off Solenoid - Left	28V	.18 A	DC Bus 1
Freon Condensor Fan Valve Solenoid - Left	28V	.18 A	DC Bus 1
Freon System Control - Right	28V	1.00 A	DC Bus 4
Recirc Fan Motor - Right	28V	.20 A	DC Bus 4
Freon Flight Position - Right	28V	.35 A	DC Bus 4
Freon Oil Pump Delay Relay - Right	28V	3.00 A	DC Bus 4
Freon Oil Pump Relay Right	28V	.25 A	DC Bus 4
Cabin Compressor Shutoff Solenoids - Right	28V	1.30 A	DC Bus 4
Freon Turbine On-Off Solenoid Right	28V	.10 A	DC Bus 4
Freon Condensor Fan Valve - Right	28V	.10 A	DC Bus 4

TABLE 7-15. DC-8-71,-72,-73 AC ELECTRICAL ENERGY REQUIREMENTS (REF 22)

EQUIPMENT	POWER REQD	LOAD WATTS	LOAD VARS	SOURCE
35^{o} Water Separator Control Left	115V 400 Hz 1Ø	5	-	AC Bus 1 ØA
35^{o} Water Separator Valve, Left	115V 400 Hz 1Ø	33	-	AC Bus 1 ØA
Pack Control Power Relay	115V 400 Hz 1Ø	21	9	AC Bus 1 ØB
Diverter Valve Actuator, Left	115V 400 Hz 1Ø	49	16	AC Bus 1 ØB
3 Way Mix Valve, Manual	115V 400 Hz 1Ø	126	81	AC Bus 1 ØB
Pack Cooling Fan - Left	200V 400 Hz 3Ø	9311	6019	AC Bus 1
Vane Door Actuator Left	115V 400 Hz 1Ø	207	-	AC Bus 2 ØB
Cabin Temp Controller Auto, Left	115V 400 Hz 1Ø	6	-	AC Bus 2 ØB
3 Way Mix Valve, Left	115V 400 Hz 1Ø	24	-	AC Bus 2 ØB
Recirc Fan Control Relay	115V 400 Hz 1Ø	21	9	AC Bus 2 ØB
Recirc Fan Power Center	200V 400 Hz 3Ø	4656	3010	AC Bus 2
Cabin Temp Controller	115V 400 Hz 1Ø	6	-	AC Bus 3 ØB
3 Way Mix Valve, Right	115V 400 Hz 1Ø	23	-	AC Bus 3 ØB
Pack Control RElay, Right	115V 400 Hz 1Ø	21	9	AC Bus 3 ØB
Vane Door Actuator, Right	115V 400 Hz 1Ø	50	9	AC Bus 3 ØC
Pack Cooling Fan, Right	200V 400 Hz 3Ø	9311	6019	AC Bus 3
Diverter Valve Actuator	115V 400 Hz 1Ø	49	16	AC Bus 4 ØA
3 Way Mix Valve, Manual	115V 400 Hz 1Ø	5	-	AC Bus 4 ØB
35^{o} Water Separator Control, Right	115V 400 Hz 1Ø	5	-	AC Bus 4 ØB
35^{o} Water Separator Control Valve, Right	115V 400 Hz 1Ø	33	-	AC Bus 4 ØB

TABLE 7-16. DC-8-71,-72,-73 DC ENERGY REQUIREMENTS (REF 22)

EQUIPMENT	POWER REQD	LOAD	SOURCE
Pack Compressor Temp Indication	28 VDC	.01 A	DC Bus 1
Pack & Mix Valve Position Indicator	28 VDC	.01 A	DC Bus 1
Flow Control Valve Solenoid, Left	28 VDC	.89 A	DC Bus 1
Duct Overheat Sensors	28 VDC	.67 A	DC Bus 1
Pack & Cabin Supply Air Temp	28 VDC	.01 A	DC Bus 4
Duct Overheat Sensors	28 VDC	.67 A	DC Bus 4
Flow Control Valve Solenoid, Right	28 VDC	.89 A	DC Bus 1
Pack Trip Lamp	28 VDC	.17 A	Battery
Pack Control Relay	28 VDC	.50 A	Battery

DC-8

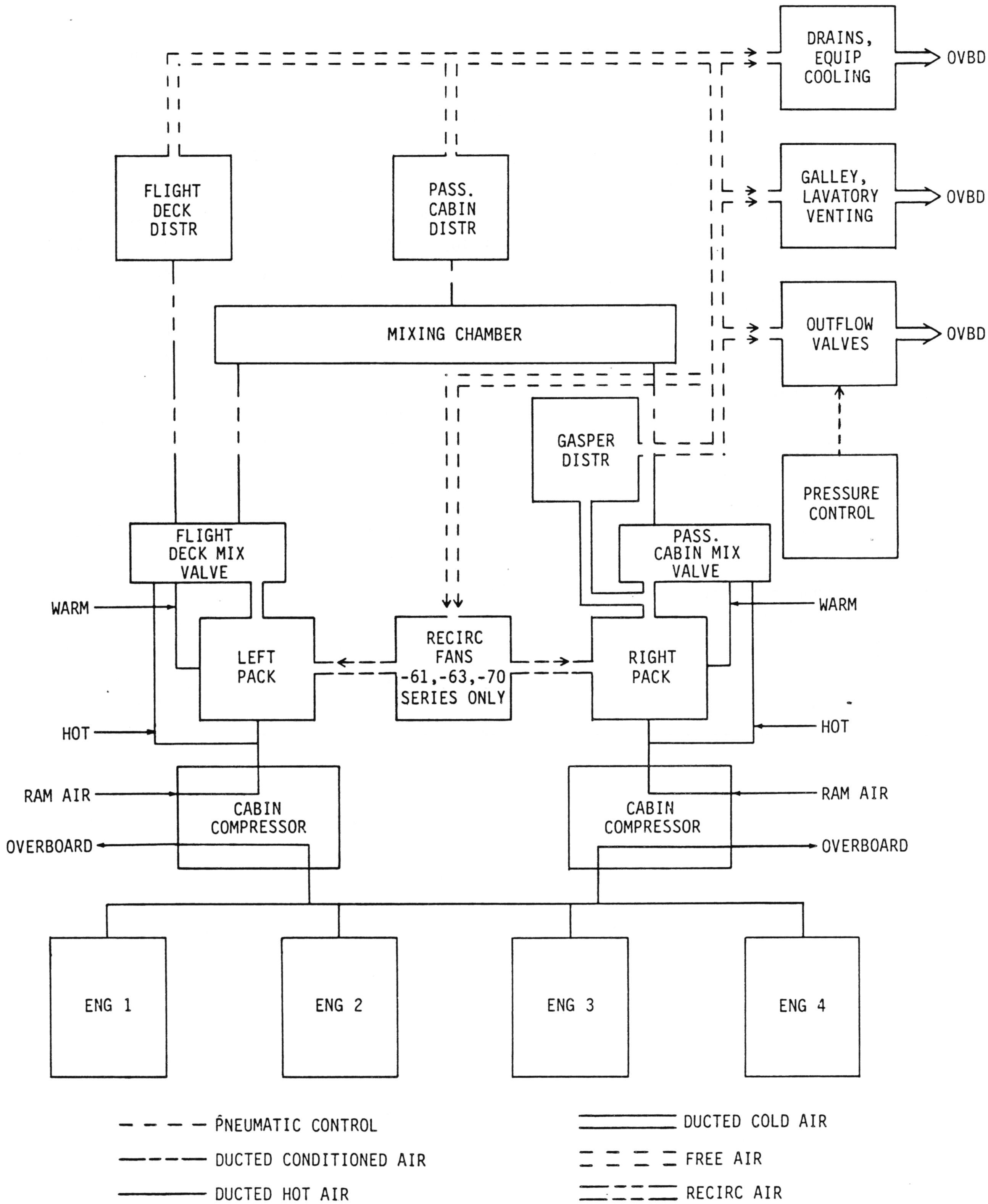


FIGURE 7-1. DC-8 AIR CONDITIONING SYSTEM BLOCK DIAGRAM

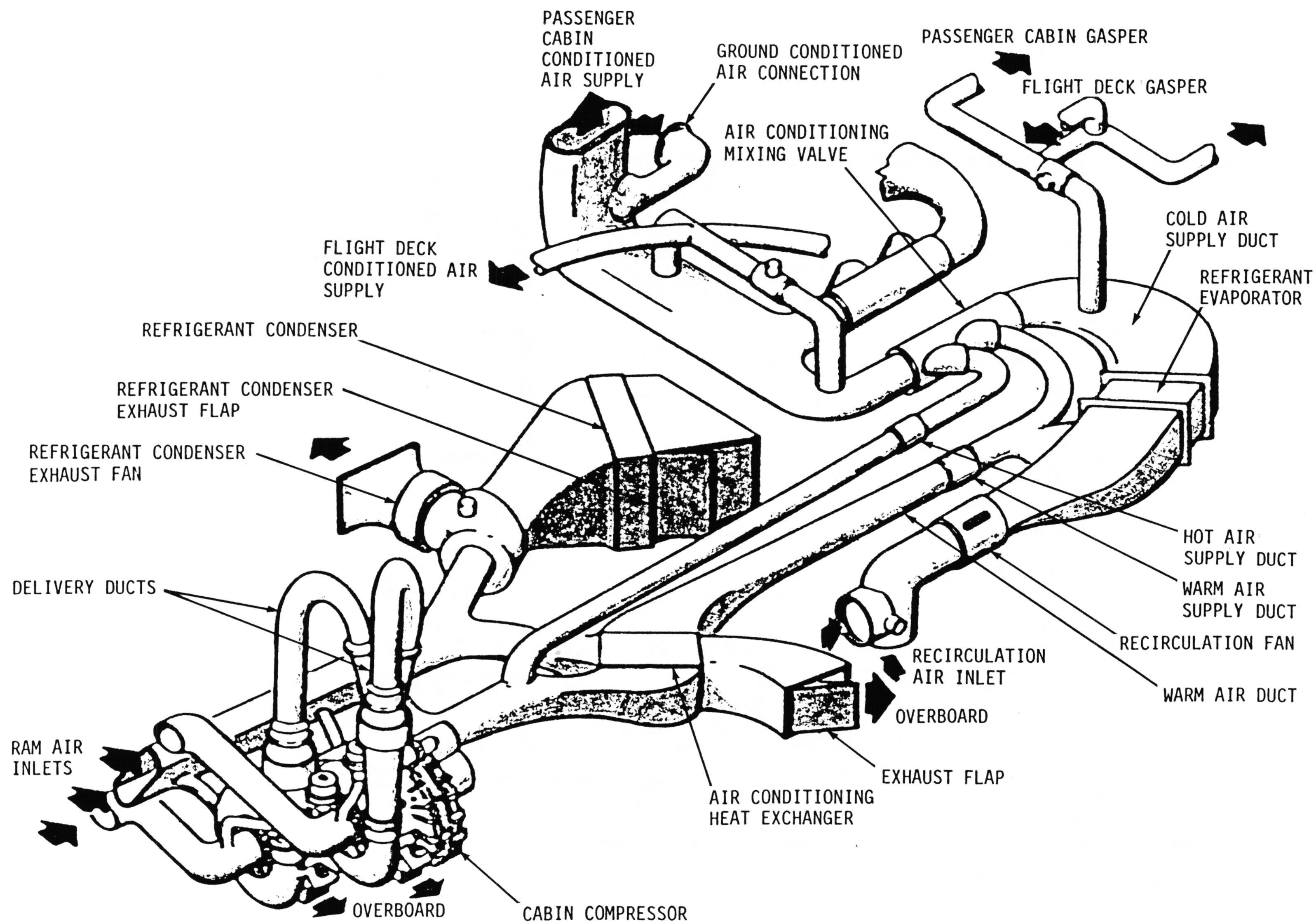


FIGURE 7-2. DC-8 VAPOR CYCLE AIR CONDITIONING SYSTEM (RIGHT PACK SHOWN)

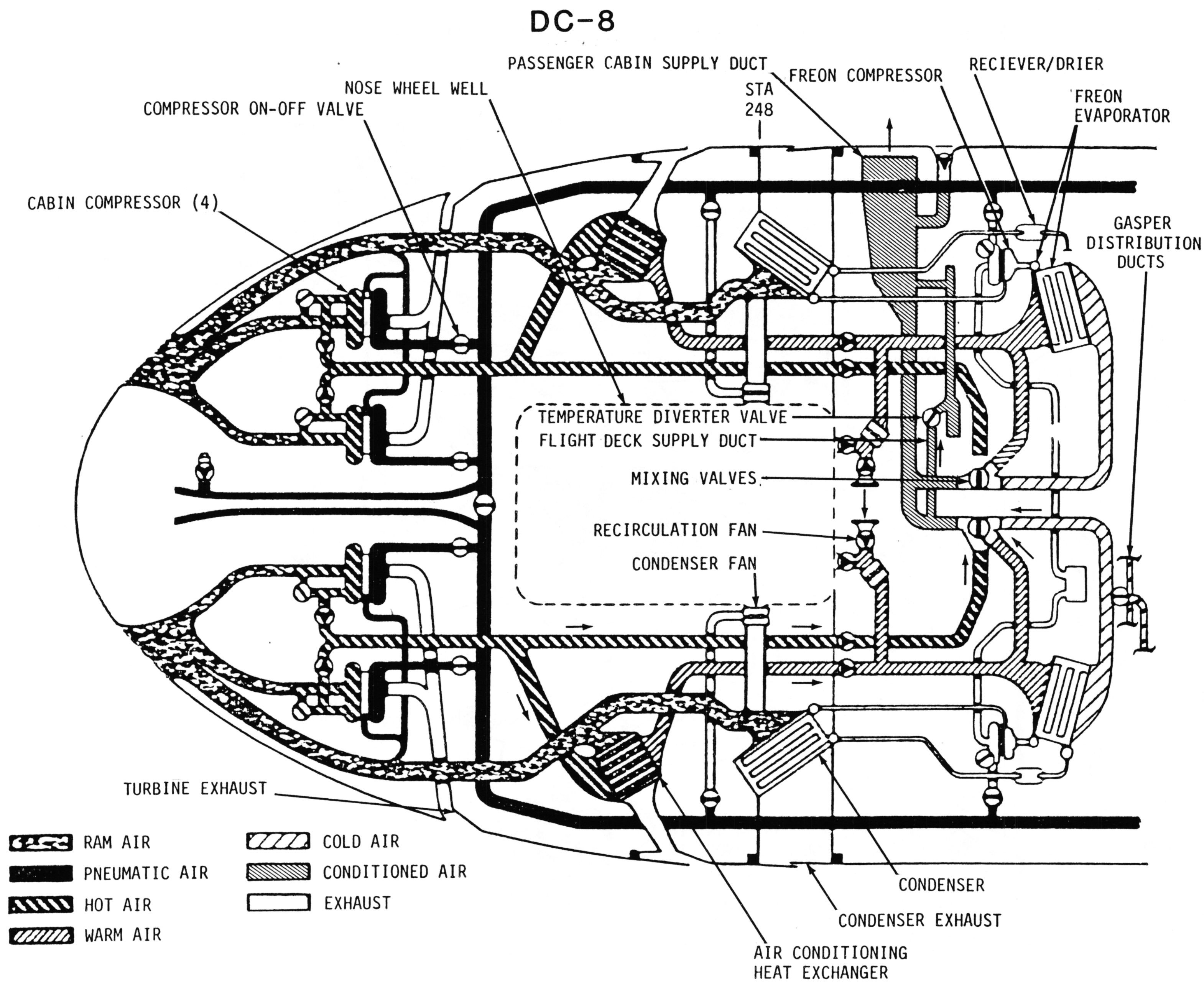


FIGURE 7-3. DC-8 VAPOR CYCLE AIR CONDITIONING SYSTEM SCHEMATIC

DC-8

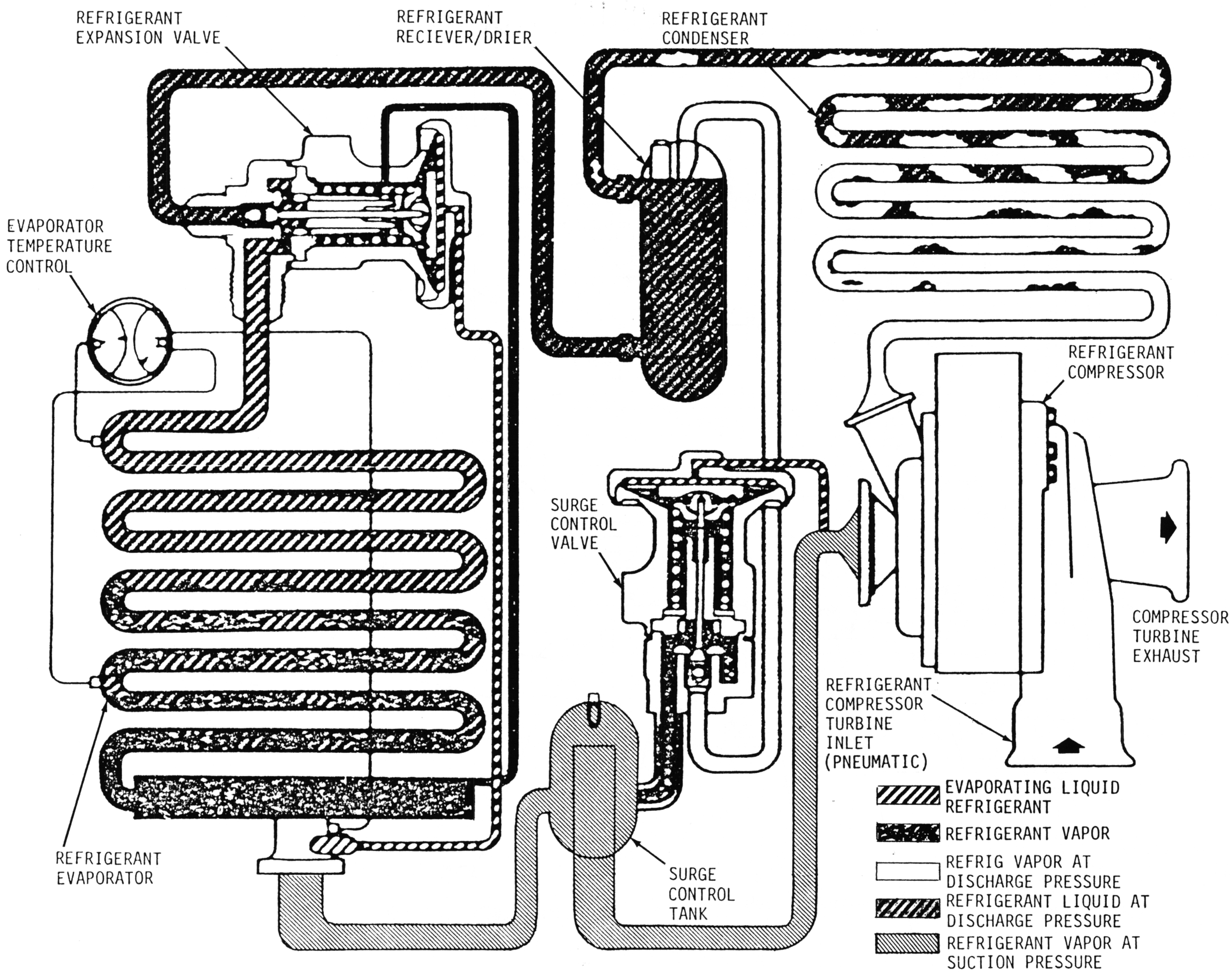


FIGURE 7-4. DC-8 REFRIGERATION SYSTEM SCHEMATIC

DC-8-70

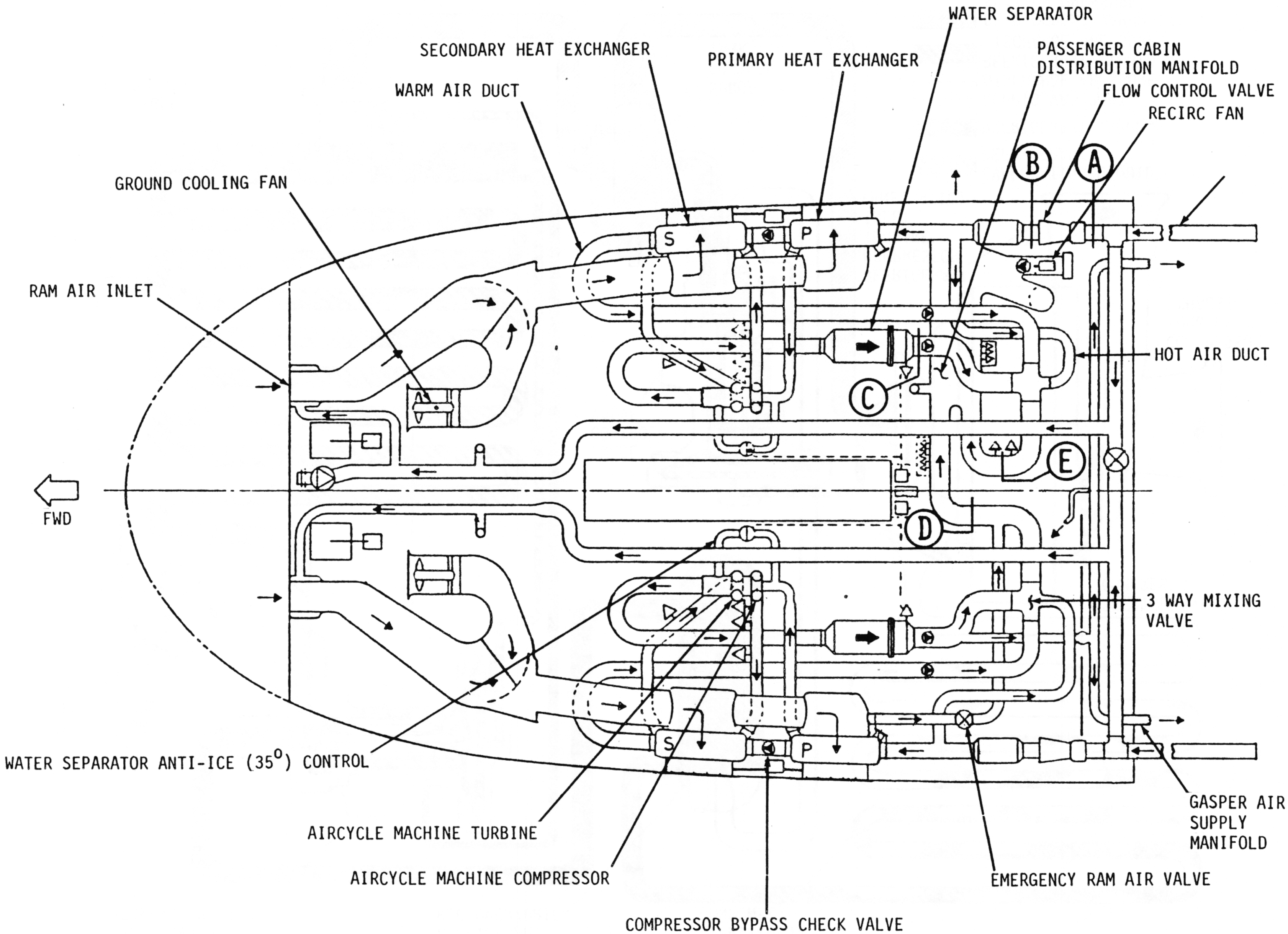


FIGURE 7-5. DC-8-70 AIR CYCLE SYSTEM SCHEMATIC

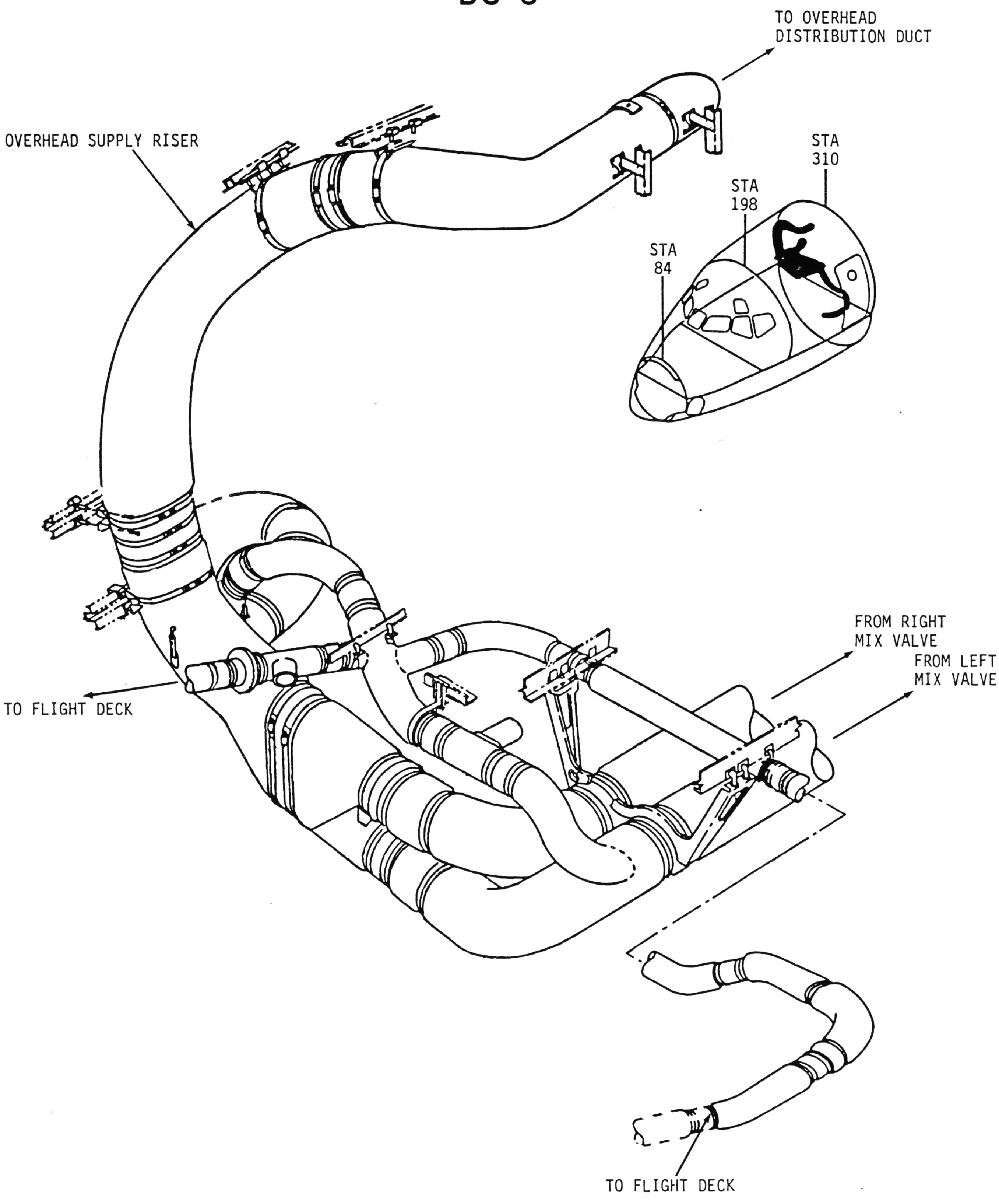


FIGURE 7-6. DC-8 MAIN DISTRIBUTION MANIFOLD

DC-8

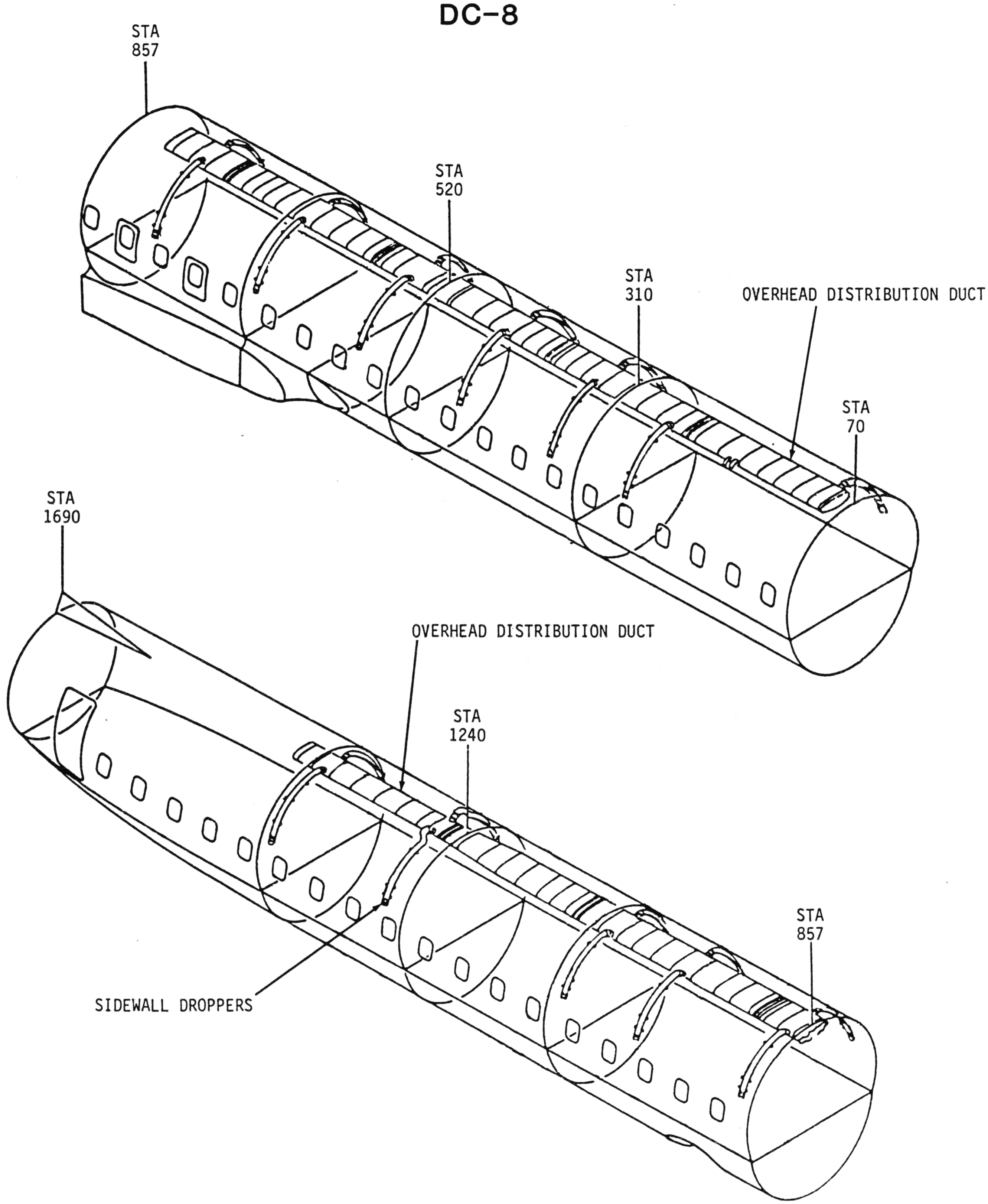


FIGURE 7-7. DC-8 PASSENGER CABIN DISTRIBUTION

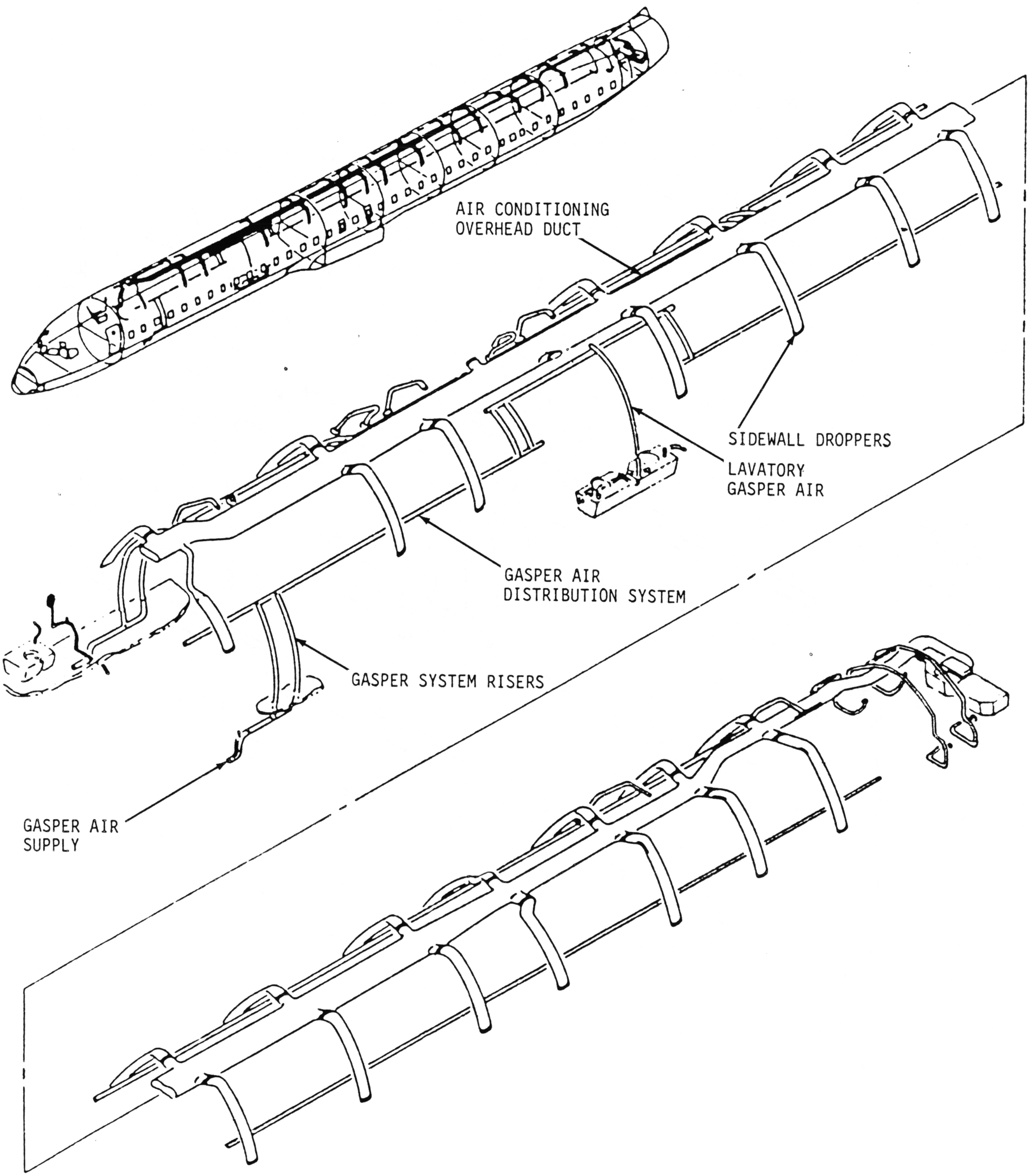


FIGURE 7-8. DC-8 PASSENGER CABIN AIR DISTRIBUTION

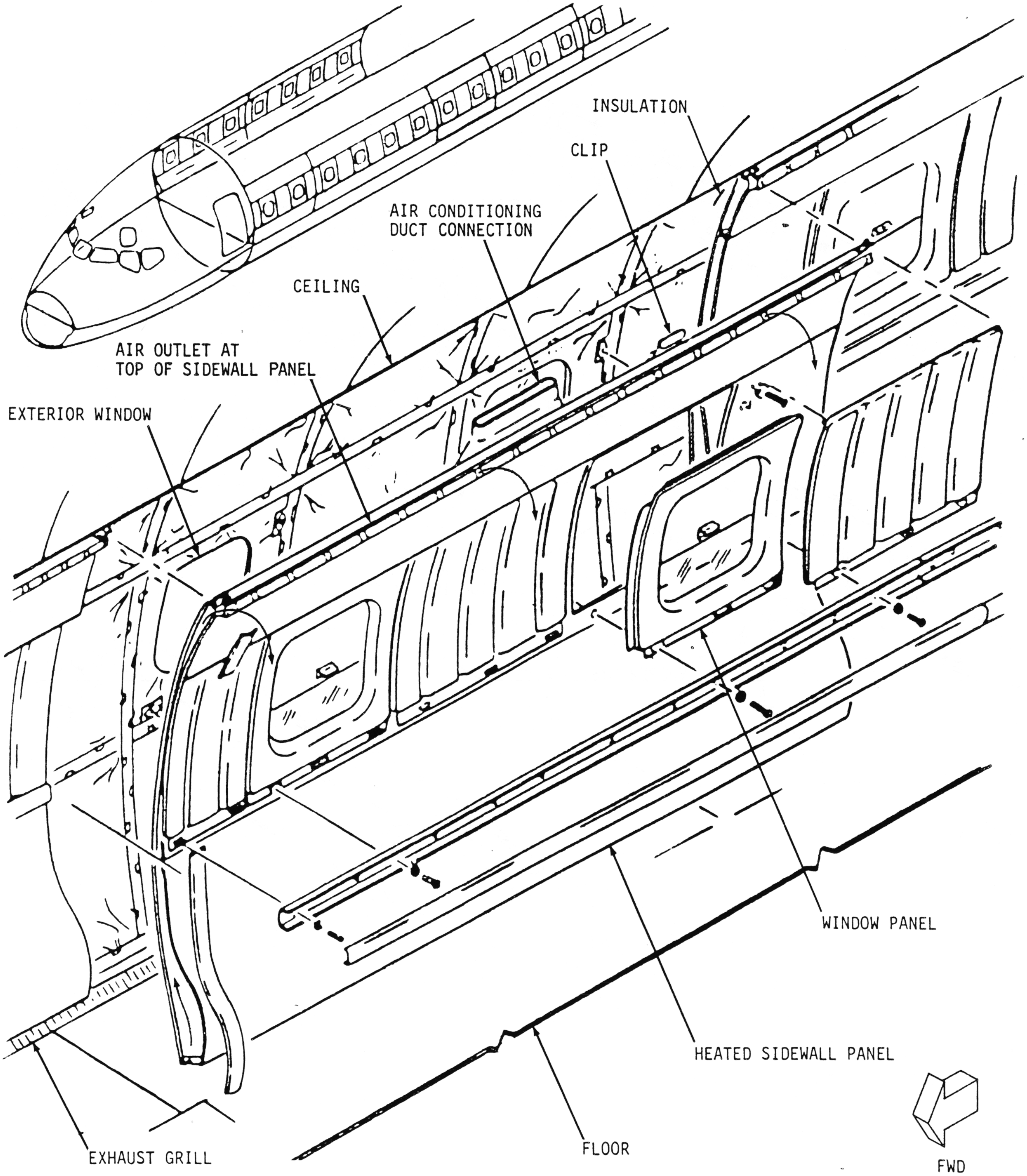
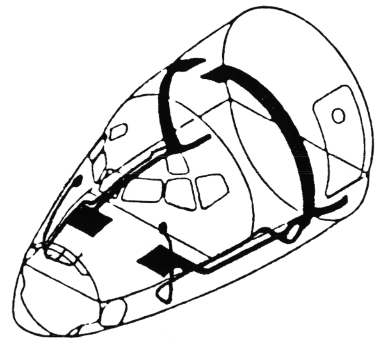


FIGURE 7-9. DC-8 SIDEWALL PANEL AND OUTLET



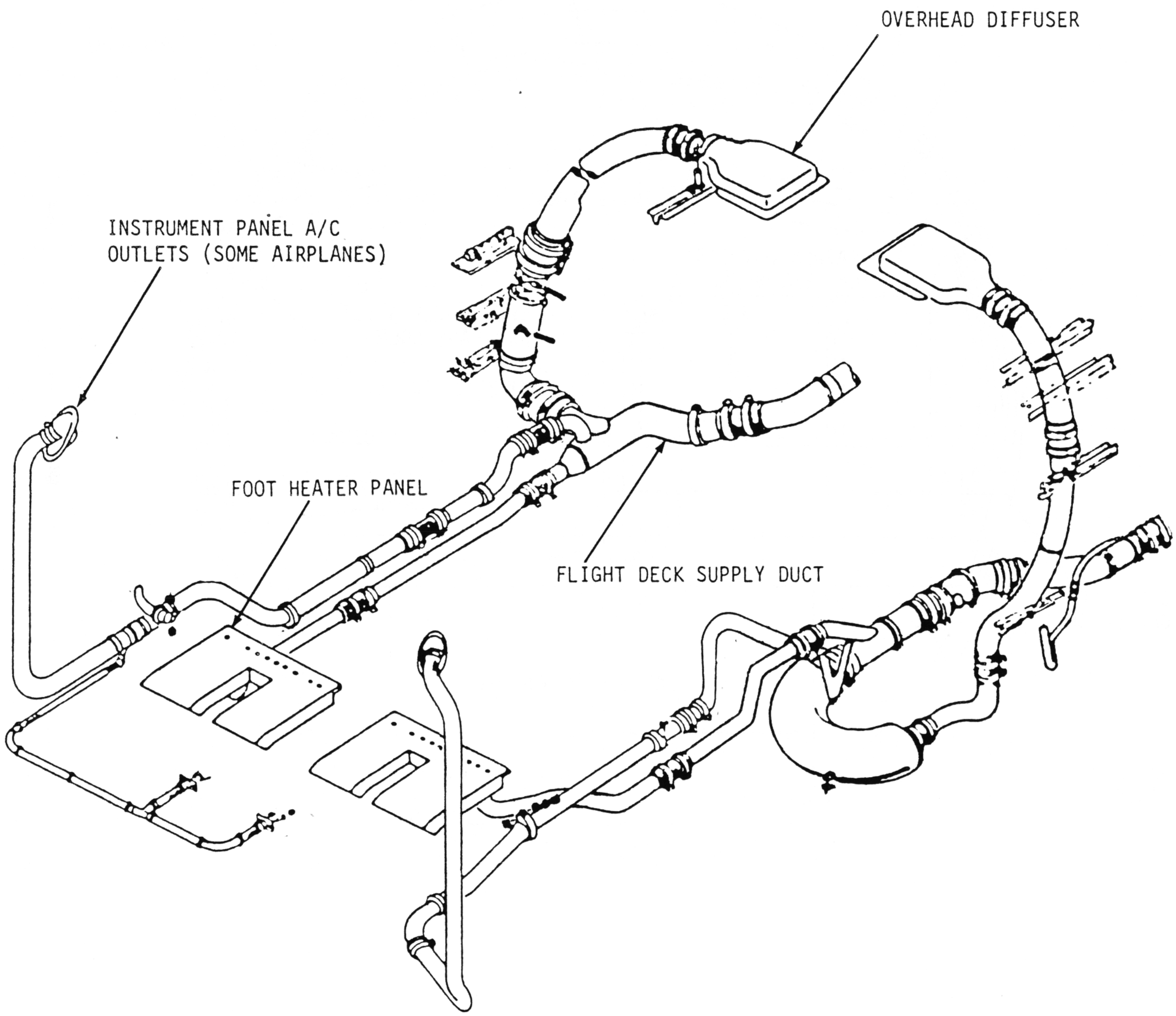


FIGURE 7-10. DC-8 FLIGHT DECK AIR DISTRIBUTION

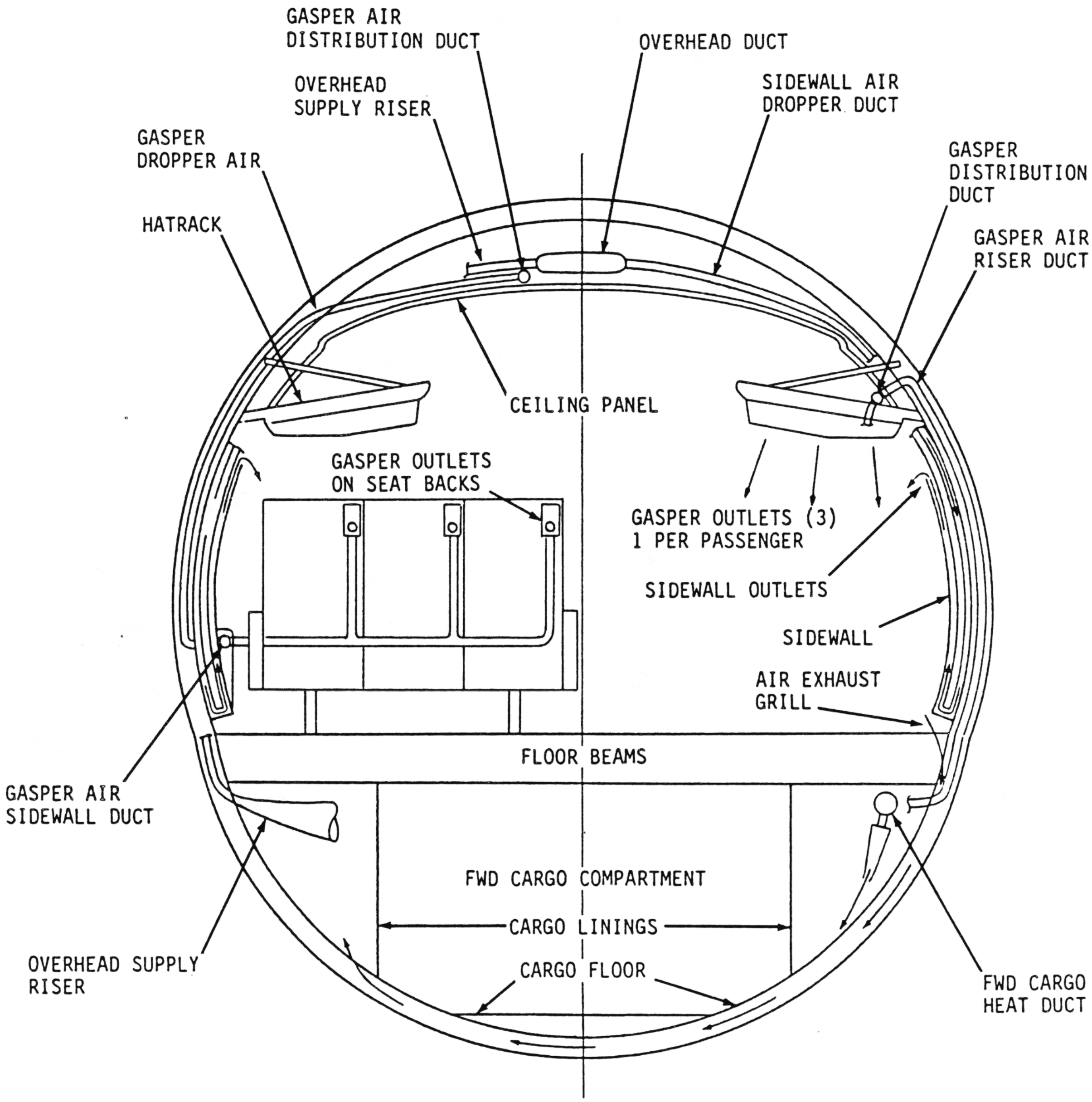


FIGURE 7-11. DC-8 PASSENGER CABIN CROSS SECTION

DC-8

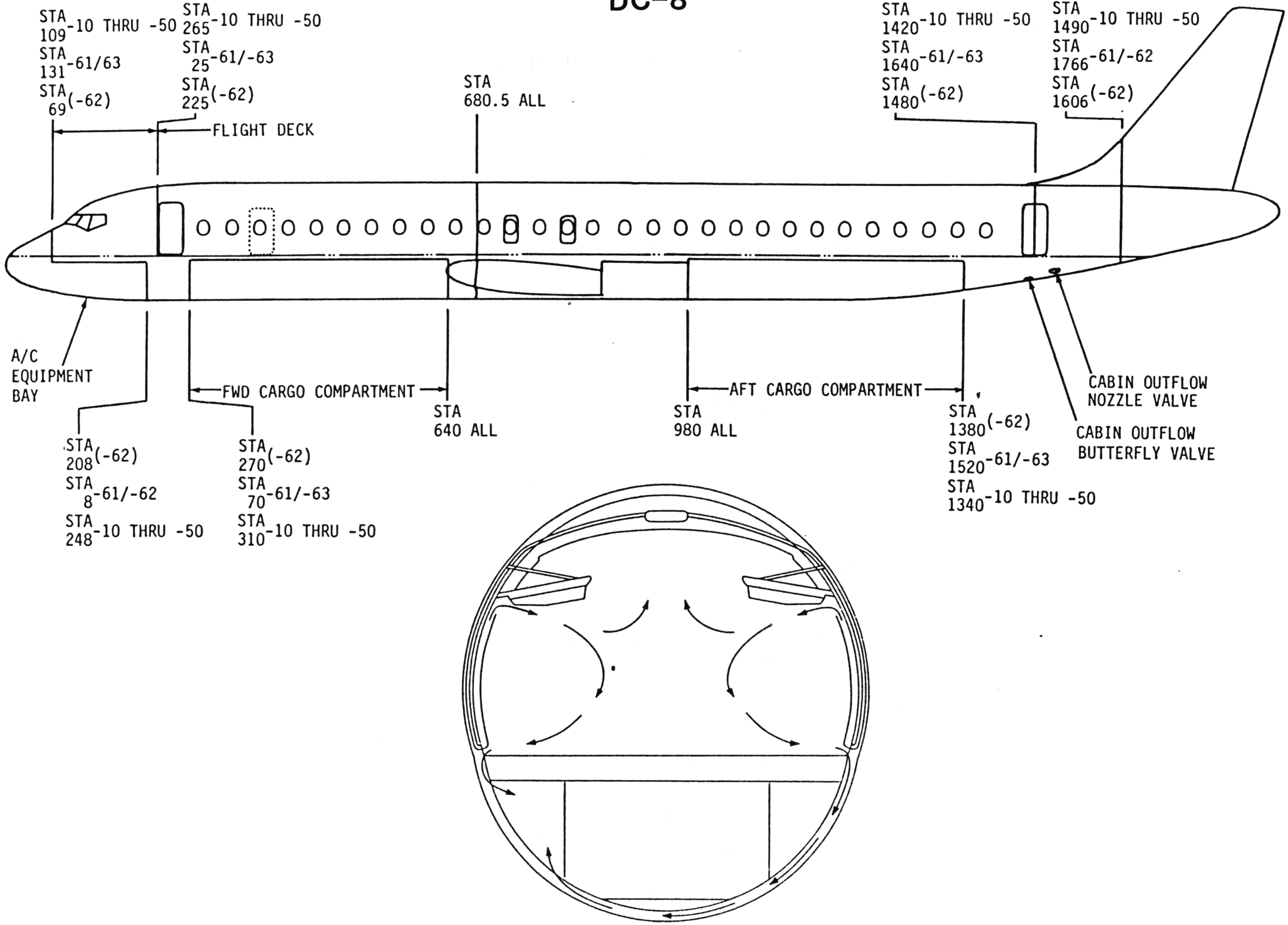


FIGURE 7-12. DC-8 PASSENGER CABIN AIR FLOW PATTERNS

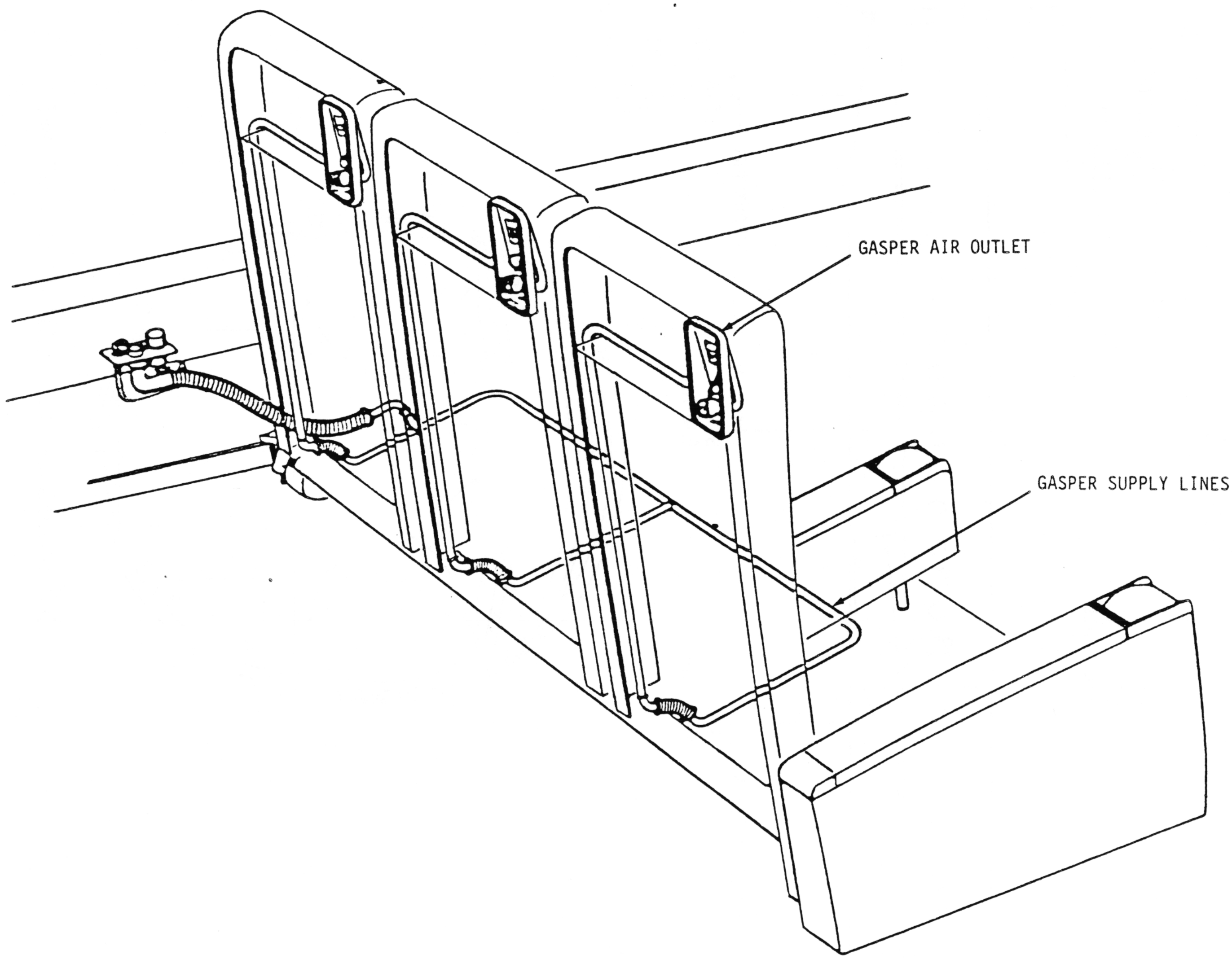


FIGURE 7-13. DC-8 PASSENGER CABIN AIR SEAT OUTLETS

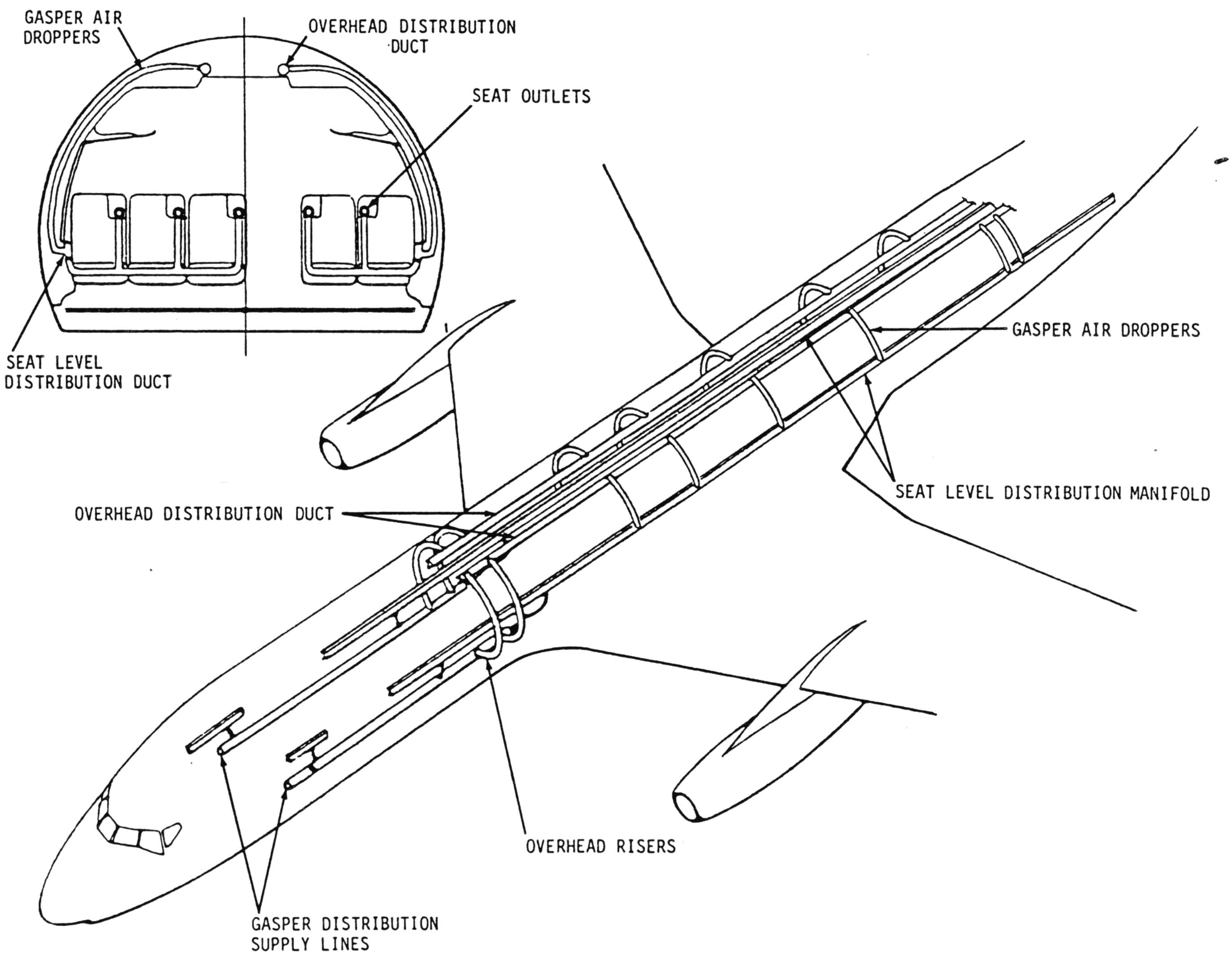


FIGURE 7-14. DC-8 PASSENGER CABIN GASPER AIR DISTRIBUTION

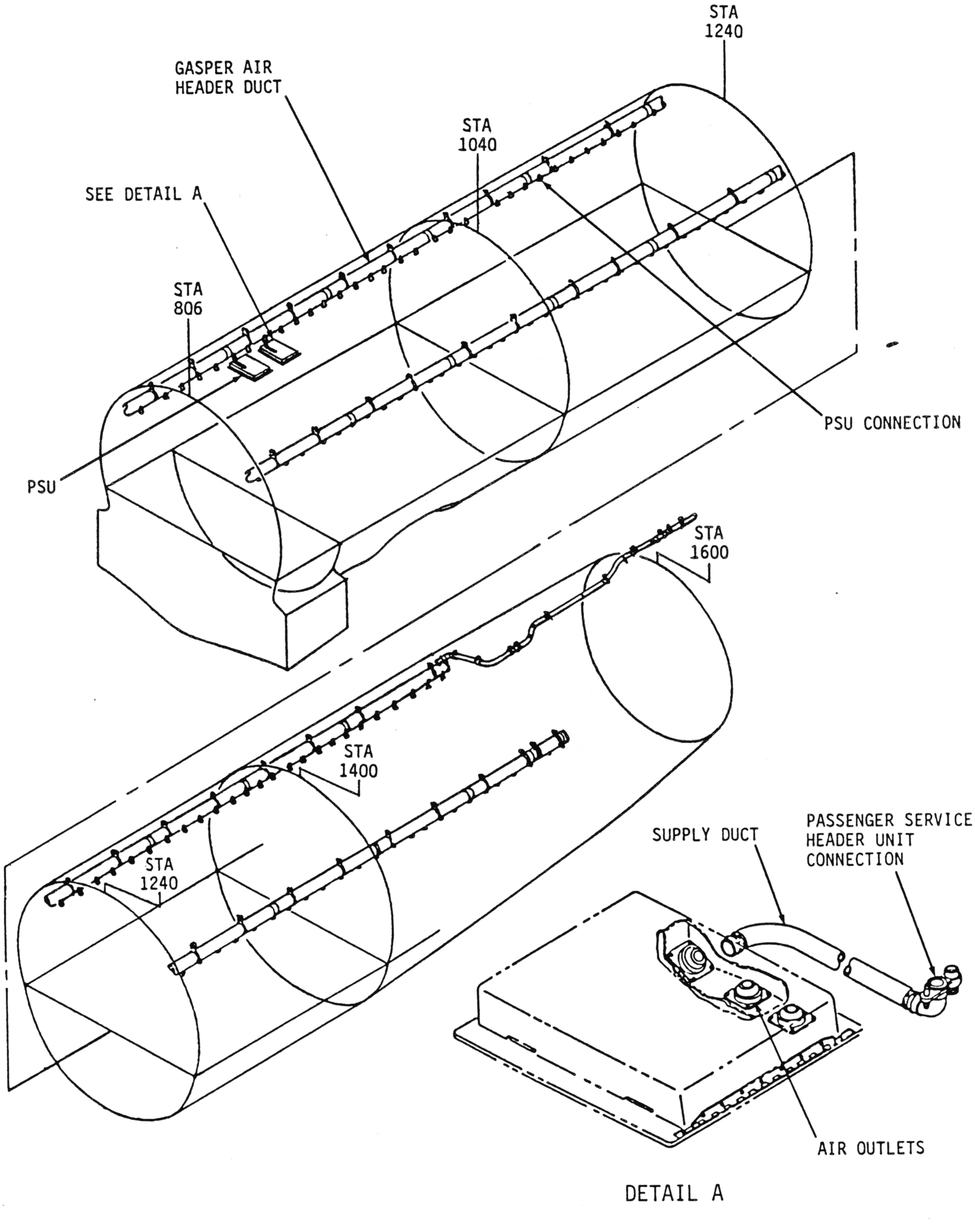


FIGURE 7-15. DC-8 PASSENGER CABIN GASPER AIR DISTRIBUTION, ALTERNATE CONFIGURATION

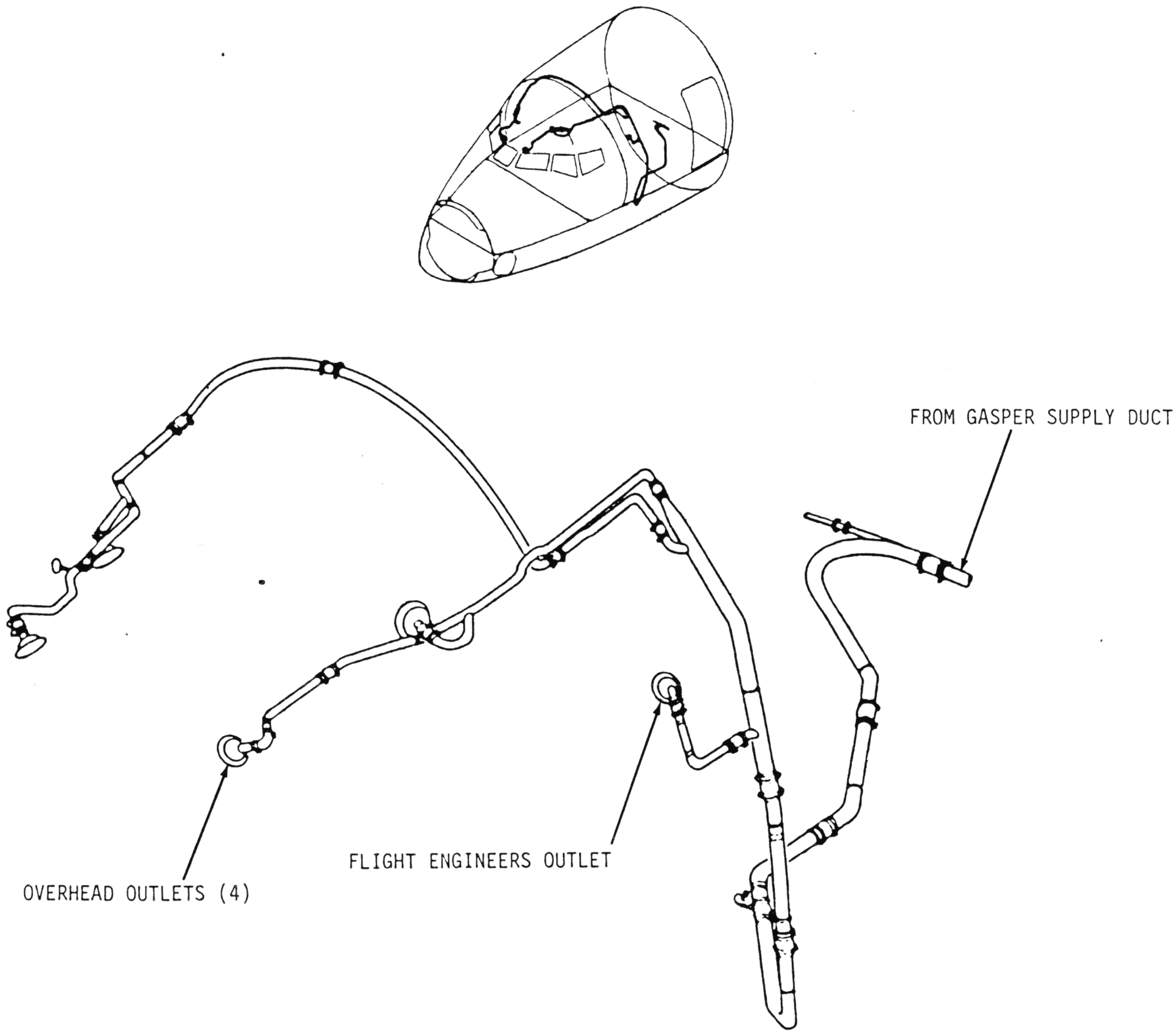


FIGURE 7-16. DC-8 FLIGHT DECK GASPER AIR DISTRIBUTION

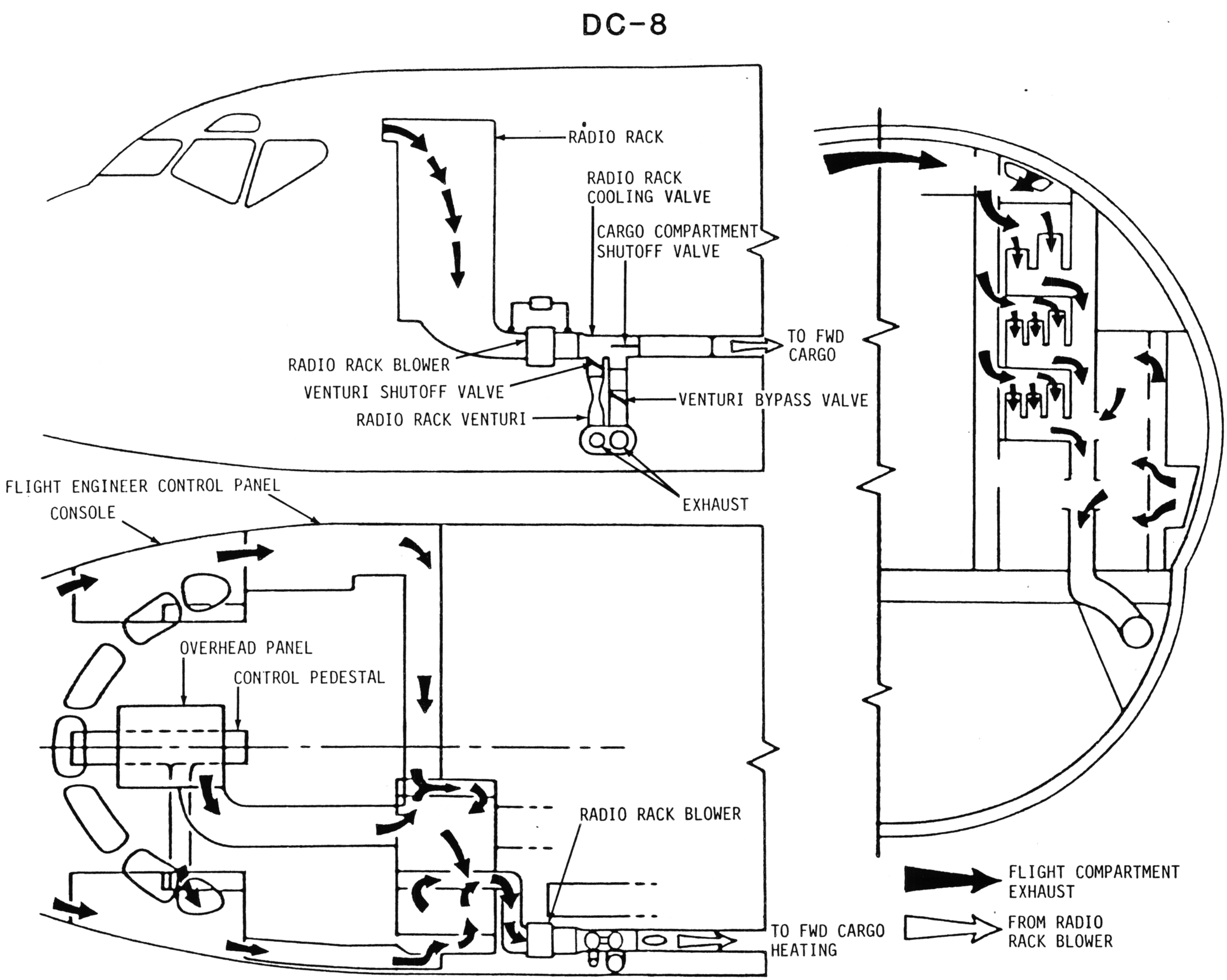


FIGURE 7-17. DC-8 EQUIPMENT COOLING SYSTEM

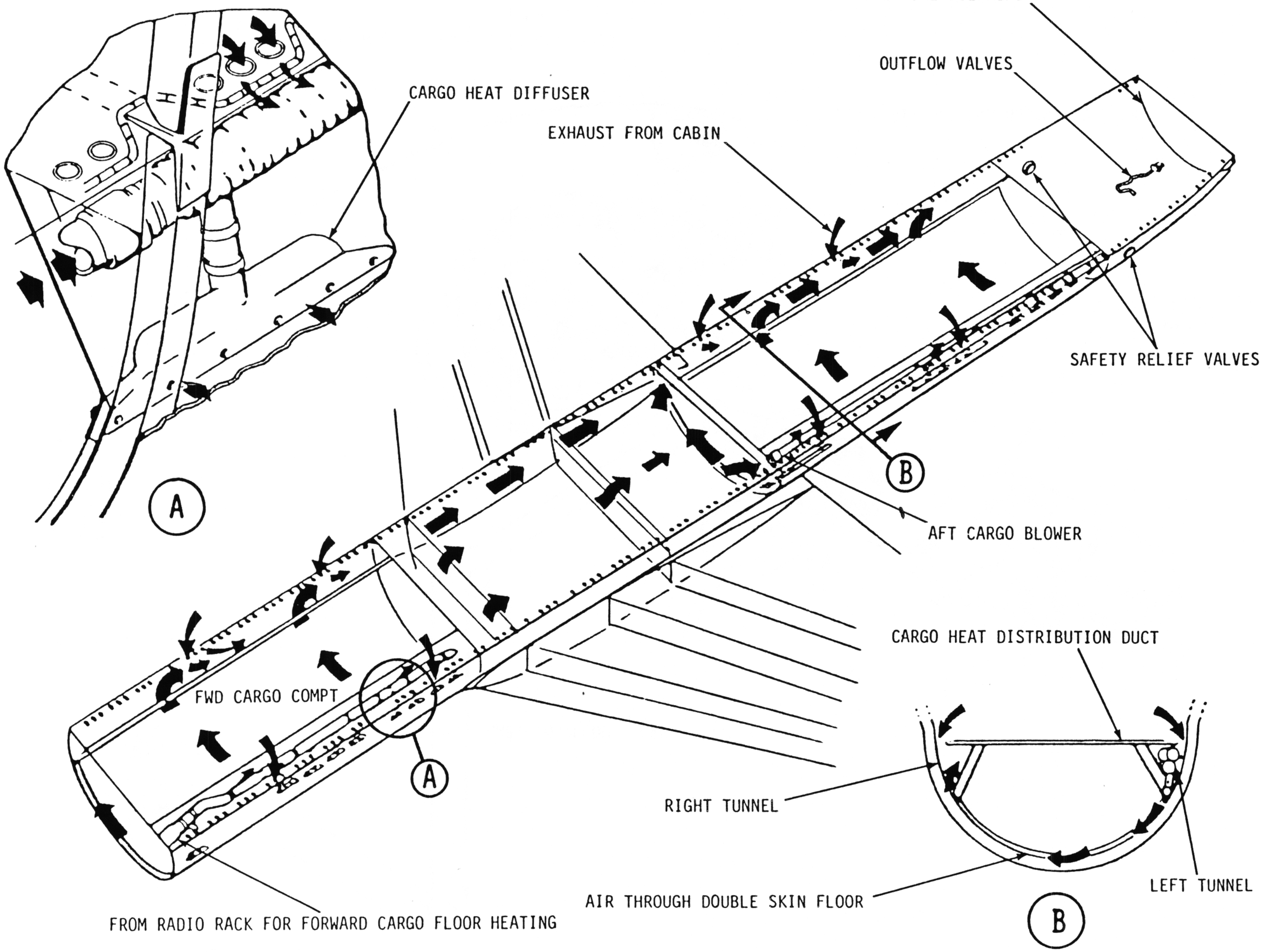


FIGURE 7-18. DC-8 CARGO HEATING

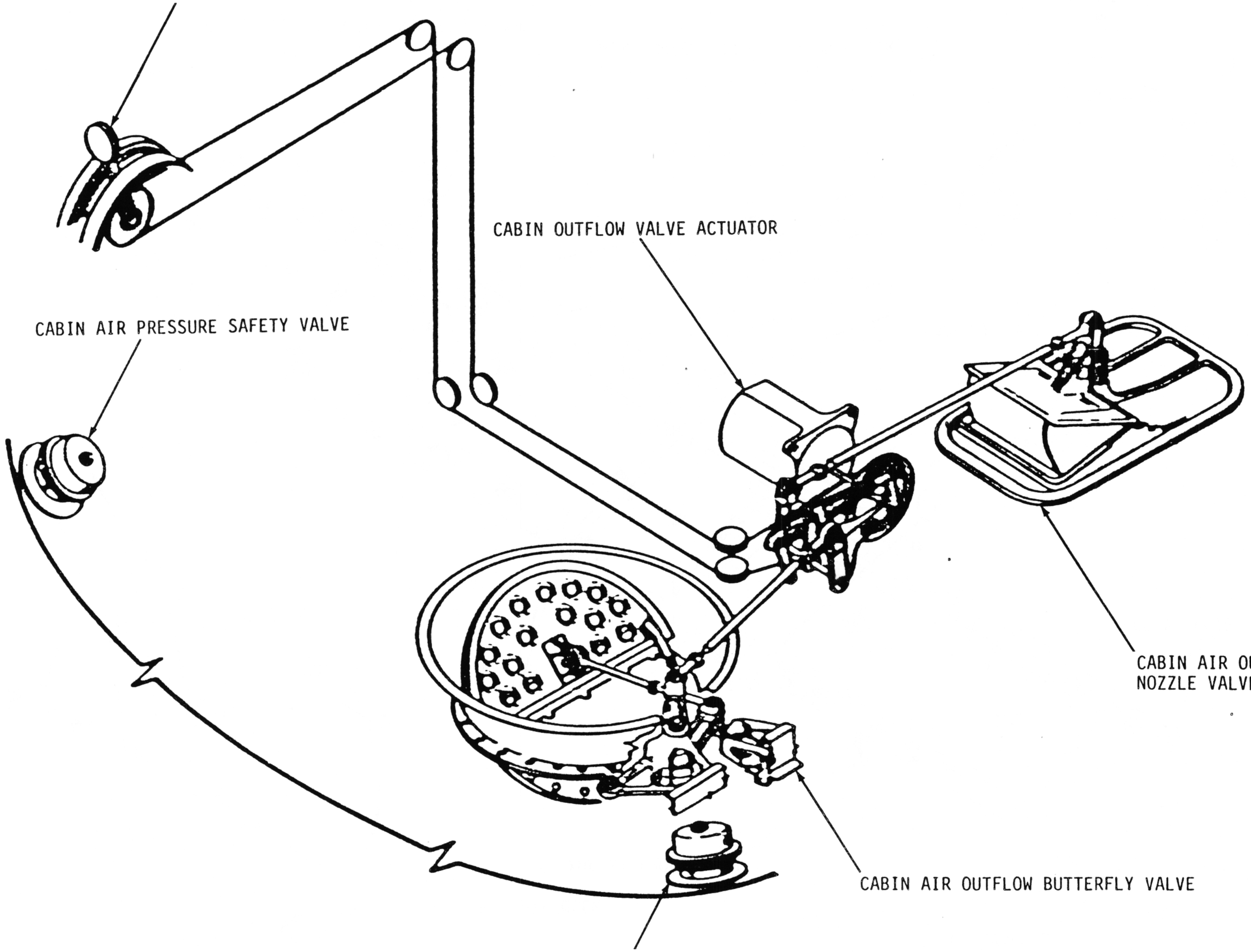


FIGURE 7-19. DC-8 PRESSURIZATION OUTFLOW VALVES

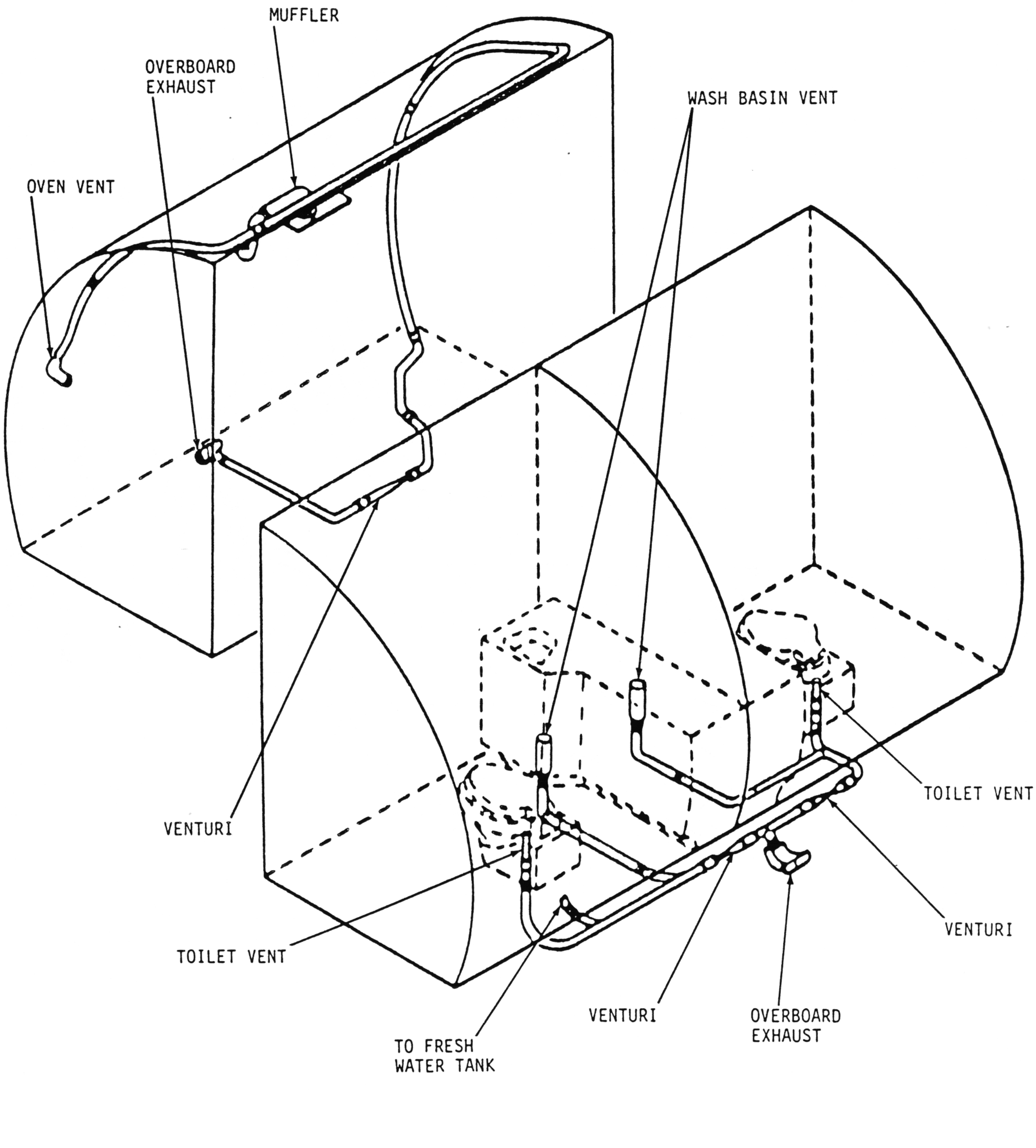


FIGURE 7-20. DC-8 FORWARD LAVATORY AND GALLEY VENTING

DC-8

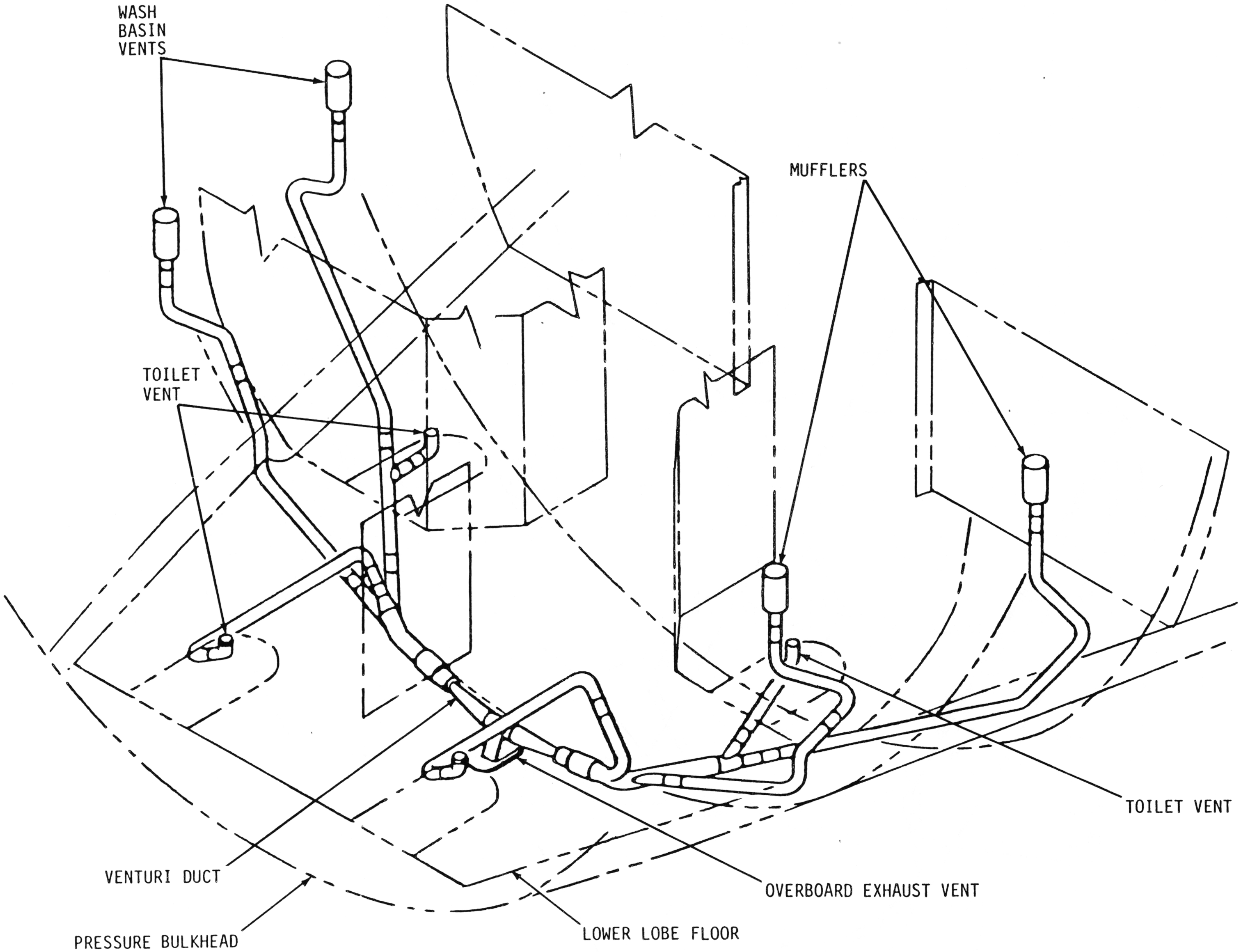


FIGURE 7-21. DC-8 AFT LAVATORY AND GALLEY VENTING

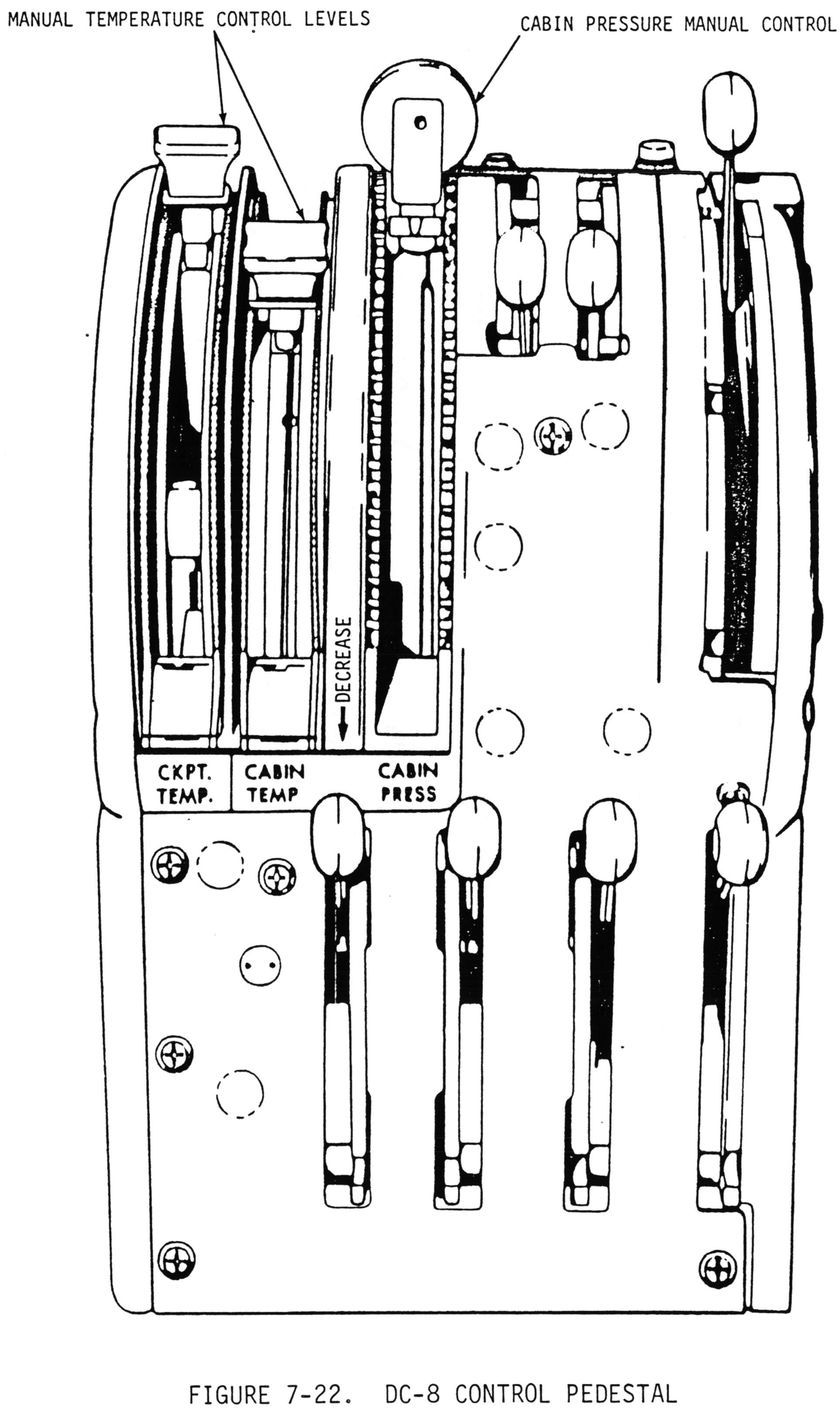
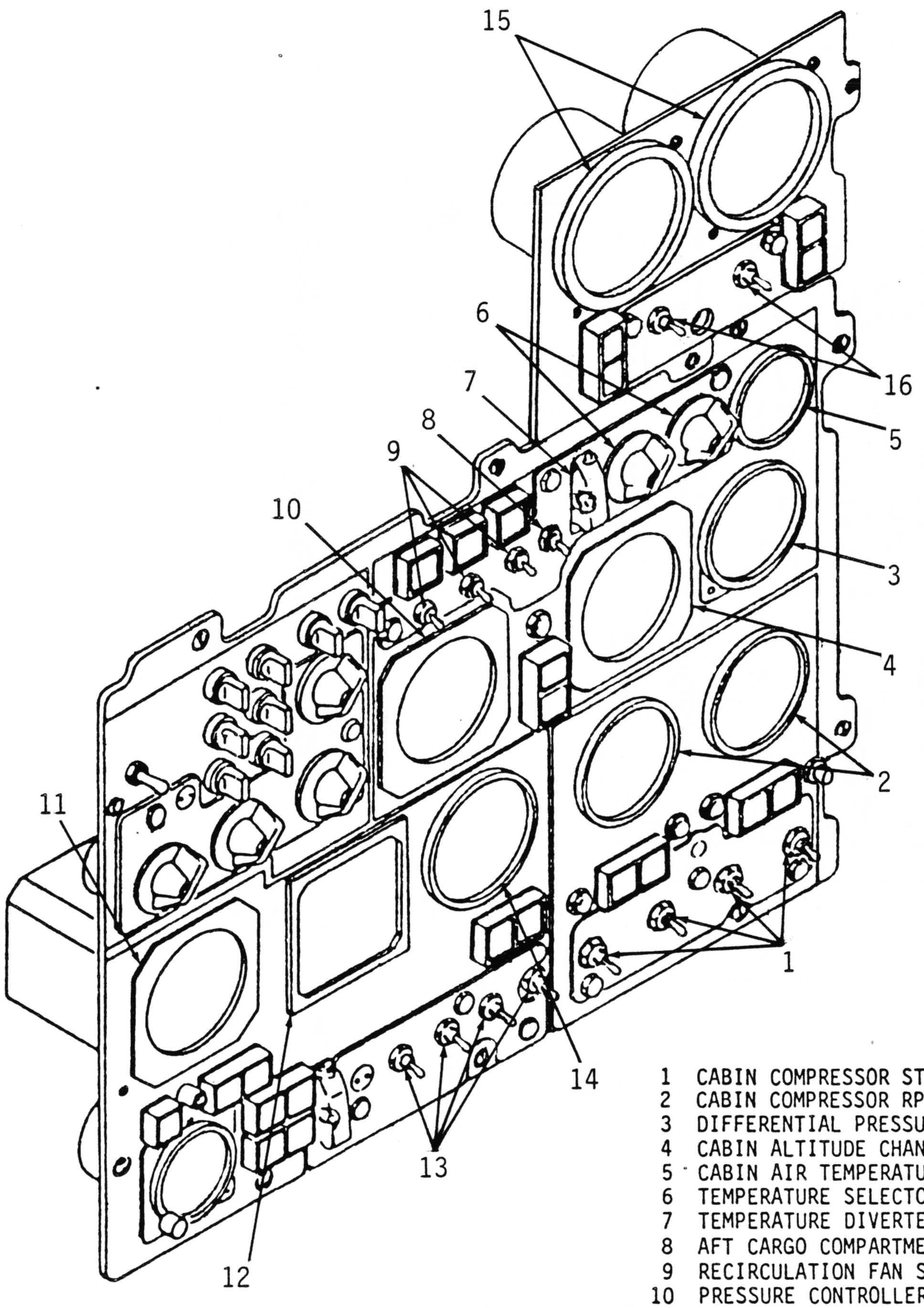


FIGURE 7-22. DC-8 CONTROL PEDESTAL



1 CABIN COMPRESSOR START SWITCHES (4)
2 CABIN COMPRESSOR RPM GAUGES
3 DIFFERENTIAL PRESSURE GAUGE
4 CABIN ALTITUDE CHANGE RATE GAUGE
5 CABIN AIR TEMPERATURE GAUGE
6 TEMPERATURE SELECTOR KNOBS
7 TEMPERATURE DIVERTER VALVE
8 AFT CARGO COMPARTMENT BLOWER SWITCH
9 RECIRCULATION FAN SWITCHES
10 PRESSURE CONTROLLER
11 PNEUMATIC SYSTEM PRESSURE GAUGE
12 STATIC AIR TEMPERATURE GAUGE
13 BLEED AIR SWITCHES (4)
14 PNEUMATIC SYSTEM TEMPERATURE GAUGE
15 FREON SATURATION/SUPERHEAT TEMPERATURE GAUGE
16 FREON COMPRESSOR START SWITCHES

FIGURE 7-23. DC-8 VAPOR CYCLE CONTROL PANEL

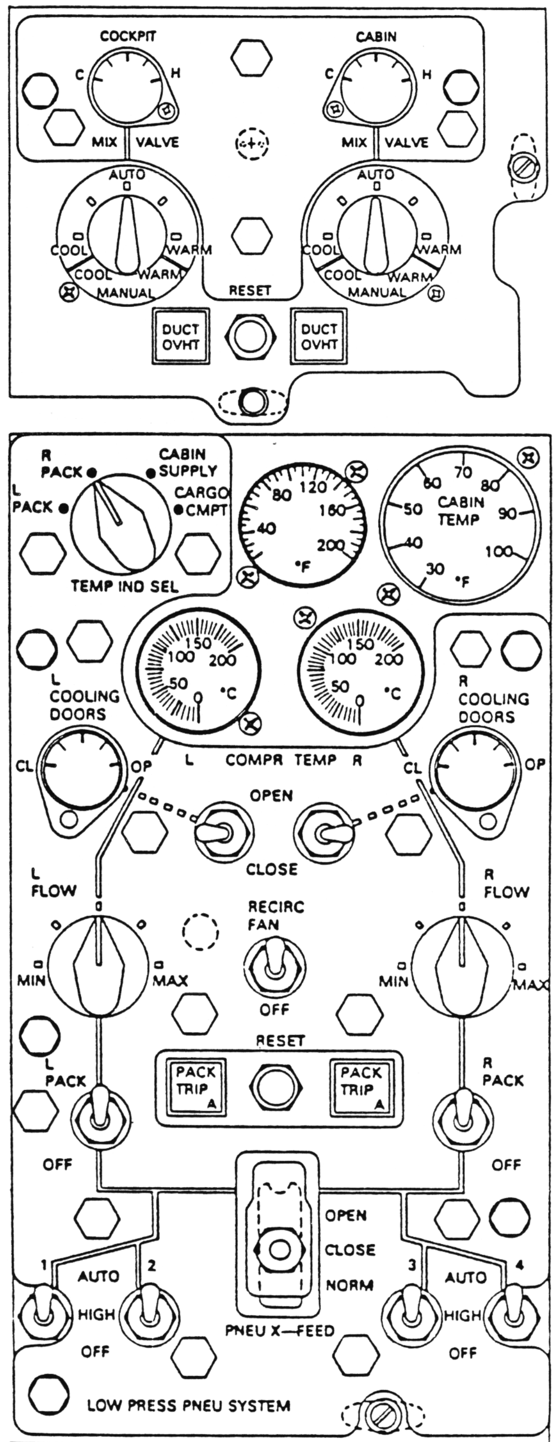


FIGURE 7-24. DC-8-70 AIR CYCLE SYSTEM CONTROLS

SECTION 8

DOUGLAS DC-9

Model Variation

The DC-9 was introduced in the mid-sixties as a short-to-medium range competitor to the 727. The series was initiated with the -10 version and was put into service by Texas International on 9-30-66. The series has been expanded to provide models suited to different markets, and to incorporate advancements in commercial jet transport technology. A summary of model production including certification dates and approximate number produced is shown in Table 8-1.

As the series progressed from the -10 through the -83 models, the trend has been toward increasing payload by stretching the fuselage and increasing engine thrust. As the fuselage length was extended, the capacity of the air-conditioning systems was increased. The series was fitted with three different systems varying in flow capacity. The basic system was used on -10 and -20 models, an increased flow system was used on -30, -40 and -50 models, and the highest flow system was used on -81, -82 and -83 models. In addition, the -80 models are fitted with recirculation capabilities. The configuration and location of the ducting is the same for all models, differing only, in the length of the overhead, sidewall dispersing, and gasper supply ducting.

The DC-9 has evolved to allow it to fit many different market segments, and it continues to do so with the introduction of the MD-83 and the pending launch of the MD-87. Currently, it is available in three versions - the MD-81, -82 and -83. At this writing, the -83 has not completed the certification process and, therefore, has not been included in this study.

DC-9 Environmental Control System (ECS)

The DC-9 ECS is a two pack air cycle system that uses engine bleed-air as the air source. A block diagram of the system is shown in Figure 8-1. The air-conditioning packs are located in the unpressurized tail cone area, just aft of the aft-pressure bulkhead. The air-conditioning packs use engine bleed-air from the 8th and 13th engine compressor stages of both engines. During ground operations, a ground cart or the APU may be used as a hot air source. The hot bleed-air pressure is regulated by the pneumatic system before being supplied to the pack flow-control and shut-off valve. A schematic of the pack is shown in Figure 8-2.

The flow-control valve regulates the amount of bleed-air flowing through the system to minimize variation in volumetric flow. After leaving the flow-control valve, the bleed-air is routed to the temperature diverter valve and the primary heat exchanger. The diverter valve controls the amount of air that bypasses the cooling pack. The bypass air is mixed with cold air leaving the pack to form conditioned air at the temperature demanded by the temperature control system. Air routed to the cooling pack is cooled in the primary heat exchanger by ram air. The air is then compressed to higher temperature and pressure in the air cycle machine (ACM) compressor. After leaving the compressor, the air is cooled in the secondary heat exchanger by ram air, then routed to the ACM turbine. Air expands in the ACM turbine to drive the compressor, and exits the turbine at low temperature. Entrained moisture is separated in the water separator, and the cold air then passes into the cold air distribution system and mixing chamber. Anti-icing controls regulate the turbine discharge temperature to 35 °F or above to prevent freezing in the water separator.

Air leaving the packs is routed to the cold air distribution ducting and the mixing manifold. The mixing manifold mixes cold air from the pack with warm air, that has bypassed the pack to form conditioned air, and divides and routes it to the proper compartment.

Pressures and temperatures at points A through E on Figure 8-2 are listed in Tables 8-2, 8-3 and 8-4.

Distribution

Air leaving the packs is routed to the mixing chamber where it is divided and routed to the proper compartments. The mixing chamber is designed so that air from the left pack supplies the flight deck and part of the passenger cabin, and the right pack supplies the passenger cabin only. One pack can supply both cabins if necessary. The distribution system is shown in Figure 8-3.

The passenger cabin distribution system consists of an overhead duct located above the ceiling panels that runs the length of the passenger cabin. The overhead duct has droppers spaced approximately every 76 inches. The droppers supply dispersing ducts located below the stowage compartments, above the sidewall. The dispersing ducts exhaust air into the cabin through a grill at the top of the sidewall.

The flight deck distribution system is shown in Figure 8-4. The flight deck air outlets are supplied from the mixing chamber by a 4-inch duct that is located above the ceiling, to the left side of the overhead duct. The supply duct supplies three outlets in the overhead at the back of the flight deck, and two outlets on each side console.

A cross-section of the passenger cabin showing the arrangement of the ducting systems is shown in Figure 8-5.

Airflow rates entering the compartments are shown in Tables 8-5, 8-6 and 8-7. Air change rates are shown in Table 8-8 through 8-12 and compartment volumes are shown in Table 8-13.

Airflow patterns are shown in Figure 8-6.

Individual (Gasper) Air

In addition to conditioned air, the passenger also has a separate supply of cold air available. The gasper air system is supplied from the water separator outlet and, therefore, the air is somewhat cooler than air supplied to the air conditioning system. The gasper distribution ducts are shown in Figure 8-7.

The gasper system supply ducts are located above the ceiling in the aft cabin, and feed distribution ducts located behind the stowage compartment on each side of the cabin. The distribution ducts run the length of the cabin, and supply outlets located below the stowage compartments. The gasper outlets are ball-and-socket type, adjustable for flow and direction.

The flight deck gasper system is supplied from the left-hand passenger gasper distribution duct. The supply duct runs up to above the ceiling panel and forward to the flight deck overhead. The supply duct feeds two outlets above the pilot and co-pilot's seat. The flight deck gasper system is shown in Figure 8-4.

Equipment Cooling

The equipment cooling system provides cooling of instruments and radio equipment by drawing flight deck air through the instrument panels and radio racks. When the airplane is on the ground, airflow is driven by a fan. When the airplane is in flight, airflow is driven by differential presure or the radio rack fan, depending on mode selection. The equipment cooling system is shown in Figure 8-8.

The system consists of primary and standby systems. The primary system is located in the forward portion of the left utility tunnel and the standby system is located on the right side.

The radio rack cooling system is controlled by the radio rack fan switch. When the switch is in the venturi position and the airplane is on the ground, both fans operate and the venturi is closed. When the airplane takes off, the fans stop and flow through the radio rack discharge venturi is driven overboard by cabin pressure. When the venturi is in the closed position, airflow is approximately 5 pounds per minute, increasing to 20 pounds per minute when full open at full differential pressure.

When the switch is selected to fan, both fans operate when the airplane is on the ground, and the venturi valve is closed. At take-off, the standby fan ceases to operate and the primary fan continues to operate. In this mode, the fans exhaust air to the forward cargo compartment heating system. If the primary fan fails, the standby fan will automatically start. If the fan motor reaches 300 °F, the fan will stop.

Cargo Heating

The DC-9 cargo compartments are classified as FAR Part 25, Class D cargo compartments. As such, they are limited to 500 cubic feet volume and 1500 cubic feet per hour leakage rate. There are no provisions for directly venting the cargo compartments. Cargo heating is partially provided by exhausting passenger cabin air between the cargo lining and fuselage skin. Cargo heat provisions are shown in Figure 8-9. Cargo compartment volumes are listed in Table 8-12.

The forward cargo compartment is heated by air exhausted from the equipment cooling system as well as cabin exhaust. When the radio rack switch is in the fan position, the fan exhausts air to the forward cargo heat system. Air discharged from the radio rack is not warm enough to permit carrying live cargo in the forward compartment. When live cargo is carried in the forward compartment, the forward cargo heat system uses a thermostatically controlled electric heater to raise the temperature of the radio rack discharge air. The heater operates on 115-volt AC power and is rated at 3 kilowatts. An over-temperature thermostat prevents the heater elements from exceeding 400 °F. The compartment temperature is thermostatically controlled between 60 -75 °F. Air leaving the heater is distributed in the left utility tunnel by the cargo heat ducting, flows to the right between the skin and cargo lining, and flows aft in the right utility tunnel.

The mid cargo compartment (-80 models only) uses a fan to draw passenger cabin exhaust air into the duct system. The air passes through diffusers and circulates from the left utility tunnel, between the cargo lining and fuselage skin, to the right utility tunnel.

The aft cargo compartment is heated by passenger cabin exhaust only. As the airflows between the cargo lining and fuselage skin, the cargo compartment is warmed. Air is then exhausted through the pressurization outflow valves.

Recirculation Systems

The MD-80 re-circulation system consists of a fan, high efficiency filter, and ducting, that draws in passenger cabin exhaust air from the area below the floor and aft of the aft-cargo compartment, and return the air to the passenger cabin distribution system. The recirculation system is shown in Figure 8-10.

The recirculation fan is mounted below the floor just forward of the aft pressure bulkhead and operates on 115 volt 400-Hz three-phase power. The fan draws 7.5A per phase when operating. Recirculated air is routed to the passenger system overhead duct through 5-inch riser ducts. The air enters the overhead downstream of the mixing chamber so that the flight deck receives all fresh air. The recirculation fan does not operate on the ground, and comes on automatically three seconds after lift off. Recirculation fan operation can be terminated only by opening the appropriate circuit breakers.

Ventilation

Air is vented overboard by equipment cooling, galley and lavatory vents, and pressurization outflow valves.

The equipment cooling system vents air overboard through the radio rack venturi. Flow rate through the venturi is approximately 20 pounds per minute when open and 5-10 pounds per minute when closed. Position of the valve is controlled by a switch on the overhead panel.

The galley and lavatory vents exhaust air overboard through flow limiting nozzles. The galley outlets are placed in the ceiling panels to vent air from the top of the galley through an orifice located on the upper portion of the fuselage, and the toilet outlets are placed beneath the toilet shroud to vent air from the waste water tank through an orifice located on the lower portion of the fuselage. Flow through the vents is driven by cabin-to-ambient pressure differential, and is non-adjustable by the flight crew. On some airplanes, the flow can be reduced by the ground crew by adjusting a valve in the vent line. There are one or two galleys, and two or three lavatories carried on the DC-9, placed in the forward and aft cabin. The galley and lavatory vents are shown in Figure 8-11.

The pressurization outflow valves are the primary means of venting air overboard. The outflow valves respond to signals generated in the pressure controller, or can be manually controlled to regulate the amount of air passing through the valves.

The outflow valves are located on the lower aft left-hand fuselage, and consist of a butterfly type valve, a nozzle type valve, actuators for automatic control, and linkages and cables for manual control. On the ground, the valves are both driven full-open by a ground sensor to depressurize the cabin. As the airplane climbs, the automatic control system begins to close the butterfly valve while the nozzle valve remains wide open. The nozzle valve remains wide open until the butterfly valve is closed. The control system then modulates the nozzle valve as required to maintain cabin pressure. During manual control the valve position is controlled by a wheel on the control pedestal through a system of cables and linkages. The linkages provide the correct opening and closing sequencing. The outflow valves are shown in Figure 8-12.

Pressurization Control

The cabin pressure control system has three operating modes; primary, standby and manual. The primary and standby modes use identical cabin pressure controllers to control the outflow valves. The manual mode allows the crew to manually position the outflow valves. The pressure controls are shown in Figure 8-13. A schematic of the pressurization control system is shown in Figure 8-14.

The primary and standby systems operate identically, and transfer to the back-up is automatic if one controller fails. To use these modes, the crew selects a controller, sets the landing altitude, cabin altitude rate of change, and a barometric correction factor for landing field. The pressure controller then monitors and adjusts the outflow valves to maintain the lowest cabin altitude possible for the selected flight altitude, without exceeding maximum allowable pressure differential or comfort limits.

The manual control consists of a system of cables and linkages that control the outflow valve position from a thumb wheel on the center control pedestal. To engauge the manual control, the automatic system is disengauged by moving the selector lever to manual. The cabin altitude and differential pressure must be monitored by the crew to keep the cabin conditions within safe limits. Position of the valve is indicated on the control pedestal.

Environmental Control system (ECS) Controls

The ECS controls are shown in Figure 8-13. The controls include switches to control pack operation, bleed-air source, compartment temperature, equipment cooling, and ram air.

The pack operation switches have two modes; high-pressure bleed off, and auto mode. Switching these switches on to high-pressure bleed off starts the air conditioning packs, but prevents 13th stage bleed-air from being used. The auto position allows the augmentation valve to supplement 8th stage bleed-air with 13th stage air when the 8th stage cannot supply all needs.

Compartment temperature can be thermostatically or manually controlled. The cockpit temperature control sets supply temperature of the left pack, and the cabin temperature control controls the right pack. When the knobs are in the upper portion of their range, compartment temperature is thermostatically controlled to the selected temperature. The lower portion of the range is for manual control. Manual control signals the temperature control valves to either open or close in response to the crew's signals. The compartment temperature must be monitored on the appropriate gauge.

The equipment cooling mode is selected by the radio rack switch. The venturi position causes air to be dumped overboard through the radio rack venturi while in flight. The fan position routes radio rack discharge air to the forward cargo heat ducting regardless of flight regime.

The ram-air switch controls a valve mounted on the right ram-air heat exchanger cooling duct. Selecting the valve to open allows ram air from the duct to enter the distribution ducting. The valve is for use only during unpressurized flight.

Gauges are provided to monitor bleed-air supply pressure, temperature control valve position and compartment temperature.

Electrical energy requirements for the ECS components and control systems are shown in Tables 8-14, 8-15 and 8-16.

TABLE 8-1. DC-9 PRODUCTION DATA

SERIES	FIRST FLIGHT (REF 17)	CERTIFICATION (REF 23)	PRODUCED (REF 3)
DC-9-10	2-25-65	11-23-65	137
-20	9-18-68	11-25-68	10
-30	8-01-66	12-19-66	662
-40	11-28-67	2-21-68	71
-50	12-17-74	8-11-75	98
MD-81	10-18-79	8-25-80	192 (MD-81 and -82 combined)
-82	1-8-81	7-29-81	
-83	12-17-84	—	11 ORDERED

TABLE 8-2. DC-9-10,-20 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(°F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	38	600	33	600	14.9	58	14.7	60	14.7	58	14.7	75	14.7	103
5,000 FT CLIMB	35	503	32	503	15	57	14.7	58	14.7	56	14.7	75	12.2	84
10,000 FT CLIMB	33	490	29	490	15	60	14.7	61	14.7	60	14.7	75	10.1	64
25,000 FT CRUISE	28	445	25	445	13.2	54	12.9	55	12.9	56	12.9	75	5.5	7
30,000 FT CRUISE	27	430	24	430	12.1	60	11.8	60	11.8	60	11.8	75	4.4	-13
35,000 FT CRUISE	DATA NOT AVAILABLE													
43,000 FT CRUISE	DATA NOT AVAILABLE													
23,000 FT DESCENT	24	380	23	380	11.2	53	10.9	54	10.9	54	10.9	75	6.0	12
15,000 FT DESCENT	26	395	26	395	14.9	51	14.7	52	14.7	52	14.7	75	8.3	46

MAXIMUM SUPPLY TEMP 130°F

MINIMUM SUPPLY TEMP 35°F

TABLE 8-3. DC-9-30,-40,-50 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(° F DRY BULB AND PSIA)

FLIGHT REGIME	A FLOW CONTROL VALVE INLET		B FLOW CONTROL VALVE OUTLET		C WATER SEPARATOR OUTLET		D FLIGHT DECK SUPPLY		E PASS. CABIN SUPPLY		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	42	600	41	600	14.8	47	14.7	50	14.7	47	14.7	75	14.7	103
5,000 FT CLIMB	39	503	37	503	15.2	58	14.7	59	14.7	58	14.7	75	12.2	84
10,000 FT CLIMB	37	490	34	490	15.2	62	14.7	62	14.7	61	14.7	75	10.1	64
25,000 FT CRUISE	32	445	30	445	13.4	56	12.9	57	12.9	55	12.9	75	5.5	7
30,000 FT CRUISE	30	430	28	430	12.4	60	11.8	60	11.8	59	11.8	75	4.4	-13
35,000 FT CRUISE	22	380	21	380	11.3	61	10.9	60	10.9	58	10.9	75	3.5	-30
43,000 FT CRUISE	DATA NOT AVAILABLE													
23,000 FT DESCENT	24	380	23	380	11.2	50	10.9	51	10.9	48	10.9	75	6.0	12
15,000 FT DESCENT	26	395	26	395	14.9	53	14.7	54	14.7	53	14.7	75	8.3	46

MAXIMUM SUPPLY TEMP 130°F

MINIMUM SUPPLY TEMP 35°F

TABLE 8-4. MD-81,-82 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(°F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	42	580	40	580	15.4	57	14.7	59	14.7	56	14.7	75	14.7	103
5,000 FT CLIMB	39	486	39	486	15.4	49	14.7	50	14.7	49	14.7	75	12.2	84
10,000 FT CLIMB	37	584	32	584	14.5	73	13.8	78	13.8	78	13.8	75	10.1	64
25,000 FT CRUISE	25	445	25	445	13.0	50	12.7	54	12.7	54	12.7	75	5.5	6
30,000 FT CRUISE	31	454	31	454	12.6	58	12.0	60	12.0	62	12.0	75	4.4	-12
35,000 FT CRUISE	29	460	28	460	11.7	61	10.9	61	10.9	59	10.9	75	3.5	-30
37,000 FT CRUISE	23	527	23	527	11.3	66	10.9	68	10.9	69	10.9	75	3.2	-37
25,000 FT DESCENT	23	353	23	353	12.8	49	12.6	54	12.6	56	12.6	75	5.5	6
15,000 FT DESCENT	26	339	26	339	13.9	40	13.6	43	13.6	50	13.6	75	8.3	45

MAXIMUM SUPPLY TEMP 130°F
MINIMUM SUPPLY TEMP 35°F

TABLE 8-5. DC-9-10,-20 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN/PACK)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	%RECIRC	TOTAL (CFM)	%RECIRC
SEA LEVEL TAKEOFF	57	1,266	NOT APPLICABLE	183	NOT APPLICABLE
5,000 FT CLIMB	58	1,332		192	
10,000 FT CLIMB	57	1,305		188	
25,000 FT CRUISE	54	1,411		202	
30,000 FT CRUISE	53	1,523		218	
35,000 FT CRUISE	DATA NOT AVAILABLE				
43,000 FT CRUISE					
23,000 FT DESCENT	51	1,577		225	
15,000 FT DESCENT	51	1,186		168	

TABLE 8-6. DC-9-30,-40,-50 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN/PACK)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	%RECIRC	TOTAL (CFM)	%RECIRC
SEA LEVEL TAKEOFF	45	971	NOT APPLICABLE	140	NOT APPLICABLE
5,000 FT CLIMB	77	1,775		254	
10,000 FT CLIMB	75	1,744		250	
25,000 FT CRUISE	72	1,894		271	
30,000 FT CRUISE	70	1,995		286	
35,000 FT CRUISE	57	1,769		254	
43,000 FT CRUISE	DATA NOT AVAILABLE				
23,000 FT DESCENT	51	1,590		229	
15,000 FT DESCENT	51	1,189		170	

TABLE 8-7. MD-81,-82 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN/PACK)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	76	1,698	0	242	0
5,000 FT CLIMB	77	2,372	28	250	0
10,000 FT CLIMB	72	2,459	26	262	0
25,000 FT CRUISE	43	1,892	43	184	0
30,000 FT CRUISE	69	2,575	22	223	0
35,000 FT CRUISE	65	2,638	24	288	0
37,000 FT CRUISE	45	2,024	32	197	0
25,000 FT DESCENT	41	1,883	42	157	0
15,000 FT DESCENT	43	1,868	44	151	0

TABLE 8-8. DC-9-10,-20 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	22.0	42.7
5,000 FT CLIMB	23.2	44.8
10,000 FT CLIMB	22.7	43.9
25,000 FT CRUISE	24.5	47.1
30,000 FT CRUISE	26.5	50.9
35,000 FT CRUISE	N/A*	N/A*
43,000 FT CRUISE	N/A*	N/A*
23,000 FT DESCENT	27.4	52.5
15,000 FT DESCENT	20.6	39.2

* NOT AVAILABLE

TABLE 8-9. DC-9-30 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	13.3	32.7
5,000 FT CLIMB	24.3	59.3
10,000 FT CLIMB	23.8	58.4
25,000 FT CRUISE	25.9	63.3
30,000 FT CRUISE	27.3	66.8
35,000 FT CRUISE	24.2	59.3
43,000 FT CRUISE	N/A*	N/A*
23,000 FT DESCENT	21.7	53.5
15,000 FT DESCENT	16.2	39.7

* NOT AVAILABLE

TABLE 8-10. DC-9-40 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	12.2	32.7
5,000 FT CLIMB	22.2	59.3
10,000 FT CLIMB	21.8	58.4
25,000 FT CRUISE	23.7	63.3
30,000 FT CRUISE	25.0	66.8
35,000 FT CRUISE	22.1	59.3
43,000 FT CRUISE	N/A*	N/A*
23,000 FT DESCENT	19.9	53.5
15,000 FT DESCENT	14.9	39.7

* NOT AVAILABLE

TABLE 8-11. DC-9-50 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	11.1	32.7
5,000 FT CLIMB	20.4	59.3
10,000 FT CLIMB	20.0	58.4
25,000 FT CRUISE	21.8	63.3
30,000 FT CRUISE	22.9	66.8
35,000 FT CRUISE	20.3	59.3
43,000 FT CRUISE	N/A*	N/A*
23,000 FT DESCENT	18.3	53.5
15,000 FT DESCENT	13.7	39.7

* NOT AVAILABLE

TABLE 8-12. MD-81,-82 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	16.7	16.7	56.5
5,000 FT CLIMB	16.7	23.3	58.4
10,000 FT CLIMB	17.9	24.2	61.2
25,000 FT CRUISE	10.6	18.6	42.9
30,000 FT CRUISE	19.7	25.3	52.1
35,000 FT CRUISE	19.7	25.9	67.2
37,000 FT CRUISE	13.5	19.9	46.0
25,000 FT DESCENT	10.7	18.5	36.7
15,000 FT DESCENT	10.3	18.4	35.3

TABLE 8-13. VENTILATION PARAMETERS

VOLUMES	DC9-10,-20	-30	-40	-50	-81,-82
TOTAL PRESSURIZED (CU FT)					
PASSENGER CABIN	3,449	4,391	4,792	5,224	6,107
CONTROL CABIN	257	257	257	257	257
FORWARD CARGO	373	562	624	577	464
MID CARGO	-	-	-	-	346
AFT CARGO	277	333	395	457	443

PRESSURIZATION CAPABILITIES	-10 THRU -50	-81,-82
MAX Δ P (PSI)		
CONTROLLER LIMITED	7.46	7.77
SAFETY VALVE LIMITED	7.96	8.27

CABIN ALTITUDE CHANGE RATES (FT/MIN)			CLIMB	DESCENT
CONTROLLER SELECTED	MIN	50	100	43
	MAX	900	2,000	857

TABLE 8-14. DC-9-10,-20 AC ELECTRICAL ENERGY REQUIREMENTS (REF 24)

EQUIPMENT	POWER REQD	LOAD WATTS	LOAD VARS	SOURCE
Cockpit Temp Control	115V 400 Hz 1Ø	2	1	AC Left ØC
Radio Rack Blower	200V 400 Hz 3Ø	780	688	AC Left
Radio Rack Cooling Valve	115V 400 Hz 1Ø	51	25	AC Left ØC
Left Heat Exchanger Cooling Fan	200V 400 Hz 3Ø	9,025	5,836	AC Left
Left Temp Control Valve	115V 400 Hz 1Ø	103	50	AC Left ØC
Radio Rack Blower Relay	115V 400 Hz 1Ø	23	0	AC Left ØC
L Heat Exchange Fan Relay	115V 400 Hz 1Ø	21	0	AC Left ØC
Left Temp Control Valve Motor	115V 400 Hz 1Ø	103	50	Emergency AC ØA
Right Temp Control Valve Motor	115V 400 Hz 1Ø	103	50	Emergency AC ØA
Pressure Controller	115V 400 Hz 1Ø	13	6	AC Right ØB
Cabin Temp Control	115V 400 Hz 1Ø	2	1	AC Right ØA
Cockpit Temp Control	115V 400 Hz 1Ø	2	1	AC Right ØA
R Heat Exchange Cooling Fan	200V 400 Hz 3Ø	9,025	5,830	AC Right
Ram Air Valve	115V 400 Hz 1Ø	103	50	AC Right ØC
Cabin Outflow Valve	115V 400 Hz 1Ø	140	105	AC Right ØB
R Temp Control Valve	115V 400 Hz 1Ø	103	50	AC Right ØA
R Heat Exchange Cooling Fan Relay	115V 400 Hz 1Ø	21	0	AC Right ØC

TABLE 8-15. MD-81,-82 AC ELECTRICAL ENERGY REQUIREMENTS (REF 25)

EQUIPMENT	POWER REQD	LOAD WATTS	LOAD VARS	SOURCE
Left Temp Control Valve	115V 400 Hz 1Ø	103	50	Emergency AC ØA
Right Temp Control Valve	115V 400 Hz 1Ø	103	50	Emergency AC ØA
Cockpit Temp Limit Relay	115V 400 Hz 1Ø	5	0	Emergency AC ØA
Cockpit Temp Control Relay	115V 400 Hz 1Ø	2	1	AC Left ØA
Cabin Pressure Controller	115V 400 Hz 1Ø	57	0	AC Left ØB
Radio Rack Fan	200V 400 Hz 3Ø	780	688	AC Left
Radio Rack Cooling Valve	115V 400 Hz 1Ø	51	25	AC Left ØC
L Heat Exchanger Cooling Fan	200V 400 Hz 3Ø	9,025	5,830	AC Left
Cabin Air Outflow Valve	115V 400 Hz 1Ø	131	63	AC Left ØB
Instrument Cooling Fan	115V 400 Hz 1Ø	60	34	AC Left ØA
Cockpit Temp Control	115V 400 Hz 1Ø	103	50	AC Left ØA
Mid Cargo Fan	200V 400 Hz 3Ø	7,810	688	AC Left
L Ram Air Exhaust Actuator	115V 400 Hz 1Ø	98	61	AC Left ØB
Radio Rack Fan Relay	115V 400 Hz 1Ø	23	0	AC Left ØA
Radio Rack Fan Control	115V 400 Hz 1Ø	8	0	AC Left ØA
Radio Rack Standby Fan Relay	115V 400 Hz 1Ø	23	0	AC Left ØA
Radio Rack Pressure Relay	115V 400 Hz 1Ø	23	0	AC Left ØA
Ram Air Exhaust Actuator Relay	115V 400 Hz 1Ø	8	0	AC Left ØB
L Heat Exchange Cooling Fan Relay	115V 400 Hz 1Ø	21	0	AC Left ØB
Cabin Temp Control	115V 400 Hz 1Ø	2	1	AC Right ØA
Cabin Pressure Controller #2	115V 400 Hz 1Ø	57	0	AC Right ØB
Fwd Cargo Heater	200V 400 Hz 3Ø	3,000	0	AC Right
Right Heat Exchange Cooling Fan	200V 400 Hz 3Ø	9,025	5,830	AC Right
Ram Air Valve Motor	115V 400 Hz 1Ø	103	50	AC Right ØC
Outflow Valve Actuator	115V 400 Hz 1Ø	131	63	AC Right ØB
Cabin Temp Control Motor	115V 400 Hz 1Ø	103	50	AC Right ØA
Standby Radio Rack Fan	200V 400 Hz 3Ø	780	688	AC Right
Recirc Fan	200V 400 Hz 3Ø	1,400	868	AC Right
R Heat Exchange Cooling Fan Relay	115V 400 Hz 1Ø	21	0	AC Right ØB
Fwd Cargo Heater Relay	115V 400 Hz 1Ø	23	0	AC Right ØC
Recirc Fan Relay	115V 400 Hz 1Ø	23	0	AC Right ØB
Recirc Fan Thermostat	115V 400 Hz 1Ø	8	0	AC Right ØB
Recirc Fan Lockout	115V 400 Hz 1Ø	9	0	AC Right ØB

TABLE 8-16. MD-81,-82 DC ELECTRICAL ENERGY REQUIREMENTS (REF 26)

EQUIPMENT	POWER REQD	LOAD	SOURCE
R A/C Press Reg Valve, Solenoid	28 VDC	.6 A	Emergency
L A/C Press Reg Valve, Solenoid	28 VDC	.6 A	Emergency
L A/C Flow Control Valve, Solenoid	28 VDC	.6 A	Emergency
R A/C Flow Control Valve, Solenoid	28 VDC	.6 A	Emergency
Cabin Pressure Controller #1	28 VDC	.2 A	DC Left
Cabin Pressure Selector	28 VDC	.16 A	DC Left
Cabin Air Outflow Valve Actuator	28 VDC	2.00 A	DC Left
Left Auto A/C Shutoff Relay	28 VDC	.30 A	DC Left
Right Auto A/C Shutoff Relay	28 VDC	.30 A	DC Left
Cabin Pressure Transfer Relay	28 VDC	.16 A	DC Left
Radio Rack Low Pressure Relay	28 VDC	.16 A	DC Left
Left High Press Augmentation Valve Relay	28 VDC	1.00 A	DC Left
Right A/C Turbine Nozzle Solenoid	28 VDC	1.00 A	DC Transfer
Left A/C Turbine Nozzle Solenoid	28 VDC	1.00 A	DC Transfer
Cabin Pressure Controller #2	28 VDC	.2 A	DC Right
A/C Temp Indicator	28 VDC	.05 A	DC Right
Right High Press Augmentation Valve Solenoid	28 VDC	1.00 A	DC Right
Left High Press Augmentation Valve Solenoid	28 VDC	1.00 A	DC Right
R Water Separator Anti-ice Valve Solenoid	28 VDC	1.00 A	DC Right
L Water Separator Anti-ice Valve Solenoid	28 VDC	1.00 A	DC Right

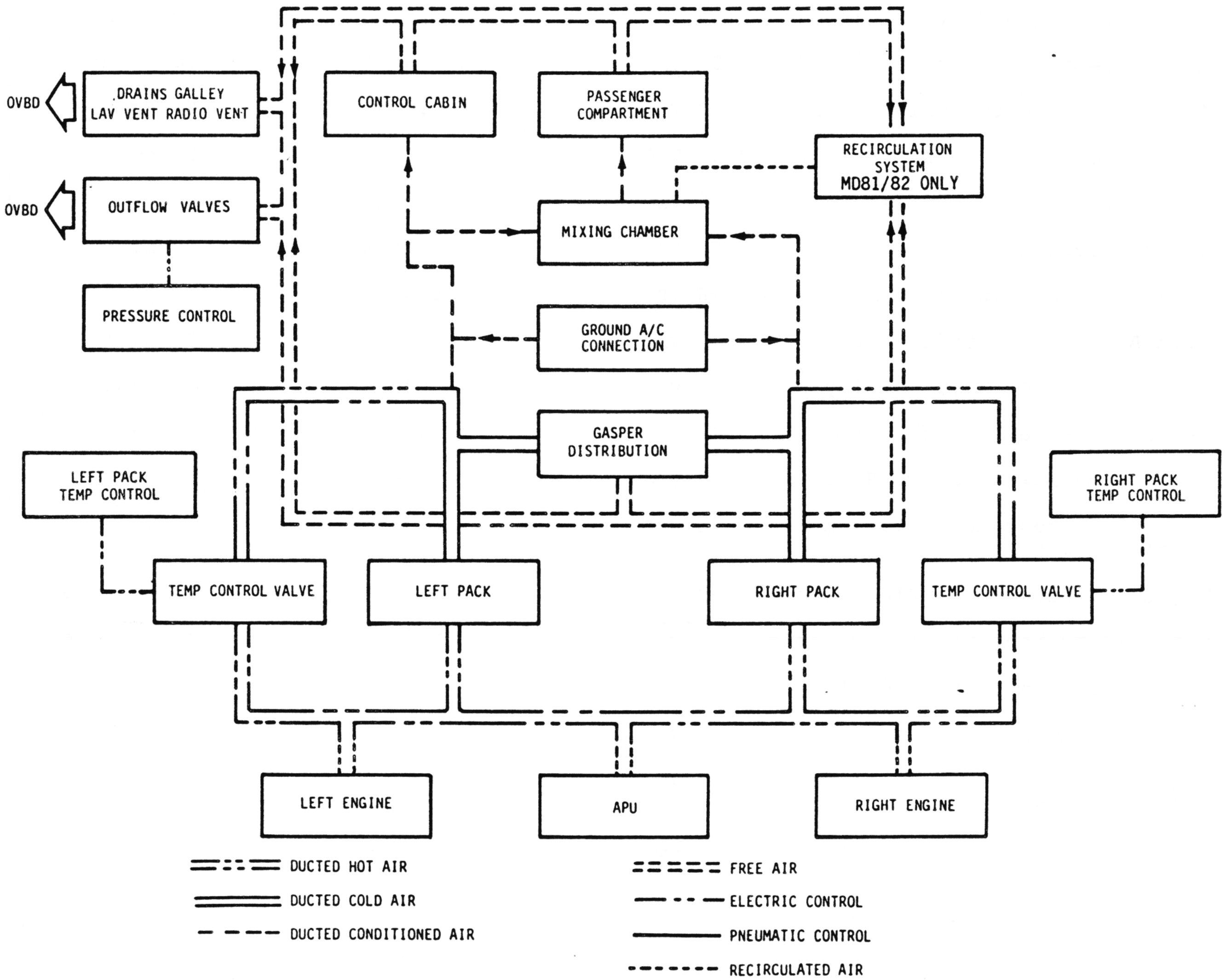


FIGURE 8-1. DC-9 AIR CONDITIONING SYSTEM BLOCK DIAGRAM

DC-9

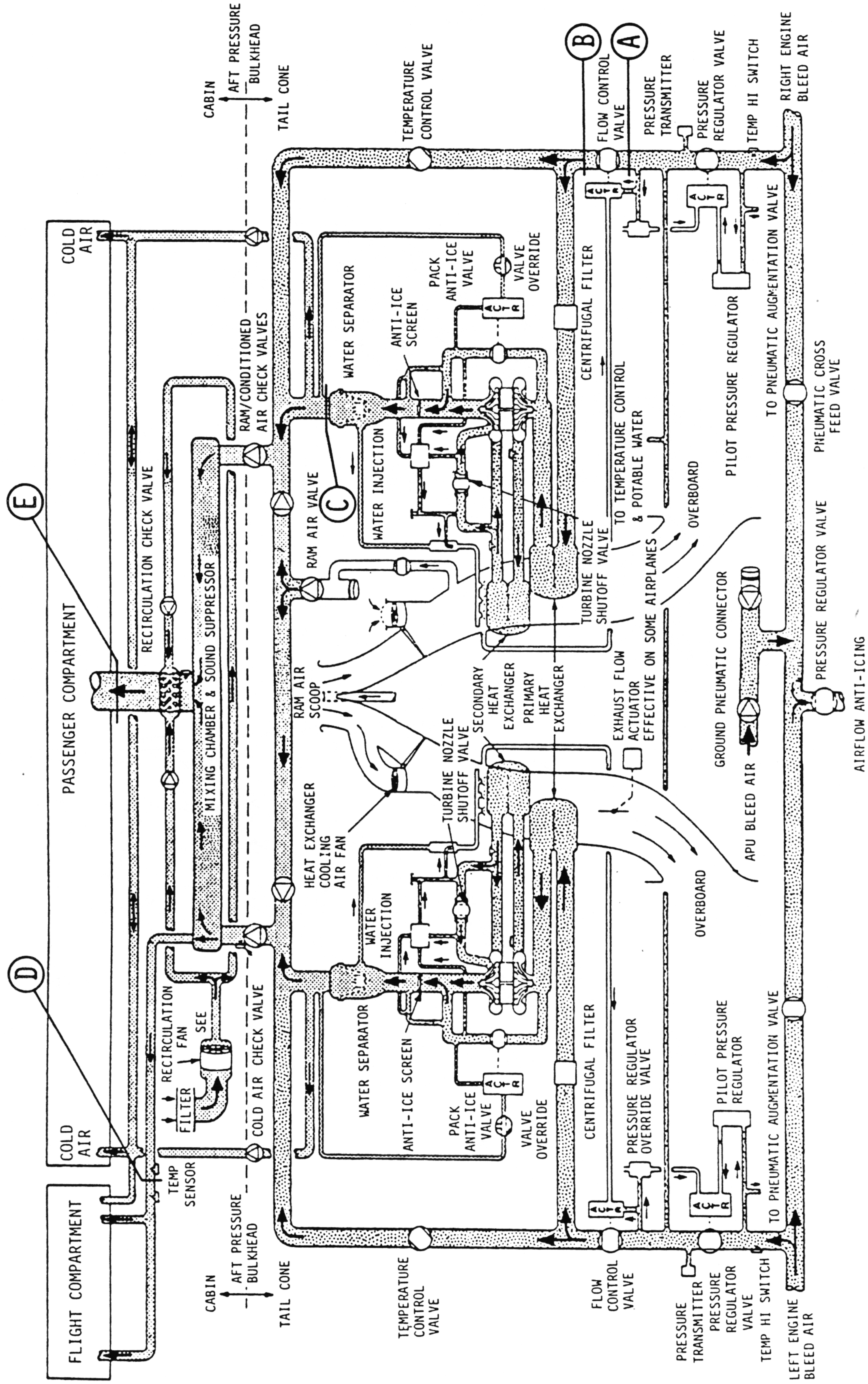


FIGURE 8-2. DC-9 AIR CONDITIONING PACK SCHEMATIC

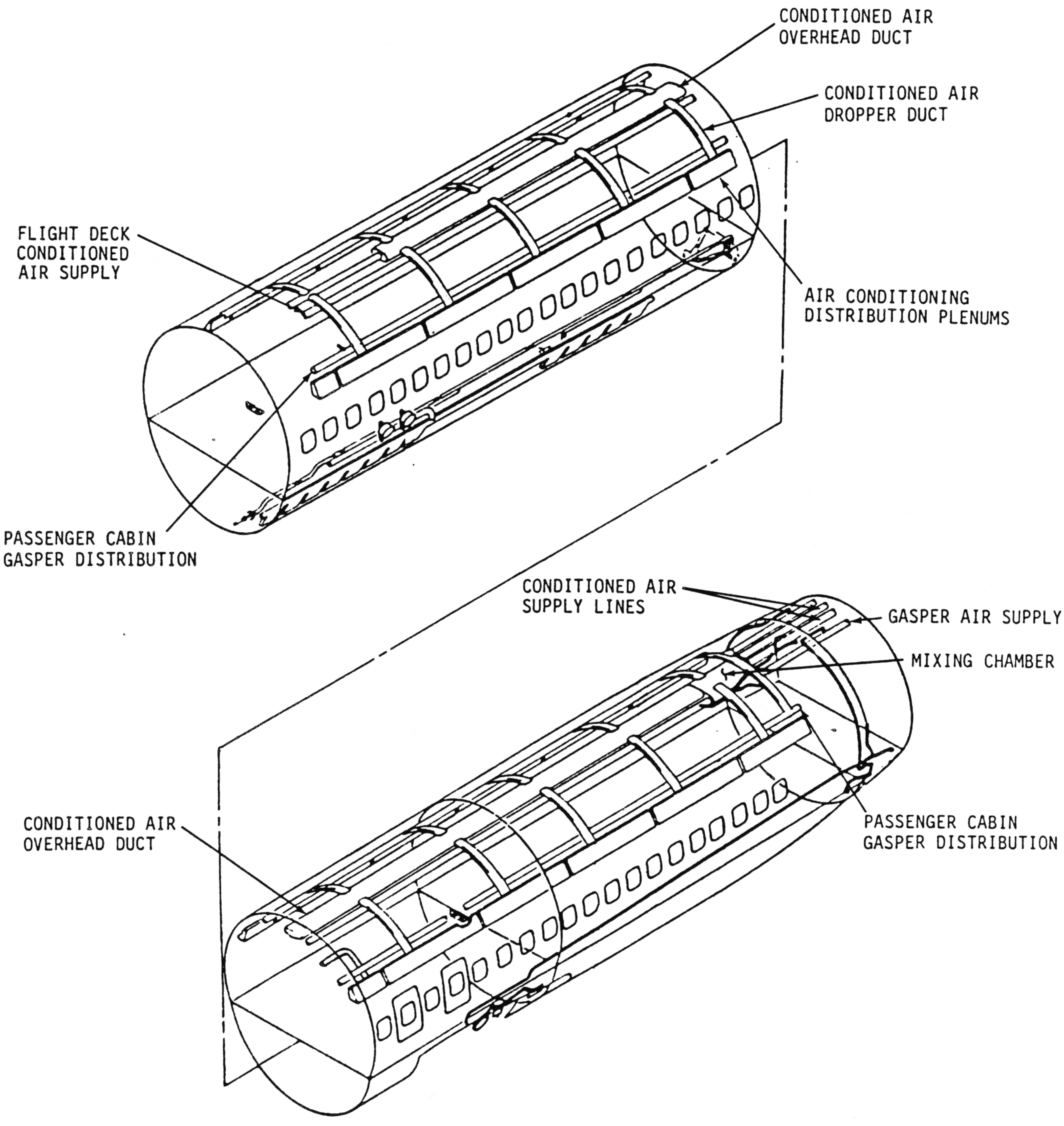


FIGURE 8-3. DC-9 PASSENGER CABIN DISTRIBUTION SYSTEM

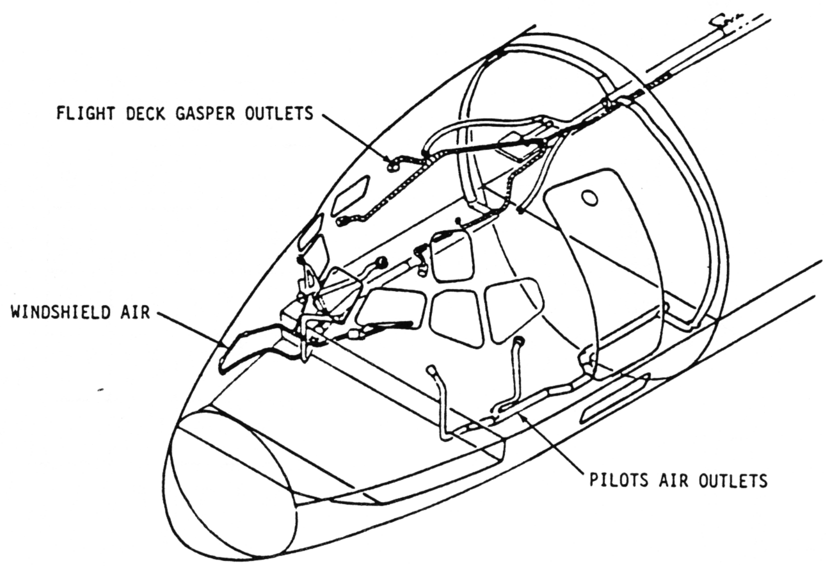


FIGURE 8-4. DC-9 FLIGHT DECK AIR DISTRIBUTION

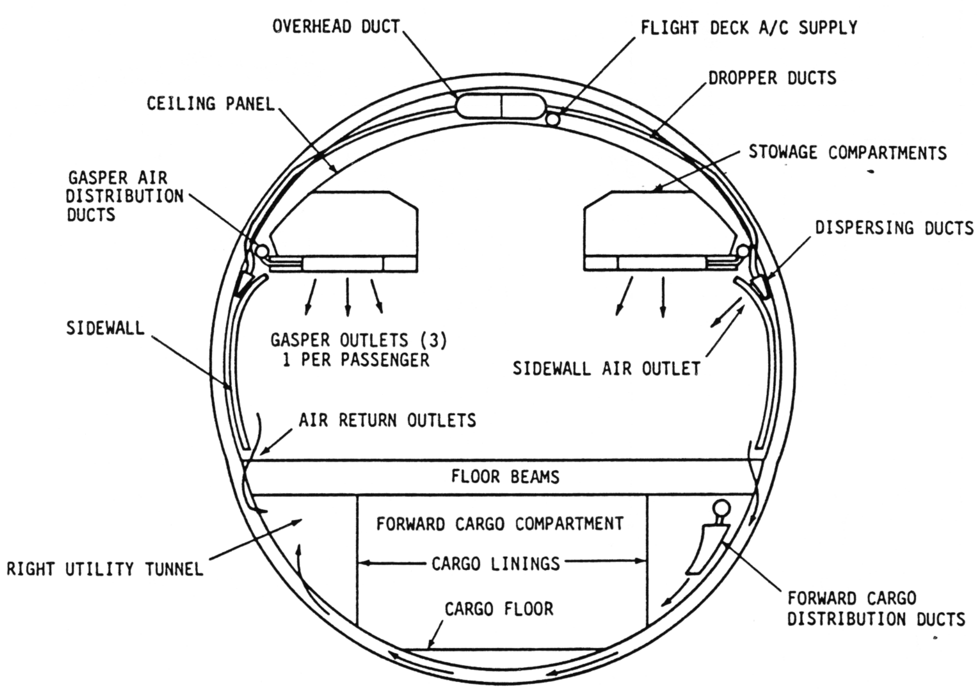
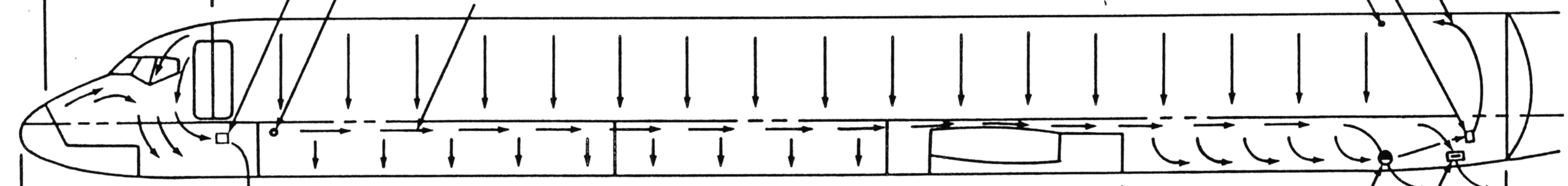
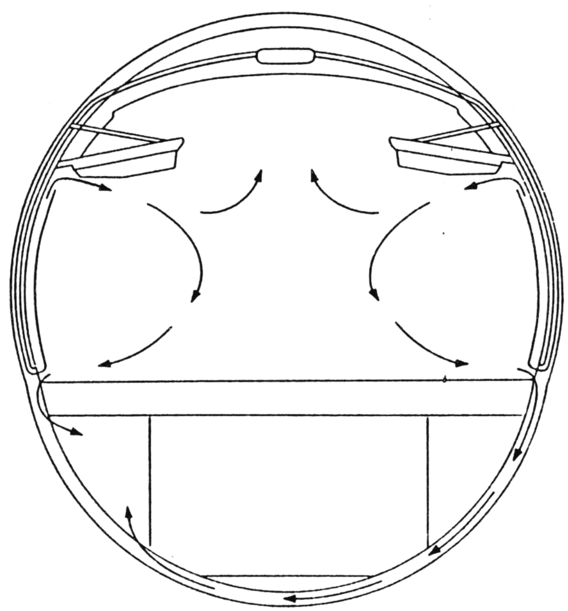


FIGURE 8-5. DC-9 PASSENGER CABIN CROSS SECTION

DC-9





DC-9-10		-20	-30	-40	-50	-80
*A	STA 198	STA 198	STA 229	STA 229	STA 229	STA 218
*B	STA 484	STA 484	STA 598	STA 636	STA 693	STA 807
*C	STA 491	STA 491	STA 606	STA 644	STA 701	STA 811
*D	STA 642	STA 642	STA 760	STA 798	STA 851	STA 1003
*E	STA 817	STA 817	STA 996	STA 1072	STA 1167	STA 1338

FIGURE 8-6. DC-9 PASSENGER CABIN AIR FLOW PATTERNS

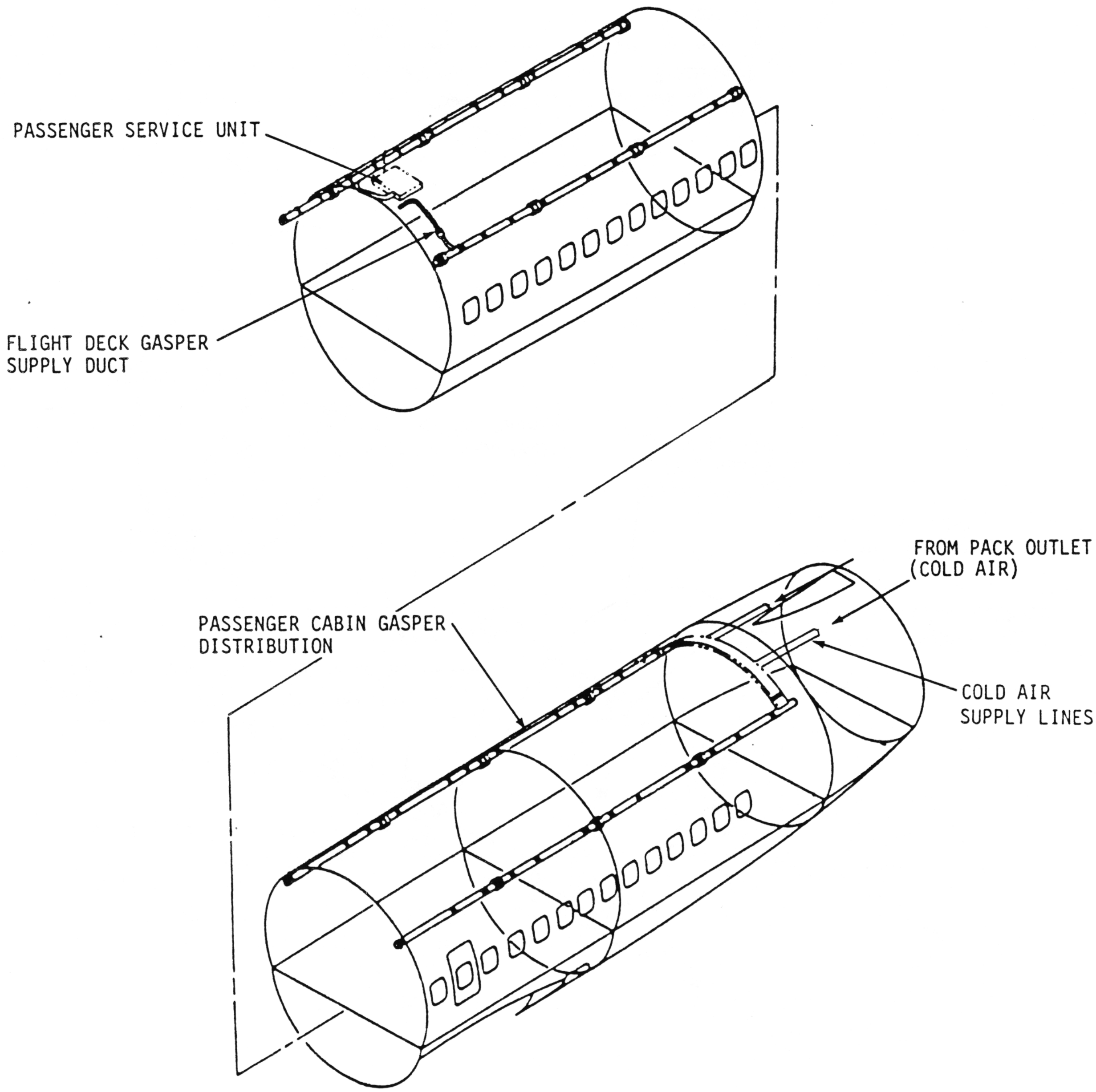


FIGURE 8-7. DC-9 PASSENGER CABIN GASPER AIR DISTRIBUTION DUCTING

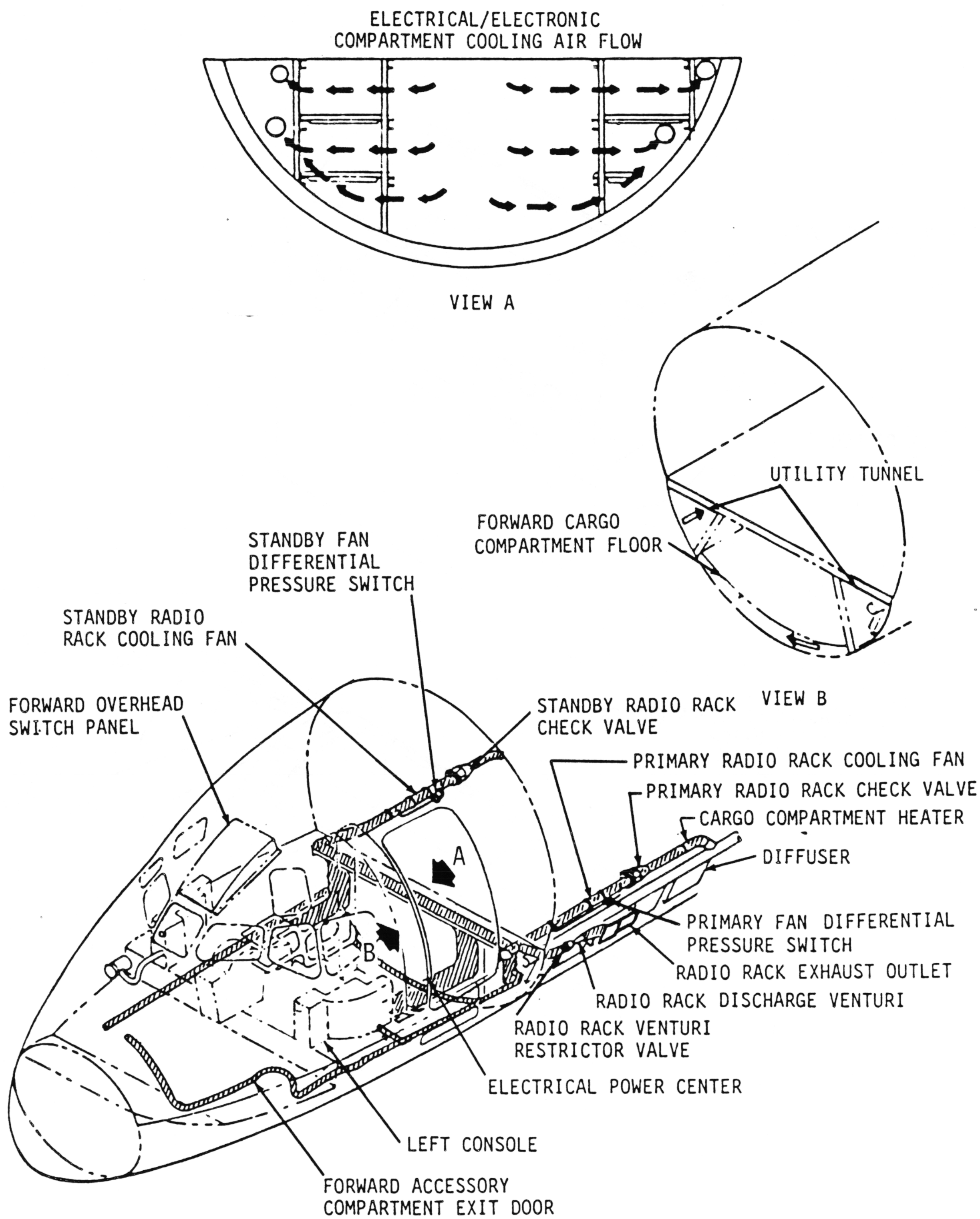


FIGURE 8-8. DC-9 EQUIPMENT COOLING SYSTEM

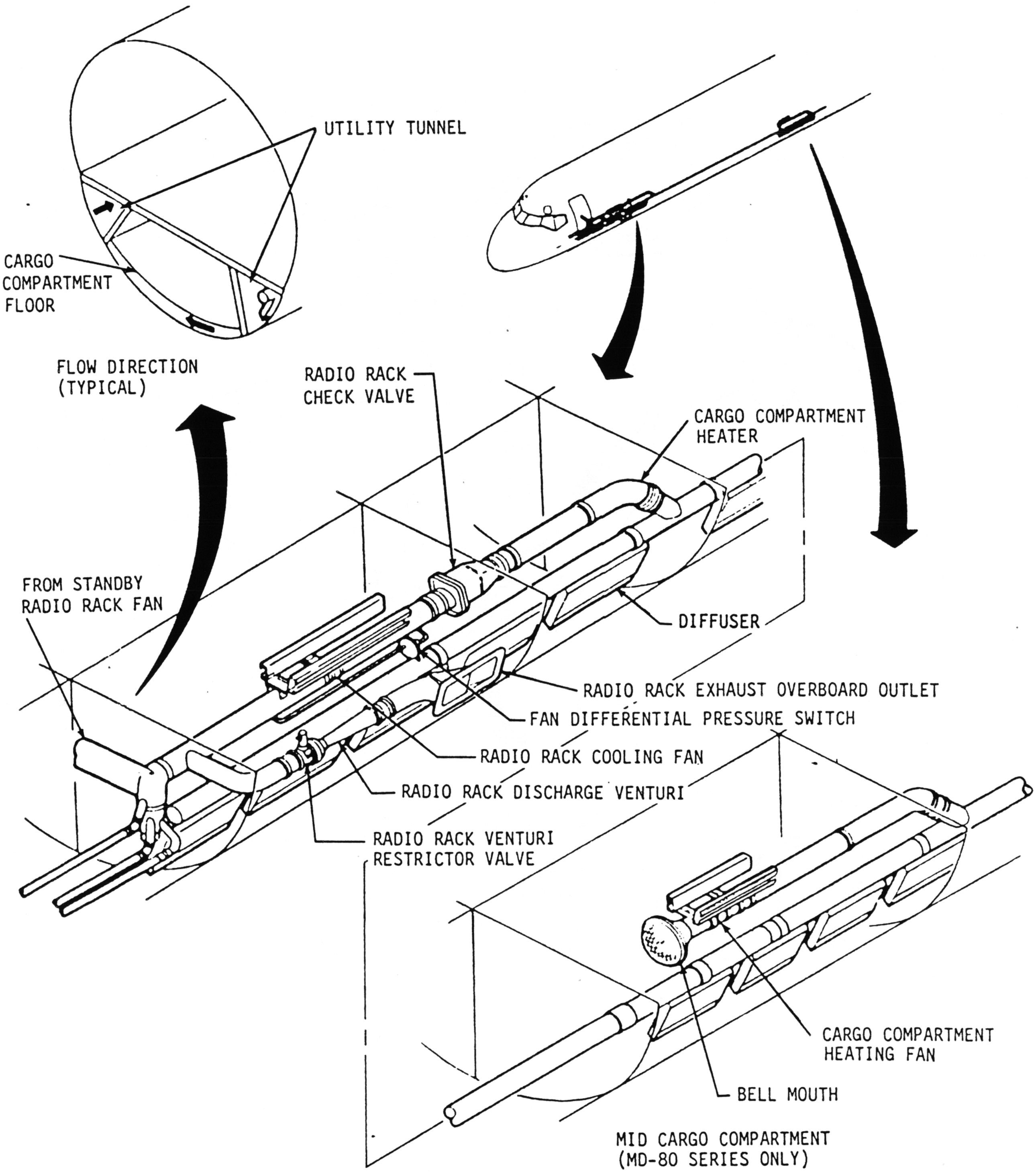


FIGURE 8-9. DC-9 CARGO HEATING SYSTEM

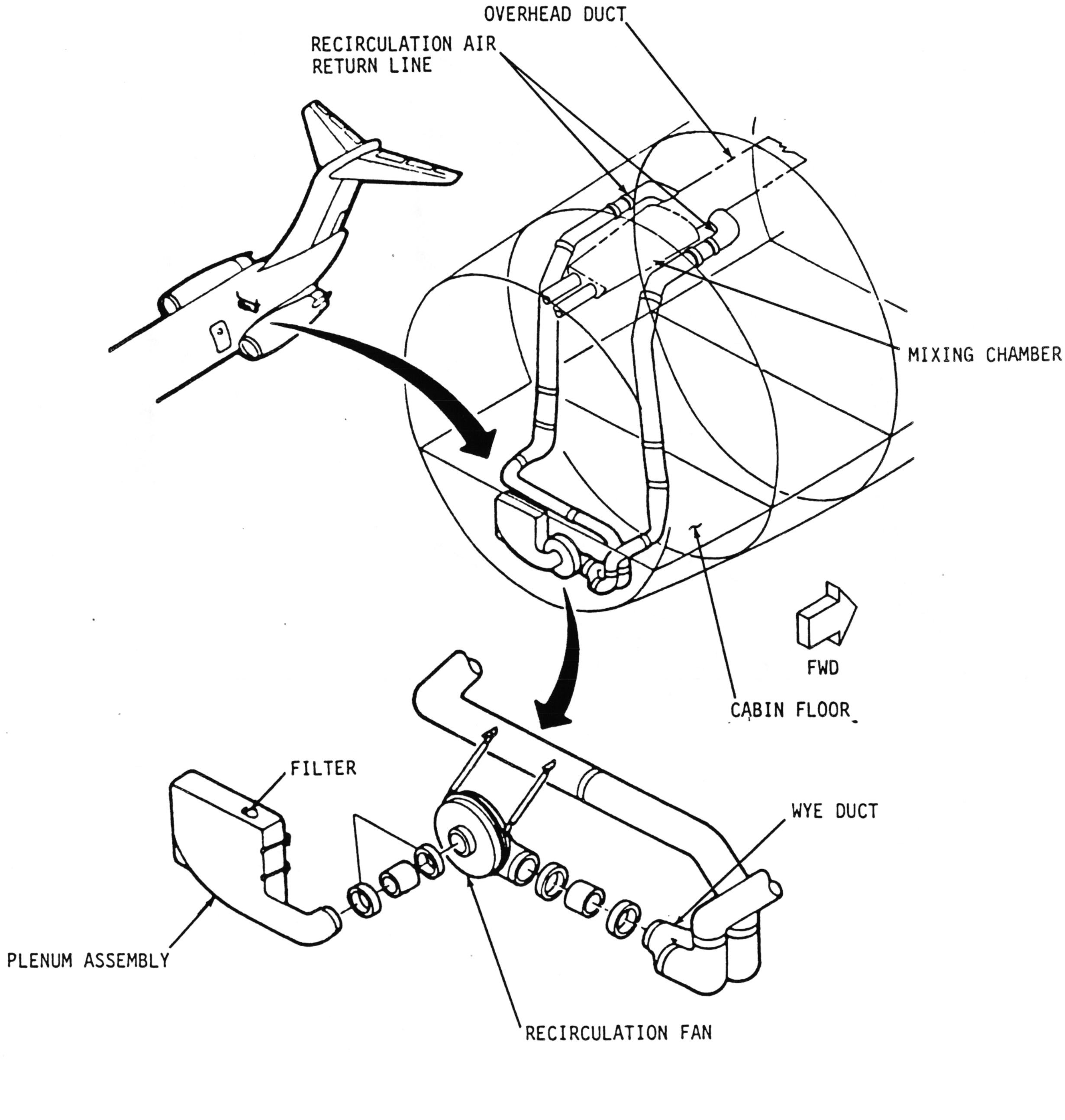


FIGURE 8-10. DC-9, MD-80'S RECIRCULATION SYSTEM

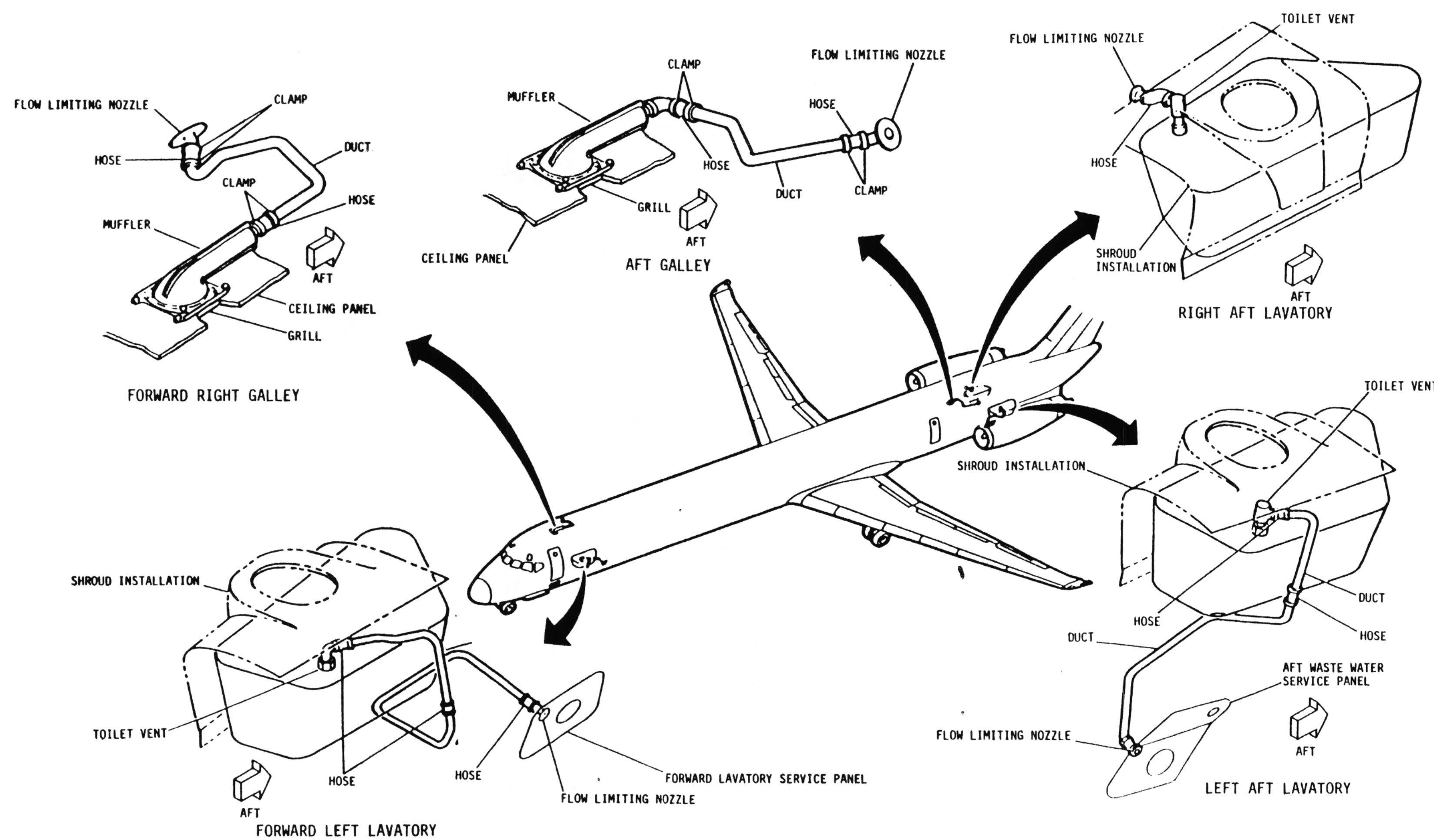


FIGURE 8-11. DC-9 LAVATORY AND GALLEY VENTING

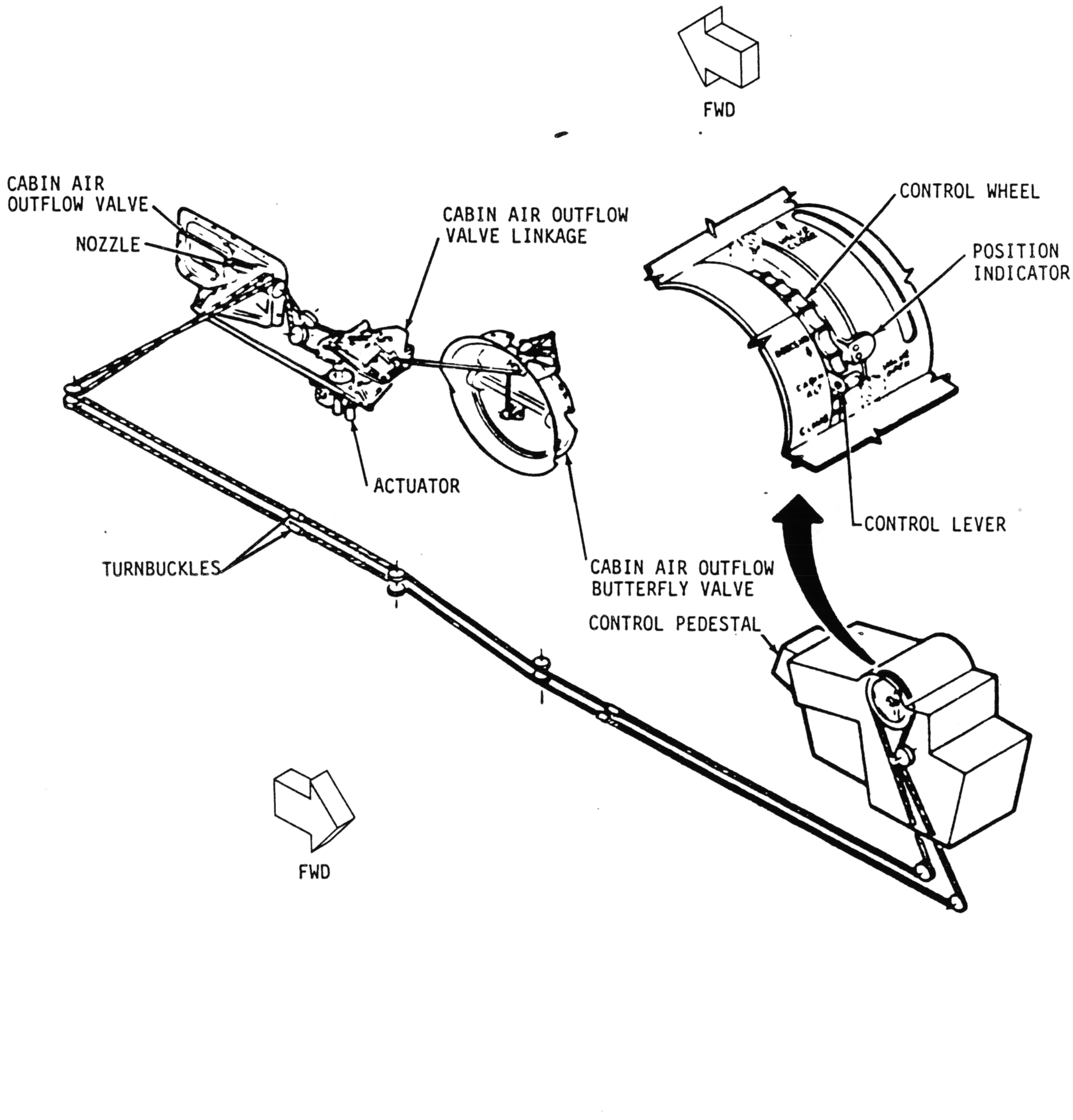


FIGURE 8-12. DC-9 PRESSURIZATION OUTFLOW VALVES

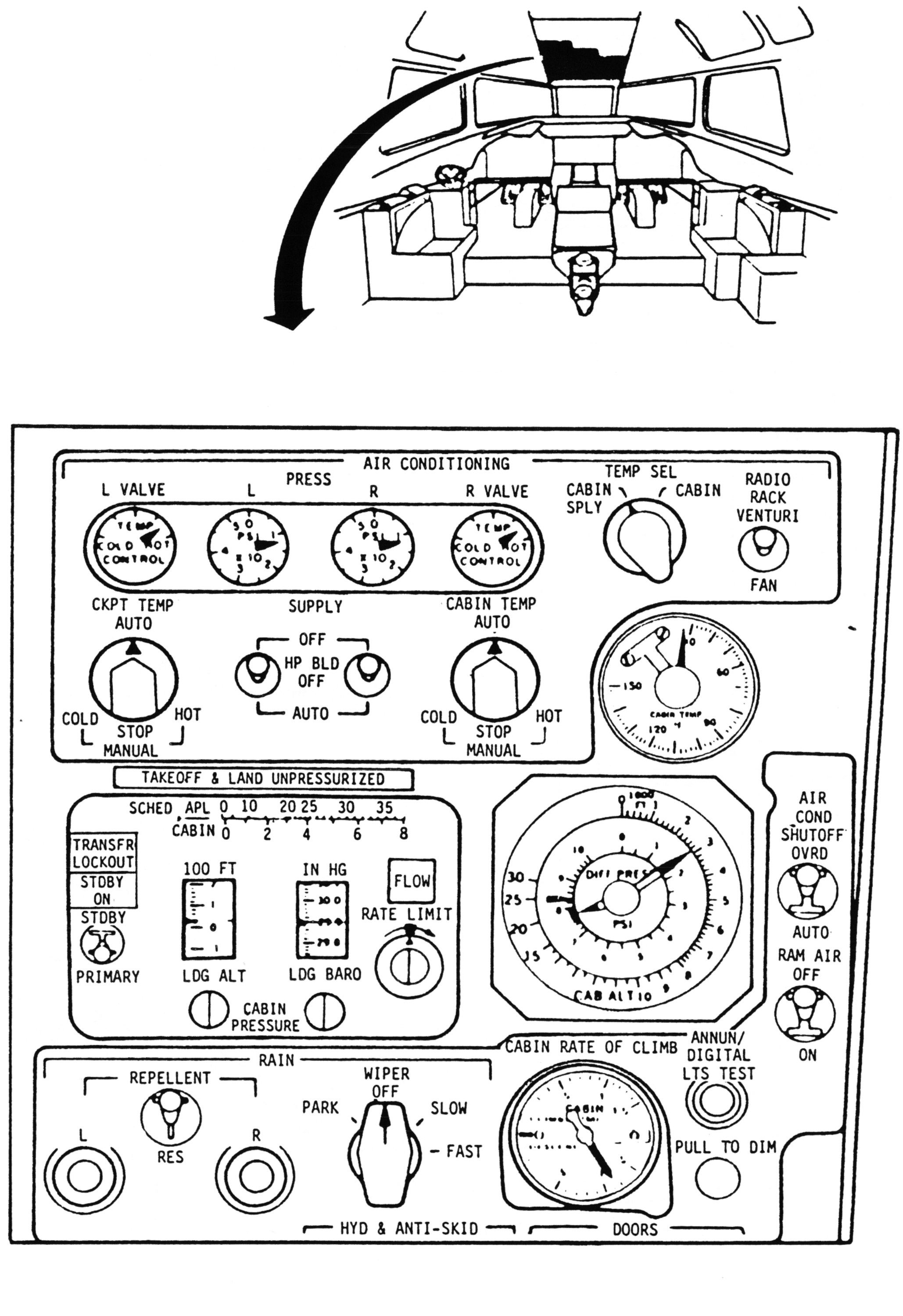


FIGURE 8-13. DC-9 ECS AND PRESSURIZATION CONTROLS

DC-9

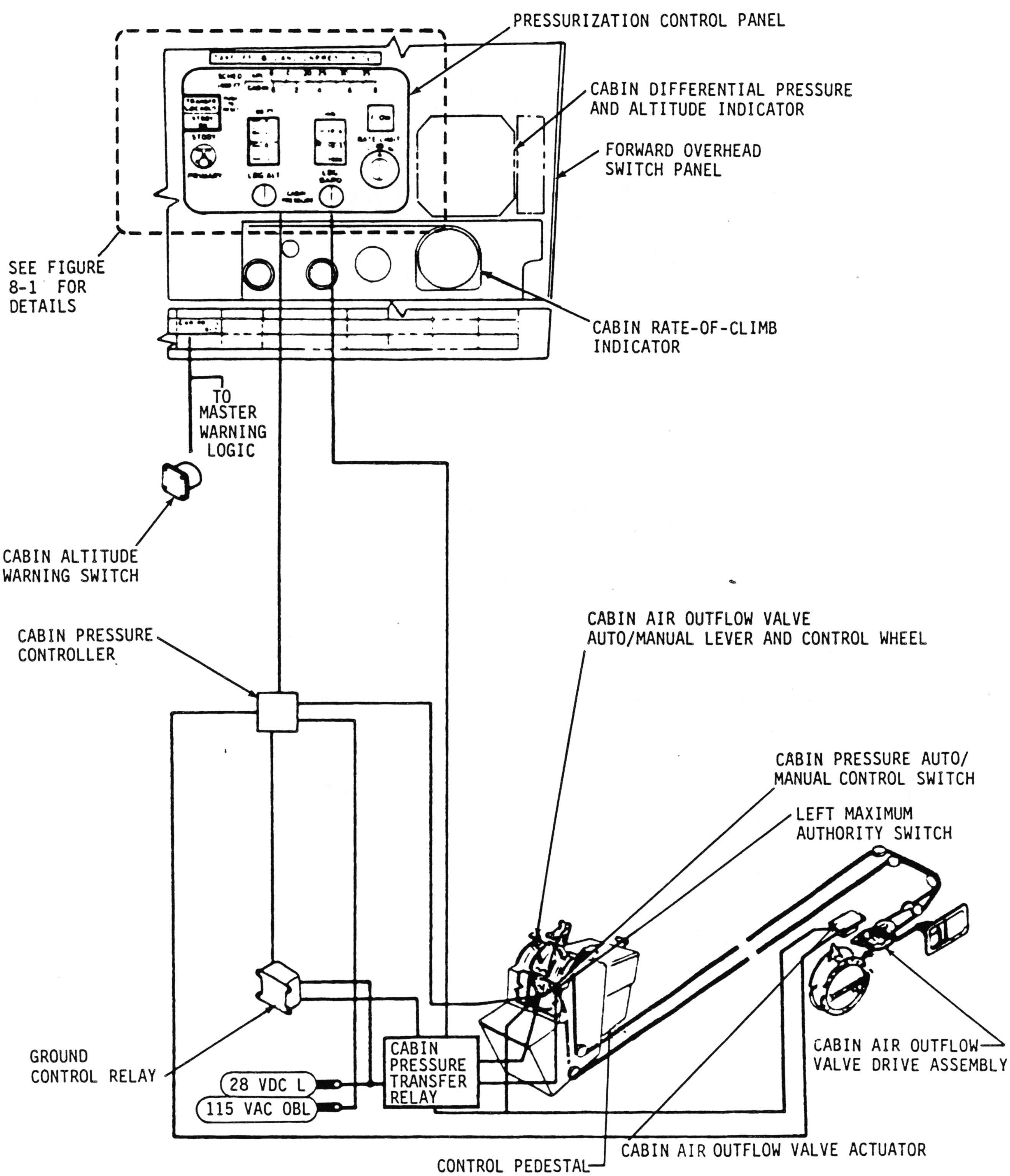


FIGURE 8-14. DC-9 PRESSURIZATION CONTROL SYSTEM SCHEMATIC

SECTION 9

DOUGLAS DC-10

Model Variation

The DC-10 was introduced in the early seventies as a wide-bodied transport to fill the gap between long range narrow-bodied transports and the newly introduced 747. The three engine configuration allowed it to be used on transcontinental flights and its passenger capacity fit a market segment that was not being efficiently served by existing airplanes.

The DC-10 was produced in four passenger models. A summary of first flights, certification dates, and total produced is shown in Table 9-1. The succession of the models represents a trend of increasing gross weights and range, as airframe developments proceed. The air conditioning system was originally the same for all models with the exception of provisions for ventilating the lower galley or aft galley. In late 1982, a service bulletin was produced that installs a passenger cabin recirculation system. The recirculation system installation includes new pack valves, recirculation fans and filters, and necessary ducting to distribute the recirculated air to all cabin zones. The DC-10 is still in production, but the only orders currently held are for the Air Force tanker version, the KC-10. The fate of the DC-10 upon completion of the Air Force order is uncertain.

DC-10 Environmental Control System (ECS)

The DC-10 ECS is a three pack air cycle system that uses engine bleed-air as the air source. A block diagram of the system is shown in Figure 9-1. The air-conditioning packs are located in an unpressurized area of the fuselage on either side of the nose landing gear wheel well. The number 1 and 2 packs are located to the left of the wheel well and the number 3 pack to the right. The packs use air from the engine compressor as the air source. The pneumatic system can be configured so that each engine supplies the corresponding pack, or the engines can supply a common manifold for the packs to draw air from. During ground operations, a pneumatic ground cart or the APU may be used as a hot air source. A schematic of the pack system is shown in Figure 9-2 for non-recirculation airplanes, and Figure 9-3 for recirculation system airplanes.

Hot bleed-air is supplied to the pack flow-control valves by the pneumatic system. The flow-control valves are operated from the flight engineer's panel, and attempt to maintain a constant mass flow for varying bleed-air conditions. On recirculation system airplanes, the pack flow-control valves have two flow schedules; full flow, which maintains the same fresh airflow as non-recirculation airplanes, and 62% flow schedule. The lower flow schedule is for use when the recirculation fans are operating.

After passing through the flow-control valve, the air is routed to the air cycle machine (ACM) compressor and compressor bypass check valve. The compressor raises the air temperature and pressure, and routes air to the heat exchanger. The bypass check valve allows air to bypass the compressor when cooling demands are low. The compressed air is mixed with bypass air, cooled in the heat exchanger by ram air and routed to the ACM turbine. The amount of air passing through the turbine, and hence the amount of cold air produced, is controlled by the turbine bypass valve. Air expands in the ACM turbine to drive the compressor, and cools in the process. The pack anti-ice valve and turbine bypass valve prevent ice formation in the turbine outlet and water separator. The amount of air flowing through the turbine is controlled to maintain discharge temperature at 35 °F or above. Entrained moisture droplets are separated in the water separator and the air then passes to the conditioned air manifold.

The number 1 pack is equipped with provisions to allow ram air to enter the air distribution system. The valve is mounted on the number 1 pack heat-exchanger-cooling duct, and is manually operated by a cable. Access to the valve handle is through an access door located in the aft floor of the flight deck. To operate the valve, the tee-handle is pulled to the open position. This provision can be used only when the air conditioning packs are off. The valve should be closed before operating any of the packs.

Distribution

Air leaving the water separator is routed to the conditioned air manifold. The conditioned air manifold divides the air, and routes it to the proper compartments. Pressure relief valves limit the manifold pressure to approximately .8 psi above cabin pressure. The conditioned air manifold is shown in Figure 9-4.

The conditioned air manifold distributes air to five cabin zones; the flight deck, the forward, mid and aft cabins, and lower deck galley (if equipped). A schematic of the distribution systems is shown in Figure 9-5.

Passenger cabin air is supplied to the distribution system by three risers located behind the right sidewall at approximately station 400. The forward riser supplies air to the forward zone, the mid riser to the mid zone and the aft riser supplies the aft zone. Each riser routes air to a distribution duct that runs aft above the ceiling to its proper zone. The distribution ducts supply dropper ducts that direct air to the passenger cabin through the overhead light fixtures on both sides of the cabin. The passenger cabin distribution system is shown in Figures 9-6 and 9-7.

The flight deck distribution ducting is supplied by a duct running forward below the left-hand floor. The supply duct branches into an overhead supply duct and an instrument panel duct. The overhead supply duct directs air to five adjustable gasper style outlets, three windshield diffusers, and a ceiling diffuser. The overhead outlets are adjustable for flow. The overhead duct also supplies cooling air to the flight engineer's instrument panel. The instrument panel duct supplies cooling air to four instrument panel outlets, and to the forward instrument panels. Two outlets are mounted at the pilot and co-pilot's feet, and two adjustable gasper style outlets mounted on the instrument panel. The flight deck distribution is shown in Figure 9-8.

On airplanes with lower deck galleys, the galley distribution system is supplied by the number 1 pack discharge duct. A duct running along the left-hand ceiling distributes air to the galley through a continuous outlet in the bottom of the duct and through four adjustable outlets. The galley distribution duct, is shown in Figure 9-9. The galley supply line also supplies air to the forward lavatory air outlets (See Figure 9-6).

On airplanes without a lower galley, conditioned air is supplied to the galleys through ceiling-mounted outlets connected to the passenger cabin distribution ducting. The galleys are located in the forward, mid and aft cabins (see Figure 9-10).

Compartment volumes are shown in Table 9-2. Air flow rates for the flight deck and cabin are shown in Tables 9-3 and 9-4. Air change rates for various airplane configurations and flight regimes are shown in Tables 9-5 through 9-8. Temperatures and pressures at various points in the system (see Figures 9-2 and 9-3) are shown in Table 9-9. Airflow patterns produced in the cabin are shown in Figure 9-11. A cross-section showing relative location of various ducting systems is shown in Figure 9-12.

Individual (Gasper) Air

The DC-10 does not have a separate gasper air system. In areas of the cabin not adequately served by the air conditioning system, separate adjustable outlets have been installed. These outlets are supplied from the air conditioning system, and are located in the lavatory, galley, flight deck, and forward row of seats in each zone.

In some airplanes, the passenger cabin is fitted with individual air blowers. The blowers are located in the seat backs, and operate on 115 VAC power. The fan draws in cabin air and blows it on the passenger. The fan motor speed and direction of flow can be adjusted by the passenger. A master switch on the cabin attendant panels control the electrical supply to all of the blowers. Typical individual air blowers are shown in Figure 9-13.

Equipment Cooling

The equipment cooling system provides blow-through and draw-through cooling to the forward instrument panels, flight engineer's panels, center pedestal, and forward instrument panel-mounted equipment.

The equipment cooling system draws air from the flight deck through the instrument panels, equipment in the avionics bay, and from the forward lavatory, and exhausts the air into the left utility tunnel or overboard, depending on flight regime.

During ground operation or low level flight, the avionics fan and instrument panel fan are operating, and draw air into the system. Air is exhausted into the left utility tunnel. As the cabin differential pressure rises to 36.8 inches of water (1.33 psi), the avionics fan switches off, and air is exhausted overboard through the flow-limiting venturi. A check valve in the fan duct prevents air from the left utility tunnel being drawn overboard. The forward equipment cooling system is shown in Figure 9-14.

Cargo Heating

The DC-10 cargo compartments are classified as FAR Part 25 Class C compartments. As such, they are required to have a means of fire detection and suppression, control of airflow within the compartment, and to prevent hazardous quantities of smoke from entering the occupied areas. The cargo compartments are heated by directing passenger cabin exhaust air between the cargo compartment lining and fuselage skin. The forward, mid, and aft cargo compartments are all heated in the same way.

The cargo heating system uses pneumatic air exhausted in a jet pump (see Figure 9-15) to draw air from the utility tunnels into a system of ducting and diffusers. The ducting runs fore and aft along the cargo compartments in the utility tunnels, and has a diffuser mounted between each frame. The diffusers direct the heated air under the cargo floor to the other side of the airplane. A typical cargo heating duct is shown in Figure 9-16.

The operation of the cargo heat system is controlled by three switches on the flight engineer's panel. The system is selected to off or norm. In the normal mode, cargo compartment temperature is thermostatically controlled between 50-90 °F or 55-70 °F, depending on the temperature element installed. Gauges are provided to monitor each compartment temperature.

The lower hold galley compartment floor is heated in the same manner. A jet pump draws air from the right utility tunnel, and a system of ducting distributes the air below the floor. The temperature of the floor is thermostatically controlled between 50-90 °F. The galley floor heat system is shown in Figure 9-17.

Recirculation System

The DC-10 recirculation system consists of four fans, filters, and necessary ducting to distribute the recirculated cabin air to the three passenger cabin zones. As originally designed, the DC-10 ECS used 100% fresh air to ventilate the cabin. In late 1982, Douglas Aircraft Company produced a service bulletin that installed a passenger cabin recirculation system. The installation includes new pack valves for reducing the flow of fresh air when recirculation is in use, resulting in the same total airflow rate as the all-fresh air systems. The recirculation system is shown in Figure 9-18.

The recirculation fans are mounted in the forward portion of the cabin, above the ceiling next to the passenger cabin distribution ducting. The fans draw air from above and below the ceiling through particulate filters, and exhaust air into a distribution duct running parallel to the passenger cabin ducting. The distribution duct adds recirculated air to each passenger cabin zone to give a mixture of approximately 38% recirculated air in the passenger cabin only. airflow to the flight deck remains 100% fresh at the previous flow rate.

Ventilation

Air is vented overboard by the two systems; equipment cooling and pressurization outflow valves. In addition, individual compartments are ventilated by systems of ducts that direct air to the outflow valves. These systems include lower galley ventilation, main deck lavatory and galley ventilation, and center accessory compartment ventilation.

The lower galley ventilation is used to evacuate food odors and carbon dioxide from the lower galley. The ventilation system is made up of two subsystems. The primary system uses a pneumatic jet pump to draw air from the galley through inlets located above the ovens, and near the floor at each end of the compartment. The jet pump exhausts air near the cabin pressure outflow valve. If the airplane is on the ground, and pneumatic pressure is inadequate to operate the jet pump, a galley vent fan draws air from the galley. The secondary ventilation system vents water and carbon dioxide overboard. A system of ducts draws air from the back of the refrigerated areas, and collects water from the floor. A valve at each end of the compartment drains overboard. The valves are spring loaded open, and close when differential pressure exceeds .75 psi. The lower galley vent system is shown in Figure 9-19.

On airplanes without lower deck galleys, the upper deck galleys are located in the aft portion of the cabin, and in the center cabin just forward of the wing.

The center cabin galley vent system (Figure 9-20), also provides ventilation for the center lavatories. Air is removed from the top of the galley through outlets in the ceiling panel, and is ducted down behind the galley to below the floor. The below-floor duct incorporates a jet pump to draw air into the ducting system, and exhausts air near the outflow valve.

The aft lavatory vent system (Figure 9-21) also provides ventilation for the aft galleys. A jet pump in a duct located below the floor causes air to be drawn into the outlets in the galley ceiling panel, and from below the toilet tank shroud. The duct exhausts air into the left utility tunnel.

The forward lavatories are vented through the avionics compartment vent.

The center accessory compartment is located below the floor just forward of the wing, and contains various electronic equipment that require auxiliary cooling. A fan located in the right utility tunnel, just forward of the center compartment, draws air from the right utility tunnel and exhausts it into the center compartment. Air leaves the compartment into the left tunnel, and moves forward and overboard through the outflow valve. The center compartment fan is shown in Figure 9-22.

The pressurization outflow valves are shown in Figure 9-23. The outflow valves are the primary method of controlling the flow of air overboard. The outflow valves respond to signals generated in the pressure controller, or the manual cable control, to control the amount of air passing overboard. The valve sequencer controls the division of flow between the butterfly and nozzle valves.

The outflow valves consist of a ram-air shield, butterfly valve, nozzle valve, and valve sequencer. The butterfly valve controls the flow of air at low altitudes and low differential pressures. During take-off and landing, the ram air shield extends to create a low pressure area over the valve opening. The nozzle valve controls the cabin pressure at high altitudes. The aft edge of the nozzle element is modulated inward to increase the opening.

Pressurization Controls

The DC-10 pressurization control system (PCS) controls the amount of air passing through the outflow valves to maintain the lowest cabin altitude for the selected flight altitude, minimize the cabin altitude rate of change, and ensure that the cabin is unpressurized at landing.

The PCS has four operating modes; automatic, semi-automatic, standby, and manual. The pressurization control panel is shown in Figure 9-24.

Normal operation is on the auto controller. To use the system, the crew inputs the landing altitude and a barometric correction factor for landing altitude. The pressure controller then maintains the lowest possible cabin altitude for the current flight altitude, and minimizes the rate of change of cabin altitude. The semi-auto mode uses the same selector panel, and is activated by transfer if the auto mode fails, or by selecting semi-auto on the mode selector switch. The semi-auto requires the same inputs as auto mode, plus selection of desired cabin altitude change rate.

The standby mode further backs up the semi-auto mode. To use this mode, the crew member pulls the control knob on the selector panel. The knob is then used to command the cabin altitude to remain unchanged, or go up or down. Rate of change is limited to between 60 and 1000 feet per minute. Excessive differential pressure is prevented by the safety relief valves. Gauges must be monitored to prevent excessive altitude change rates, and to insure an unpressurized cabin at landing.

The manual control allows the crew to control the outflow valve position through a series of cables. A thumb wheel style control on the control pedestal is engaged by lifting the engagement lever. The outflow valve position is varied by adjusting the control wheel. A indicator is located next to the control wheel to show outflow valve position. The manual controls are shown in Figure 9-25.

Gauges are provided to indicate cabin altitude, differential pressure and cabin altitude change rates. Limits of the pressurization control system are shown in Table 9-2.

Environmental Control System (ECS) Controls

The ECS controls include controls to set the pack mode and compartment temperature, operate cargo compartment heat system, recirculation fans and lavatory and galley venting. The ECS controls are shown in Figure 9-26.

The pack mode selector switches are located on the lower left portion of the flight engineer's upper panel. On airplanes without recirculation capacity, the packs have two modes; auto and manual. On airplanes with recirculation features, the pack has three operating modes; auto low, auto high, and manual. When using either of the auto modes, the pack outlet temperature is controlled by the pack temperature controller in conjunction with the zone temperature heating system. The auto high and auto low modes are used for adjusting the pack flow when the recirculation fans are operating. The manual mode allows the crew to adjust the temperature of the pack discharge to either colder or hotter by directly controlling the position of the turbine bypass valve. The pack turbine inlet temperature, pack temperature control valve position, and pack discharge temperatures can be monitored on the gauges provided.

A selector controls which pack's parameters are displayed. Gauges are also provided to indicate the relative pack supply flow from low to high.

The zone temperature controls are located above the pack controls. The airplane is divided into four or five temperature control zones, the fifth zone being the lower galley, if so equipped. The zone temperature control system adds a controlled amount of hot pneumatic trim air to the pack outlet air to adjust the supply temperature of each zone. The trim air ducting is shown in Figure 9-4. The zone temperature control system uses a system of sensors to automatically regulate the temperature of various compartments. The temperature of a zone can be set and thermostatically maintained anywhere between 63 -85 °F, or can be manually adjusted to hotter or colder. Gauges are provided for the crew to monitor the zone air temperatures, zone supply temperature, and temperature control valve position. A master switch starts and stops the flow of trim air.

On some airplanes, the cargo compartment heating system operates continuously, and the only control is the cargo heat override switch, which interrupts all cargo heat systems. Other airplanes have switches to control the individual heating systems at each cargo compartment. The heat systems are selected normal or off. In all cases, the cargo compartment temperature is controlled automatically within preset limits. The cargo compartment temperatures are shown on the gauges at the upper portion of the panel.

The lav/galley vent, or lav/galley vent and cargo heat switch, controls the flow of pneumatic air to the cargo heating and galley venting jet pumps.

Electrical energy requirements for ECS components and control systems are shown in Tables 9-10 and 9-11. The load shown is the total load of all units. To find the unit load, divide the listed load by the number of units.

TABLE 9-1. DC-10 PRODUCTION DATA

MODEL	FIRST FLIGHT (REF 17)	CERTIFICATION (REF 27)	NO. PRODUCED (REF 3)
-10	8-29-70	7-29-71	131
-15	1-8-81	6-12-81	7
-30	6-21-72	11-21-72	214
-40	2-28-72	10-20-72	42

TABLE 9-2. DC-10 VENTILATION PARAMETERS

VOLUMES (CU FT)	WITH LOWER DECK GALLEY	W/O LOWER DECK GALLEY
TOTAL PRESSURIZED		
PASSENGER CABIN	14,784	14,032
FLIGHT DECK	400	400
FWD CARGO	1,300	3,045
MID CARGO	1,550	1,935
AFT CARGO	805	510
LOWER GALLEY	1,600	—

PRESSURIZATION	
MAX ΔP (PSI)	
CONTROLLER LIMITED	8.6
SAFETY VALVE LIMITED	8.85 - 9.10

CABIN ALTITUDE CHANGE RATES (FT/MIN)		CLIMB	DESCENT
CONTOLLER	MAX	2,000	1,200
	MIN	100	60

TABLE 9-3. DC-10 VOLUME FLOW, NON RECIRCULATION AIRPLANES (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	147.7	5,310	NOT APPLICABLE	519.3	NOT APPLICABLE
5,000 FT CLIMB	149.2	5,313		519.7	
10,000 FT CLIMB	150.0	5,309		516.6	
20,000 FT CRUISE	144.9	5,511		538.4	
30,000 FT CRUISE	134.7	5,635		550.5	
35,000 FT CRUISE	127.7	5,717		558.5	
43,000 FT CRUISE	DATA NOT AVAILABLE				
30,000 FT DESCENT	128.6	5,648		551.7	
20,000 FT DESCENT	145.2	5,451		532.5	

TABLE 9-4. DC-10 VOLUME FLOW, RECIRCULATION AIRPLANES (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	91.6	5,310	38	519.3	0
5,000 FT CLIMB	92.5	5,313	38	519.7	0
10,000 FT CLIMB	93.0	5,309	38	516.6	0
20,000 FT CLIMB	89.8	5,511	38	538.4	0
30,000 FT CRUISE	83.5	5,635	38	550.5	0
35,000 FT CRUISE	79.2	5,717	38	558.5	0
43,000 FT CRUISE	DATA NOT AVAILABLE				
30,000 FT DESCENT	79.7	5,648	38	551.7	0
20,000 FT DESCENT	90.0	5,451	38	532.5	0

TABLE 9-5. DC-10 AIR CHANGE RATES, NON RECIRCULATION AIRPLANES WITH LOWER DECK GALLEY

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	21.6	77.9
5,000 FT CLIMB	21.6	78.0
10,000 FT CLIMB	21.5	77.5
20,000 FT CLIMB	22.4	80.7
30,000 FT CRUISE	22.9	82.6
35,000 FT CRUISE	23.2	83.8
43,000 FT CRUISE	N/A*	N/A*
30,000 FT DESCENT	22.9	82.8
20,000 FT DESCENT	22.1	79.9

*NOT AVAILABLE

TABLE 9-6. DC-10 AIR CHANGE RATES, NON RECIRCULATION AIRPLANES WITHOUT LOWER DECK GALLEY

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	22.7	77.9
5,000 FT CLIMB	22.7	78.0
10,000 FT CLIMB	22.7	77.5
20,000 FT CLIMB	23.6	80.7
30,000 FT CRUISE	24.1	82.6
35,000 FT CRUISE	24.4	83.8
43,000 FT CRUISE	N/A*	N/A*
30,000 FT DESCENT	24.2	82.8
20,000 FT DESCENT	23.3	79.9

*NOT AVAILABLE

TABLE 9-7. DC-10 AIR CHANGE RATES, RECIRCULATION AIRPLANES WITH LOWER DECK GALLEY

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	13.4	21.6	77.9
5,000 FT CLIMB	13.4	21.6	78.0
10,000 FT CLIMB	13.4	21.5	77.5
25,000 FT CRUISE	13.9	22.4	80.7
30,000 FT CRUISE	14.2	22.9	82.6
35,000 FT CRUISE	14.4	23.2	83.8
43,000 FT CRUISE	N/A*	N/A*	N/A*
30,000 FT DESCENT	14.2	22.9	82.8
20,000 FT DESCENT	13.7	22.1	79.9

*NOT AVAILABLE

TABLE 9-8. DC-10 AIR CHANGE RATES, RECIRCULATION AIRPLANES WITHOUT LOWER GALLEY

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	14.1	22.7	77.9
5,000 FT CLIMB	14.1	22.7	78.0
10,000 FT CLIMB	14.1	22.7	77.5
25,000 FT CRUISE	14.6	23.6	80.7
30,000 FT CRUISE	14.9	24.1	82.6
35,000 FT CRUISE	15.1	24.4	83.8
43,000 FT CRUISE	N/A*	N/A*	N/A*
30,000 FT DESCENT	14.9	24.2	82.8
20,000 FT DESCENT	14.4	23.3	79.9

*NOT AVAILABLE

TABLE 9-9. DC-10 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(^{o}F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	58.68	425.3	47.35	425.3	15.31	32.1	14.7	33.0	14.7	32.5	14.7	75	14.7	103
5,000 FT CLIMB	56.10	424.9	47.30	424.9	15.43	32.2	14.83	33.1	14.83	32.5	14.83	75	12.23	83.7
10,000 FT CLIMB	53.9	424	47.7	424	15.56	32	14.95	33.0	14.95	32.5	14.95	75	10.1	64.3
20,000 FT CLIMB	50.4	408.3	37.15	408.3	14.8	46.5	14.15	51.4	14.15	48.9	14.15	75	7.04	25.5
30,000 FT CRUISE	35.9	407.2	26.48	407.2	13.5	55.1	12.92	55.1	12.92	67.8	12.92	75	4.61	-12.3
35,000 FT CRUISE	32.4	406.0	24.34	406.0	12.7	56.2	12.07	56.2	12.07	70.0	12.07	75	3.64	-30.1
43,000 FT CRUISE	DATA NOT AVAILABLE													
30,000 FT DESCENT	25.8	397.2	25.11	397.2	13.5	49.7	12.10	54.5	12.10	52.1	12.10	75	4.61	-12.3
10,000 FT DESCENT	37.6	408.3	36.96	408.3	14.8	47.9	14.19	52.6	14.19	50.5	14.19	75	7.04	25.5

TABLE 9-10. DC-10 AC ELECTRICAL ENERGY REQUIREMENTS (REF 32)

EQUIPMENT	POWER REQD	LOAD WATTS	LOAD VARS	NO. OF UNITS	SOURCE
Cabin Pressure Auto Controller	115V 400 Hz 1Ø	121	123	1	AC Bus 1ØC
L Mid Cabin Outbd Individual Air Fans	115V 400 Hz 1Ø	240	180	20	AC Bus 1ØB
L Mid Cab Inbd Individual Air Fans	115V 400 Hz 1Ø	240	180	20	AC Bus 1ØB
L Overwing Sidewall Individual Air Fans	115V 400 Hz 1Ø	24	18	2	AC Bus 1ØB
L Aft Cab Outboard Individual Air Fans	115V 400 Hz 1Ø	336	252	28	AC Bus 1ØA
L Aft Cab Inboard Individual Air Fans	115V 400 Hz 1Ø	360	270	30	AC Bus 1ØA
R Aft Cab Outboard Individual Air Fans	115V 400 Hz 1Ø	336	252	28	AC Bus 1ØA
R Aft Cab Inboard Individual Air Fans	115V 400 Hz 1Ø	312	234	26	AC Bus 1ØA
Avionics Compt Vent Fan	200V 400 Hz 3Ø	2,111	1,308	1	AC Bus 1ØA
Ctr Inst Panel Vent Fan	115V 400 Hz 1Ø	59	37	1	AC Bus 1ØC
Pack 1,2,3 Ram Air Door Actuator	115V 400 Hz 1Ø	225	74	3	AC Bus 1ØA
Cabin Pressure Standby Controller	115V 400 Hz 1Ø	81	83	1	AC Bus 2ØB
Cockpit Temp Controller	115V 400 Hz 1Ø	75	25	1	AC Bus 2ØB
Galley Temp Controller	115V 400 Hz 1Ø	75	25	1	AC Bus 2ØB
Pack 2 Temp Controller	115V 400 Hz 1Ø	127	69	1	AC Bus 2ØA
APU/Pack Temp Demand Controller	115V 400 Hz 1Ø	40	0	1	AC Bus 2ØB
Center Accessory Compt. Fan	115V 400 Hz 1Ø	161	100	1	AC Bus 2ØA
Fwd, Center, Aft Trim Air Valve Motor	115V 400 Hz 1Ø	84	63	3	AC Bus 2ØB
Fwd, Center, Aft Cabin Temp Control	115V 400 Hz 1Ø	225	74	3	AC BUS 3ØA
Pack 1 Temp Controller	115V 400 Hz 1Ø	127	69	1	AC BUS 3ØA
Pack 3 Temp Controller	115V 400 Hz 1Ø	127	69	1	AC BUS 3ØC
L Fwd Cab Outbd Individual Air Fans	115V 400 Hz 1Ø	168	126	14	AC Bus 3ØA
L Fwd Cab Inbd Individual Air Fans	115V 400 Hz 1Ø	144	108	12	AC Bus 3ØA
R Fwd Cab Outbd Individual Air Fans	115V 400 Hz 1Ø	168	126	14	AC Bus 3ØA
R Fwd Cab Inbd Individual Air Fans	115V 400 Hz 1Ø	144	108	12	AC Bus 3ØA
L Fwd Cab Sidewall Individual Air Fans	115V 400 Hz 1Ø	24	18	2	AC Bus 3ØA
R Fwd Cab Sidewall Individual Air Fans	115V 400 Hz 1Ø	24	18	2	AC Bus 3ØA
Fwd Cab Partition Individual Air Fans	115V 400 Hz 1Ø	24	18	2	AC Bus 3ØA
Fwd Cab Movie Projector Fan	115V 400 Hz 1Ø	24	18	2	AC Bus 3ØA
L Ctr Cab Sidewall Individual Air Fans	115V 400 Hz 1Ø	24	18	2	AC Bus 3ØA
R Ctr Cab Sidewall Individual Air Fans	115V 400 Hz 1Ø	24	18	2	AC Bus 3ØA
Service Center Individual Air Fans	115V 400 Hz 1Ø	48	36	4	AC Bus 3ØA
R Mid Cab Outbd Individual Air Fans	115V 400 Hz 1Ø	168	126	14	AC Bus 3ØA
R Mid Cab Inbd Individual Air Fans	115V 400 Hz 1Ø	240	180	20	AC Bus 3ØA
R Overwing Sidewall Individual Air Fans	115V 400 Hz 1Ø	24	18	2	AC Bus 3ØA
Overwing Partition Individual Air Fans	115V 400 Hz 1Ø	48	36	4	AC Bus 3ØA
Cockpit Trim Air Valve	115V 400 Hz 1Ø	28	21	1	AC Bus 3ØA
Lower Galley Trim Air Valve	115V 400 Hz 1Ø	28	21	1	AC Bus 3ØA
Radio Rack Fan	200V 400 Hz 3Ø	2,111	1,308	1	AC Bus 3ØA

TABLE 9-11. DC-10 DC ELECTRICAL ENERGY REQUIREMENTS (REF 33)

EQUIPMENT	POWER REQD	LOAD AMPS	NO. OF UNITS	SOURCE
Pack 1,2,3 Off Lamp	28 VDC	.24 A	3	Battery Bus
Pack 1,2,3 Flow Control Valve	28 VDC	2.25 A	3	Battery Bus
Fwd, Mid, Aft Individual Air Fan Relays	28 VDC	.33 A	3	Ground Service
Individual Air Control	28 VDC	.24 A	3	Ground Service
Cabin Pressure Selector	28 VDC	.08 A	1	Cockpit DC Bus 1
Cabin Pressure Auto Controller	28 VDC	.28 A	1	Cockpit DC Bus 1
Pack Discharge Temp Indicator	28 VDC	.04 A	1	Cockpit DC Bus 1
Lower Galley Duct & Compt Temp Indicator	28 VDC	.09 A	1	Cockpit DC Bus 1
Cockpit Duct & Compt Temp Indicator	28 VDC	.09 A	1	Cockpit DC Bus 1
Fwd, Ctr, Aft Duct & Compt Temp Indicator	28 VDC	.27 A	3	Cockpit DC Bus 1
Avionics Vent Fan Control Relay	28 VDC	.35 A	1	Cockpit DC Bus 1
Fwd Cargo Compt Heat Shut-off Valve	28 VDC	1.00 A	1	Cockpit DC Bus 1
Galley Pressure Regulator Valve	28 VDC	1.00 A	1	Cockpit DC Bus 1
Pack 1 Trim Air Pressure Regulator Valve	28 VDC	1.00 A	1	Cockpit DC Bus 1
Galley Floor Heat Shut-off Valve	28 VDC	1.00 A	1	Cockpit DC Bus 1
Trim Air Pressure High Indicator	28 VDC	.08 A	1	Cockpit DC Bus 1
Cabin Pressure Standby Controller	28 VDC	.16 A	1	Cockpit DC Bus 2
Fwd, Ctr, Aft Duct & Compt. Temp Indicator	28 VDC	.27 A	3	Cockpit DC Bus 2
Cabin Pressure Relief Valve Open Light	28 VDC	.08 A	1	Cockpit DC Bus 2
Avionic Duct Overheat Light	28 VDC	.08 A	1	Cockpit DC Bus 2
Trim Air Pressure Manual Shut-off Relay	28 VDC	.12 A	1	Cockpit DC Bus 2
Center Cargo Compt Shut-off Valve	28 VDC	1.00 A	1	Cockpit DC Bus 2
Cockpit Duct & Compt Temp Indicator	28 VDC	.09 A	1	Cockpit DC Bus 3
Lower Galley Duct & Compt Temp Indicator	28 VDC	.09 A	1	Cockpit DC Bus 3
Cargo Compt Temp Fwd, Ctr and Aft	28 VDC	.12 A	3	Cockpit DC Bus 3
Turbine Inlet Temp Indicator	28 VDC	.04 A	1	Cockpit DC Bus 3
Cabin Low Pressure Warning Relay	28 VDC	.12 A	1	Cockpit DC Bus 3
Trim Air Pressure Auto Shut-off Relay	28 VDC	.12 A	1	Cockpit DC Bus 3
Aft Cargo Heat Shut-off Valve	28 VDC	1.00 A	1	Cockpit DC Bus 3
Aft Lav Pressure Valve	28 VDC	1.00 A	1	Cockpit DC Bus 3
Pack 3 Trim Air Pressure Valve	28 VDC	1.00 A	1	Cockpit DC Bus 3

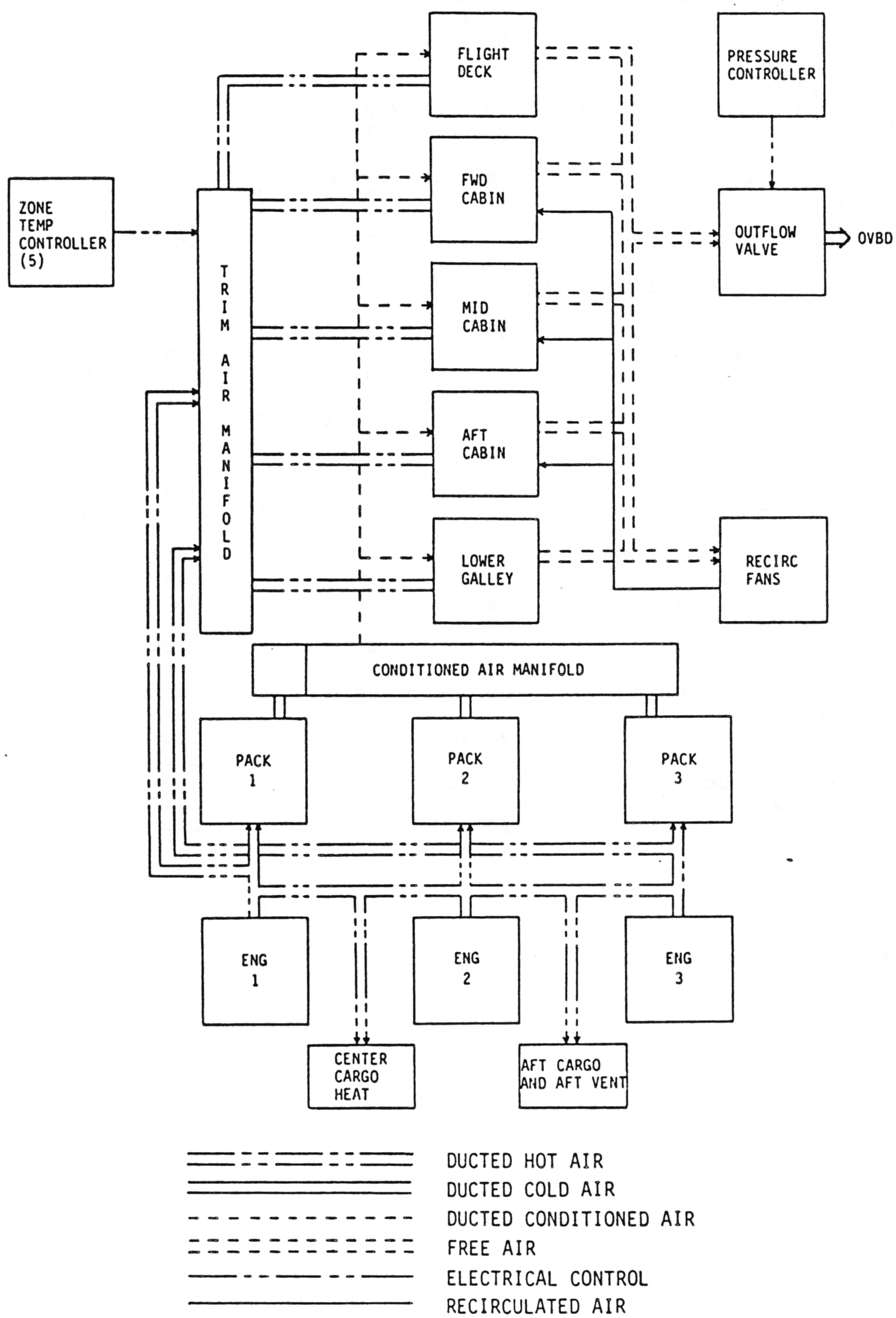


FIGURE 9-1. DC-10 AIR CONDITIONING AND PRESSURIZATION CONTROL BLOCK DIAGRAM

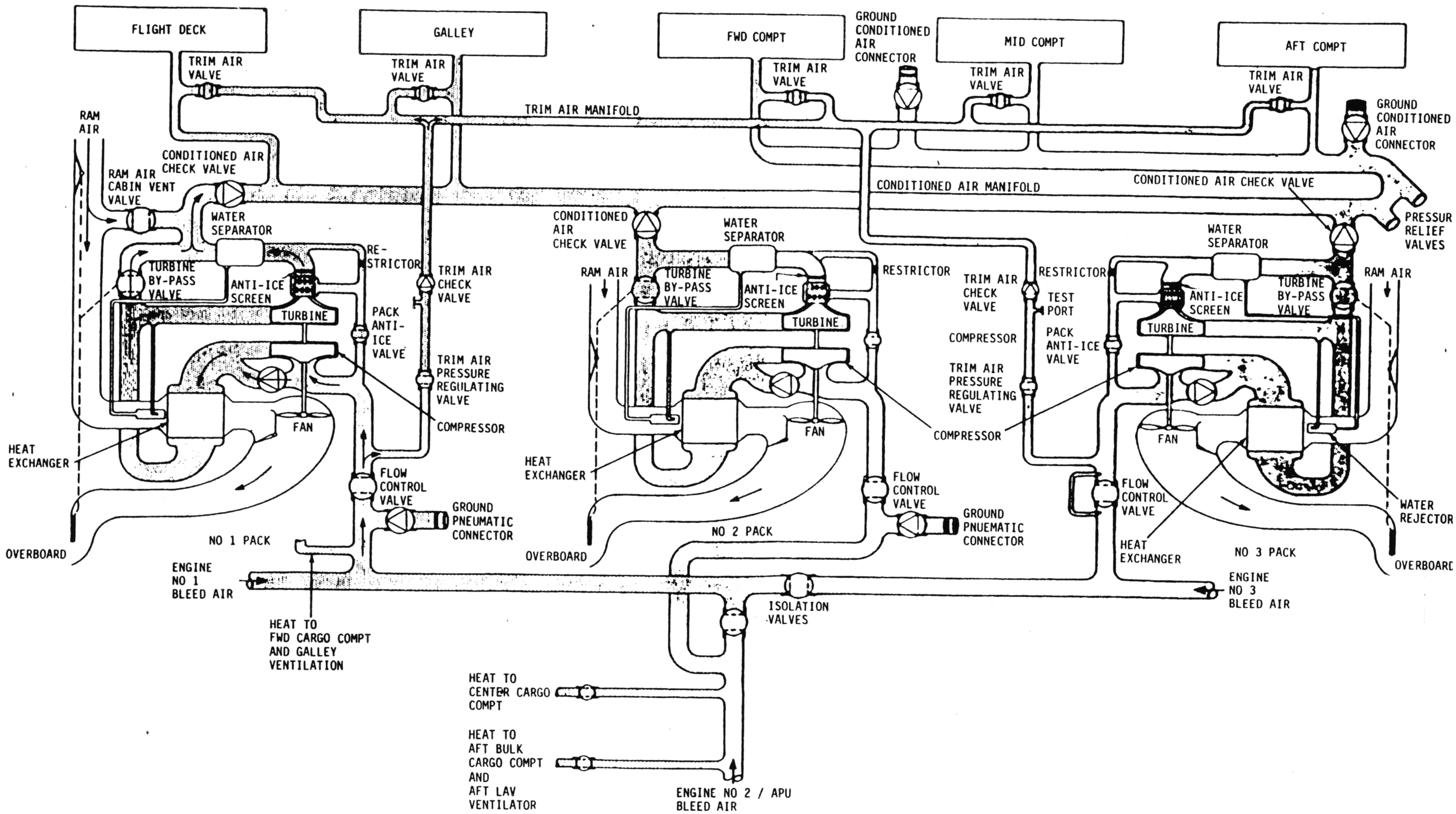


FIGURE 9-2. DC-10 AIR CONDITIONING PACK SCHEMATIC, NON RECIRCULATION AIRPLANES

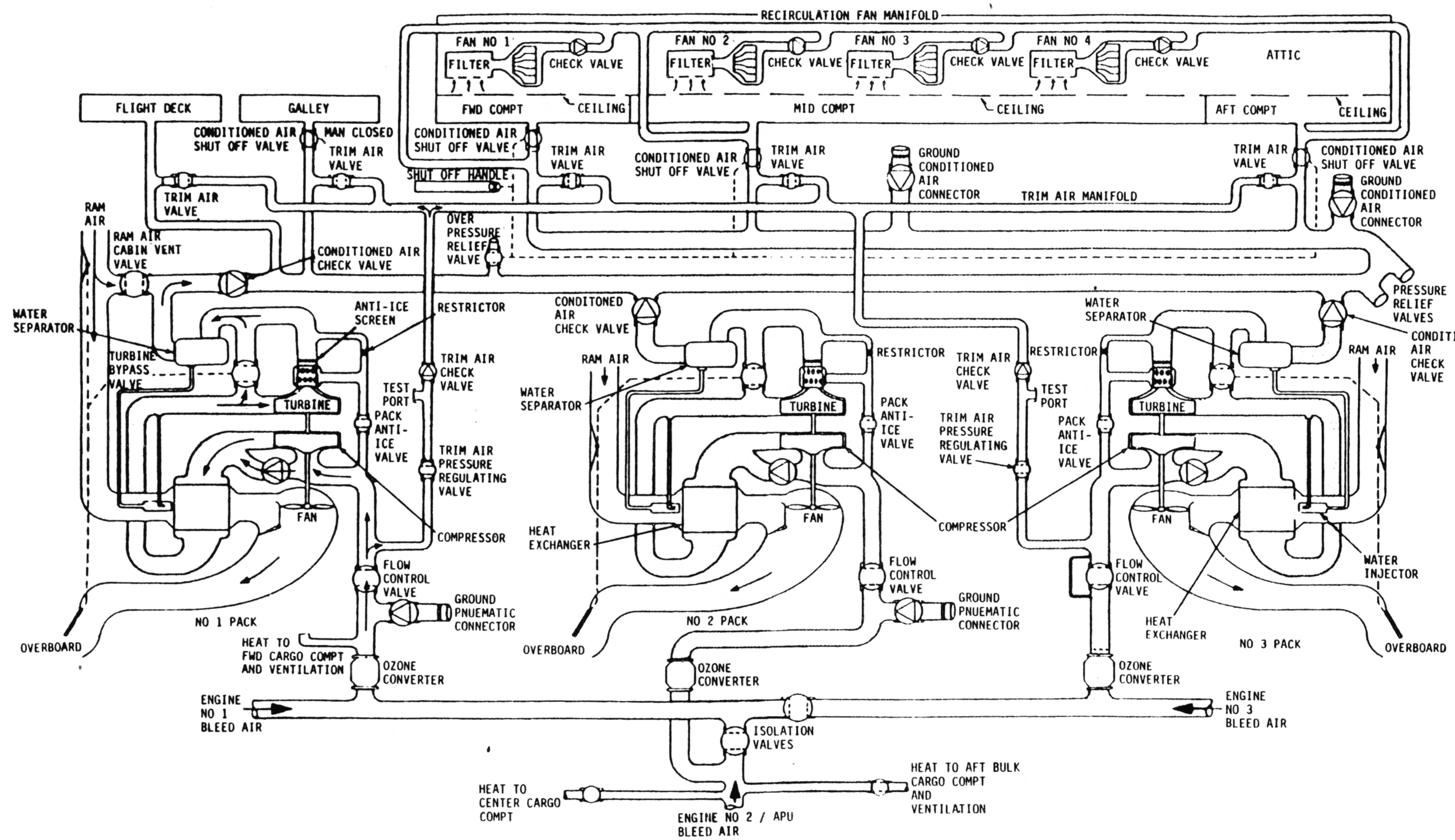


FIGURE 9-3. DC-10 AIR CONDITIONING PACK SCHEMATIC, RECIRCULATION AIRPLANES

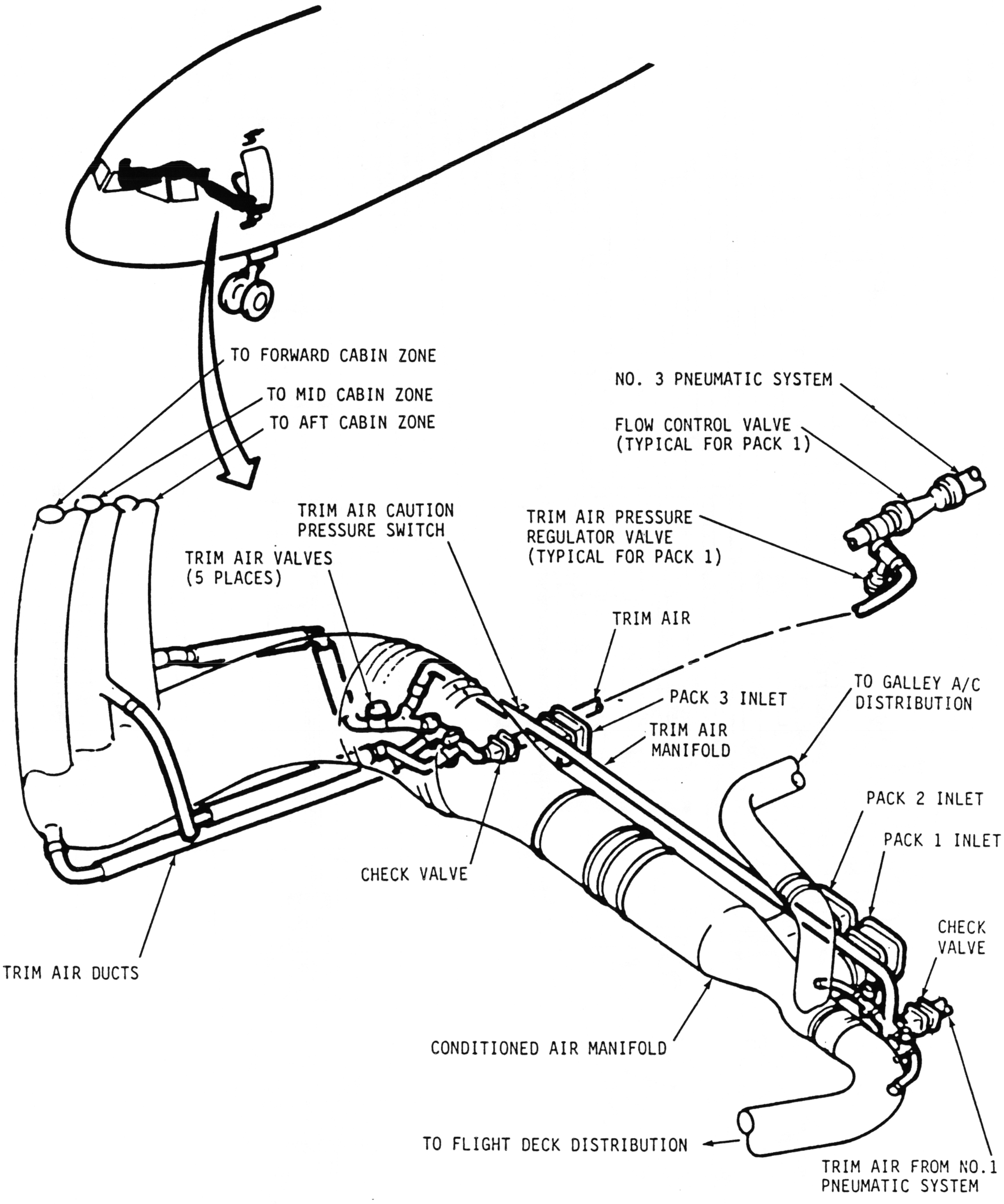


FIGURE 9-4. DC-10 CONDITIONED AIR MANIFOLD

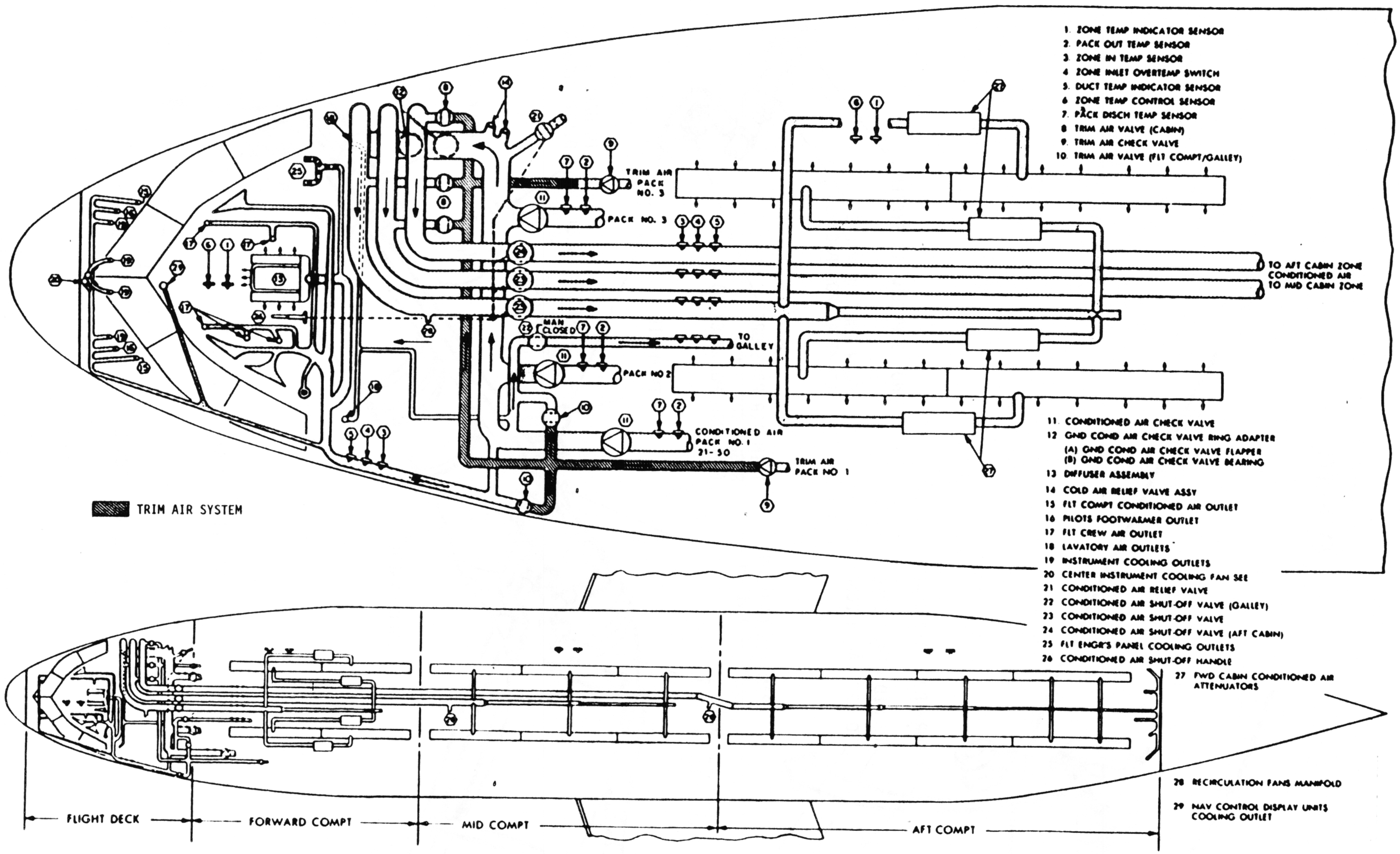


FIGURE 9-5. DC-10 AIR CONDITIONING DISTRIBUTION SCHEMATIC

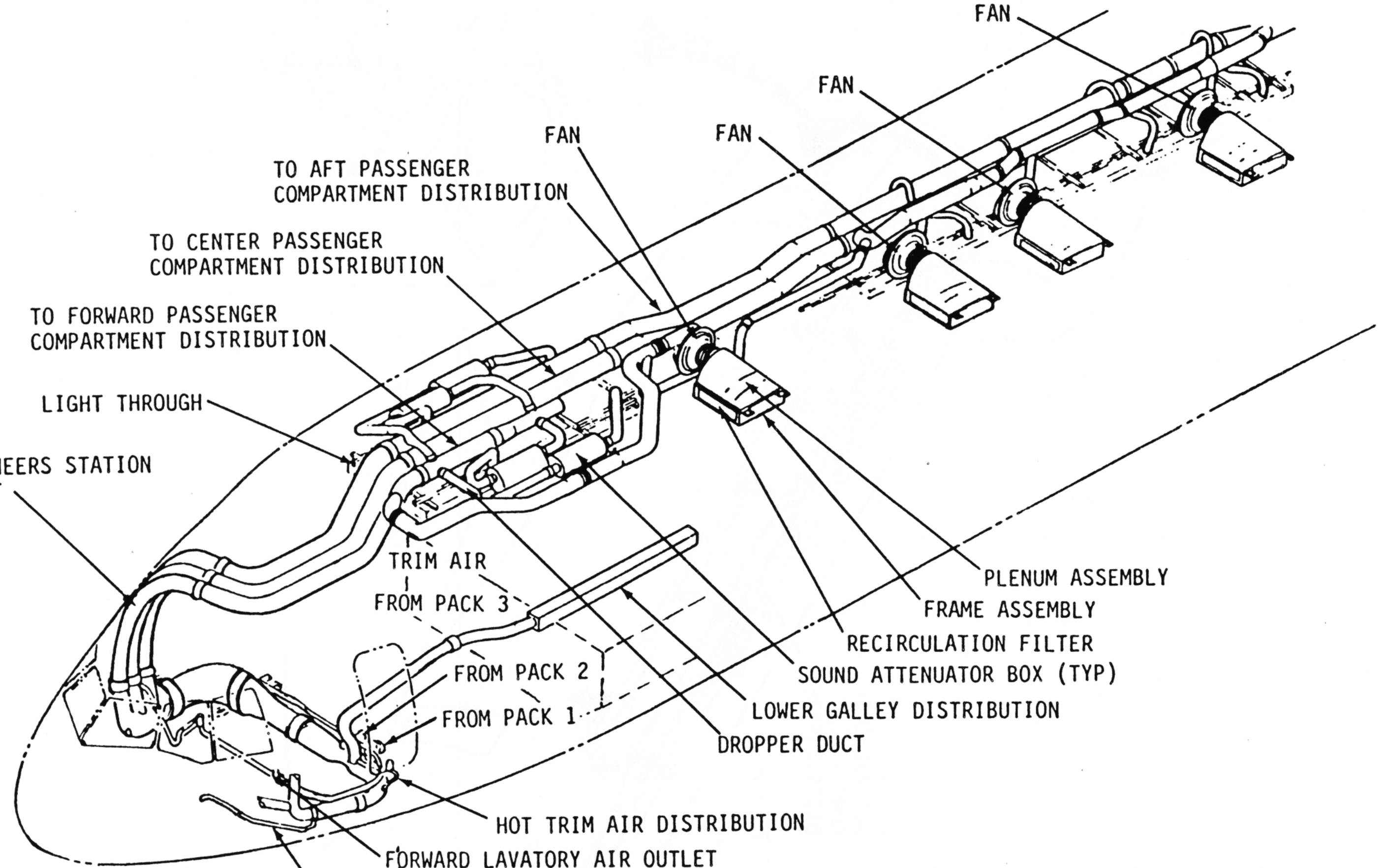


FIGURE 9-6. DC-10 PASSENGER CABIN DISTRIBUTION, FORWARD SECTION

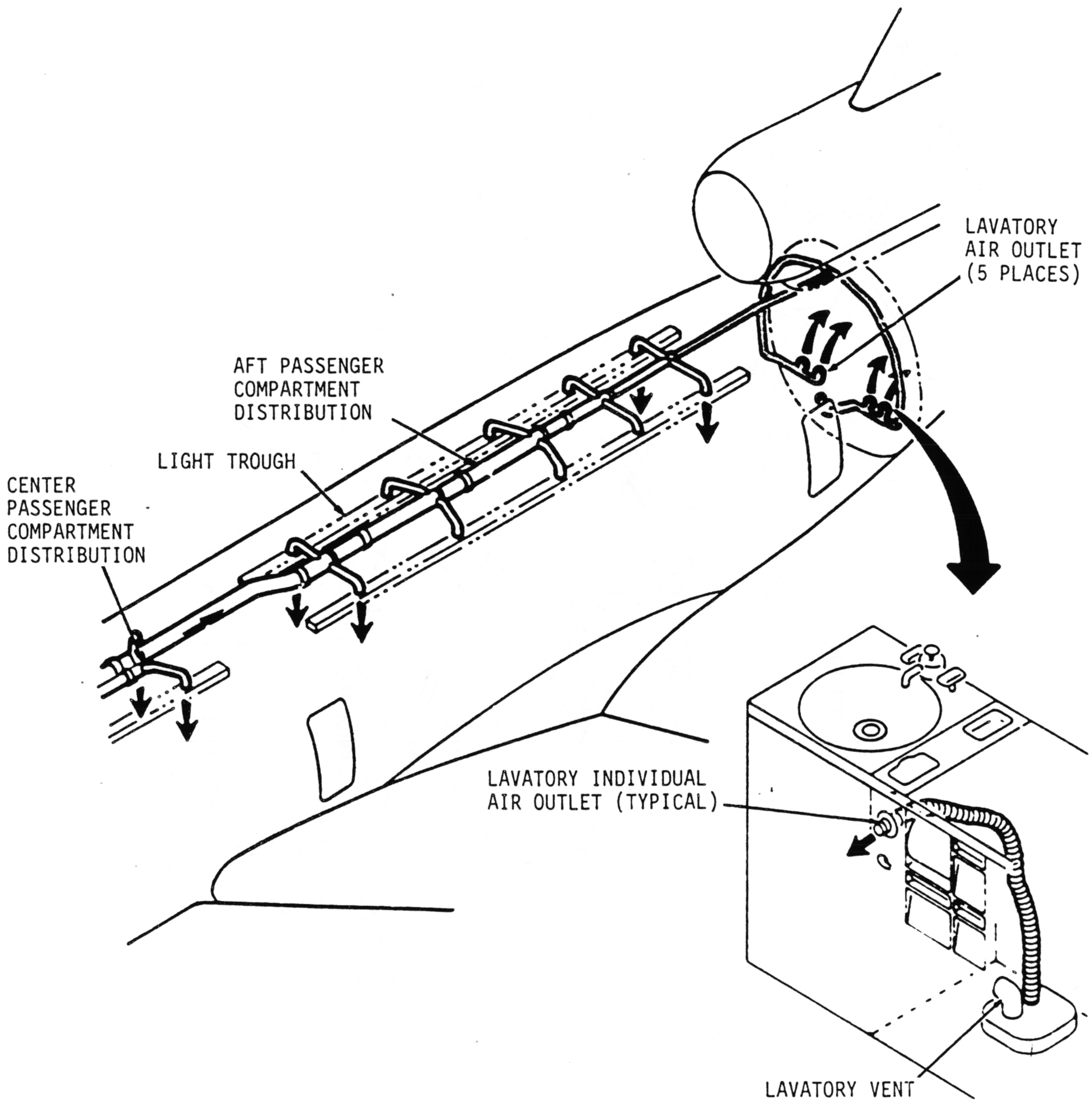


FIGURE 9-7. DC-10 PASSENGER CABIN DISTRIBUTION, AFT SECTION

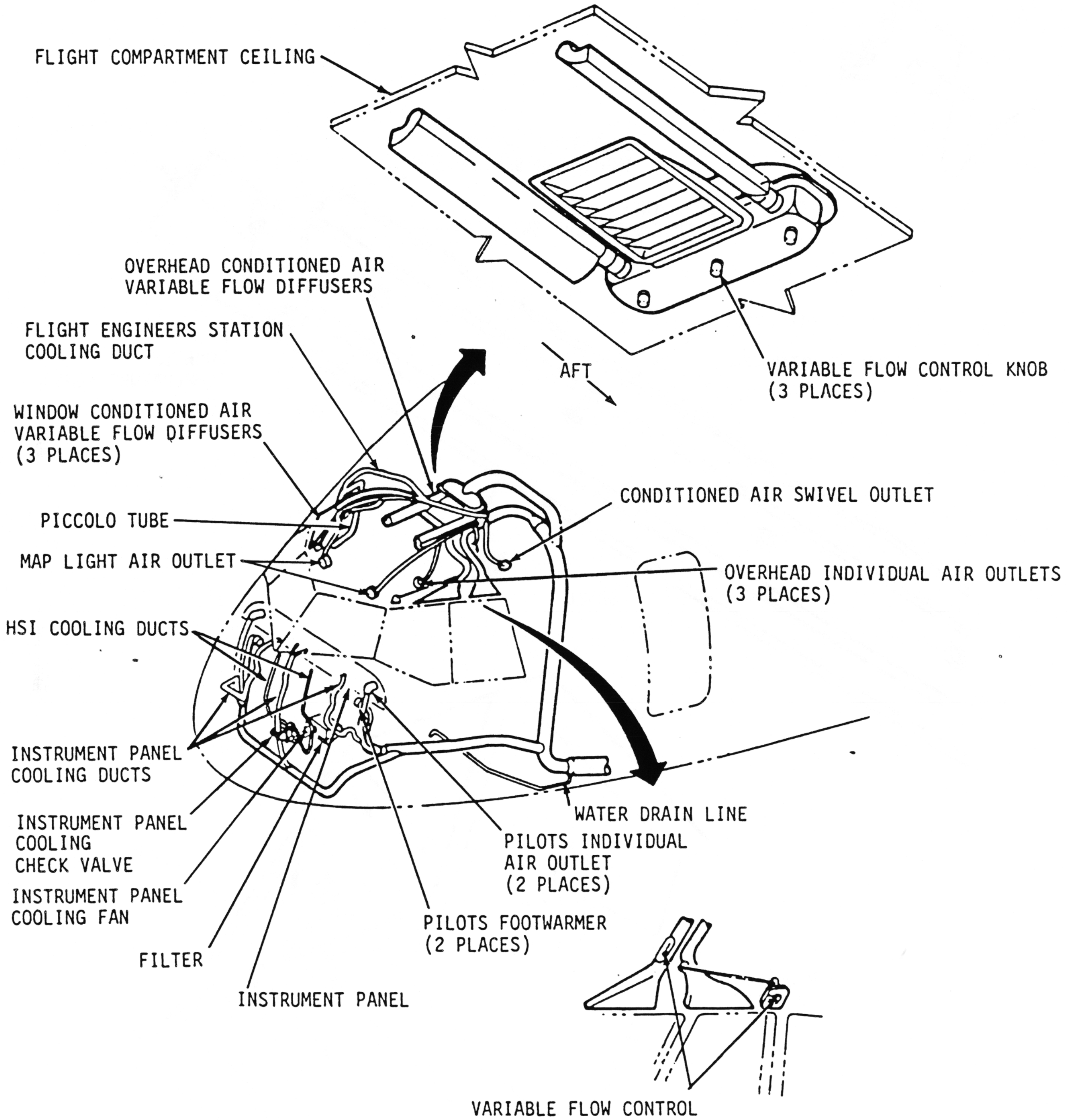


FIGURE 9-8. DC-10 FLIGHT DECK DISTRIBUTION

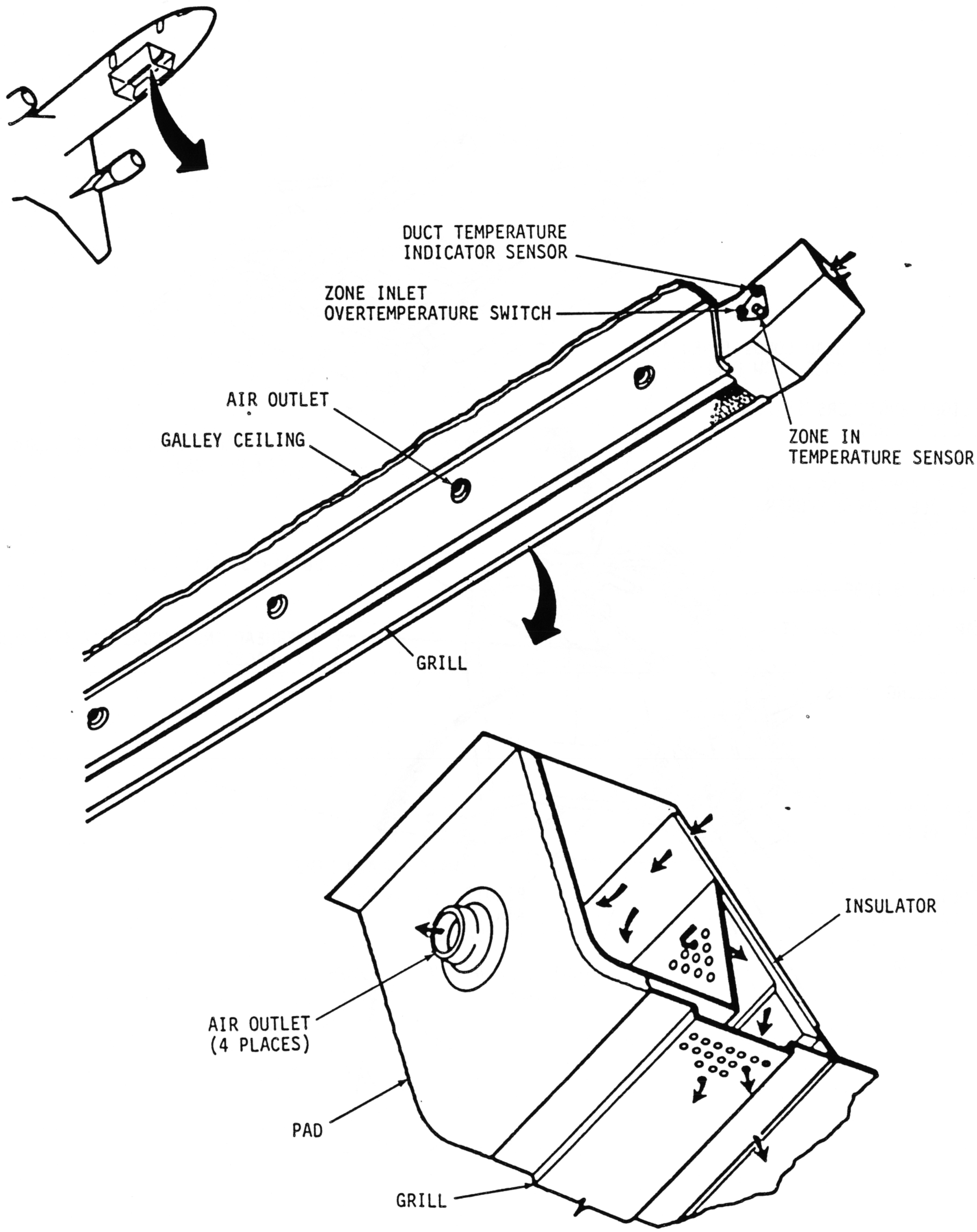


FIGURE 9-9. DC-10 LOWER GALLEY DISTRIBUTION

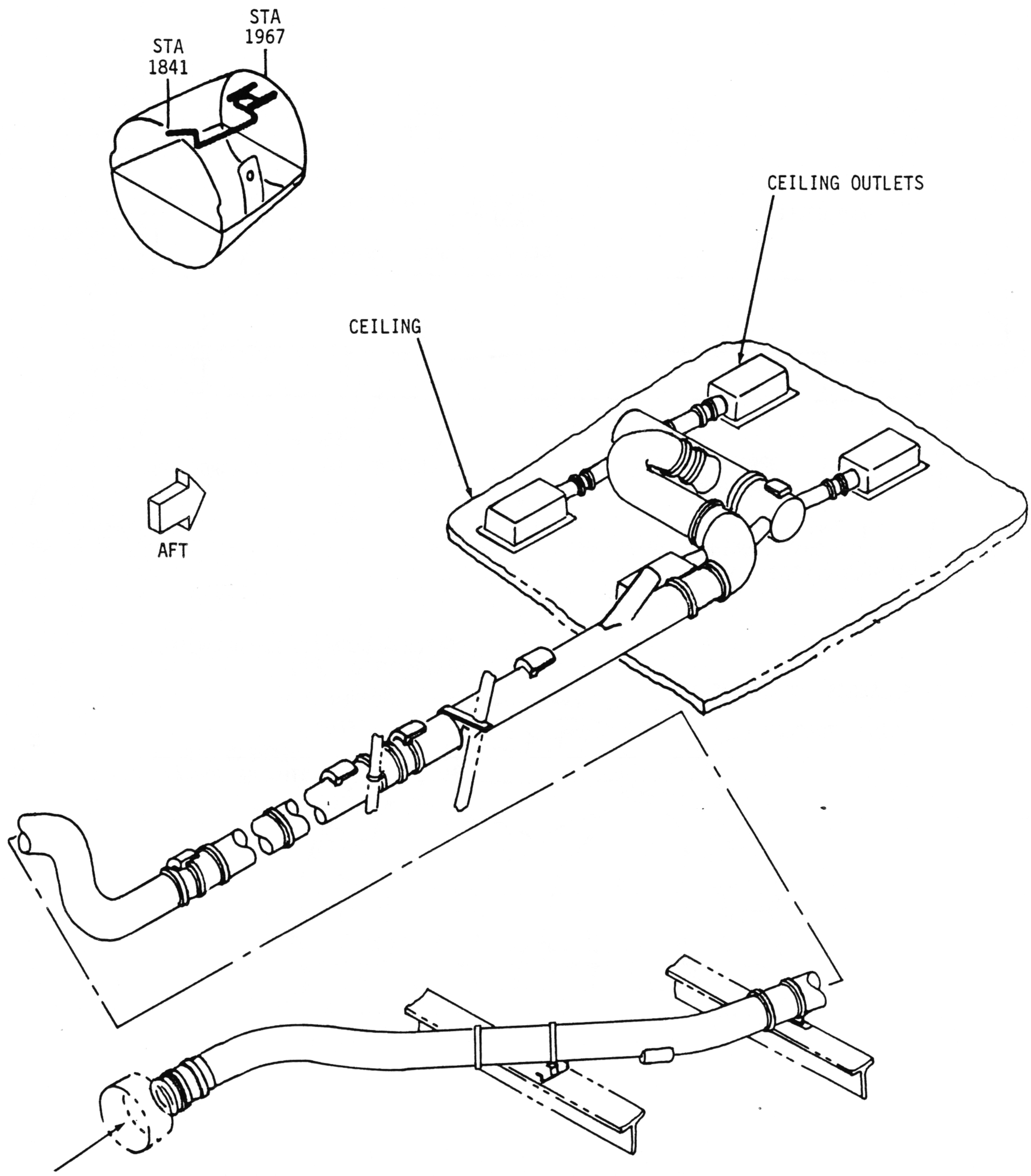
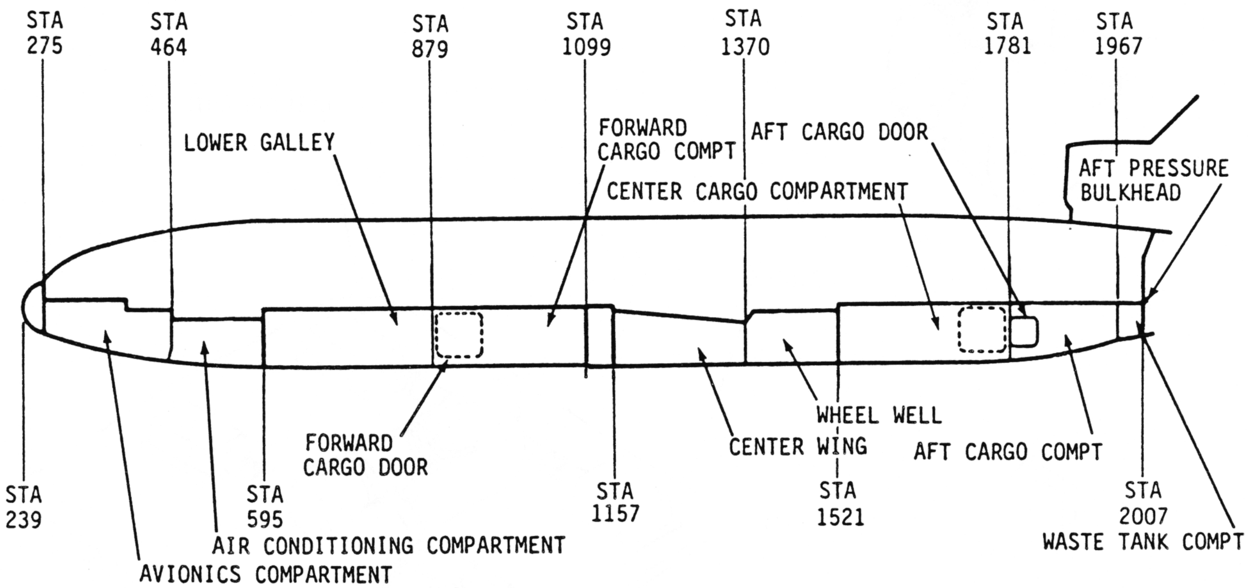
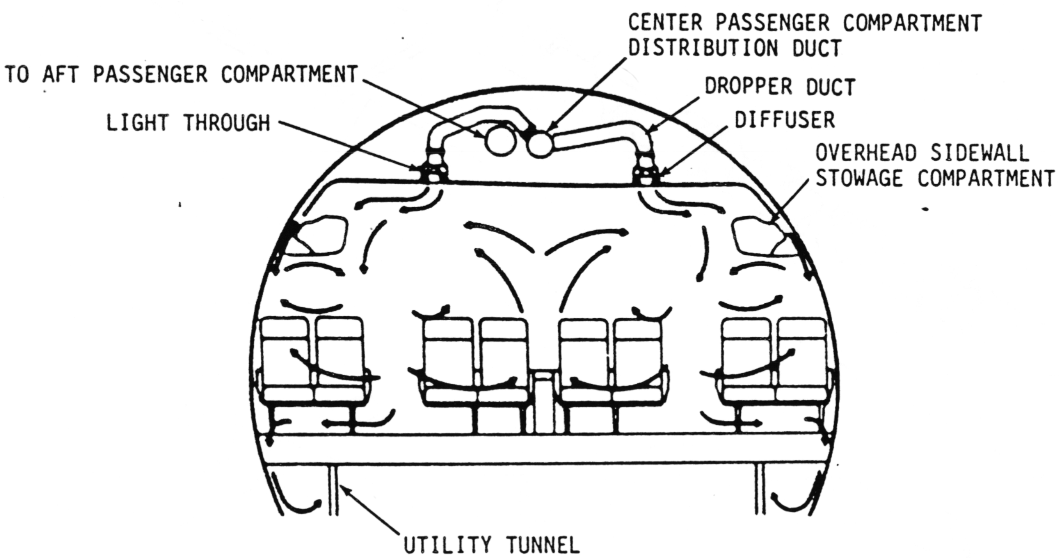


FIGURE 9-10. DC-10 AFT GALLEY AIR DISTRIBUTION





PASSENGER CABIN AIR CIRCULATION
(TYPICAL ALL PASSENGER COMPARTMENTS)

FIGURE 9-11. DC-10 PASSENGER CABIN AIR FLOW PATTERNS

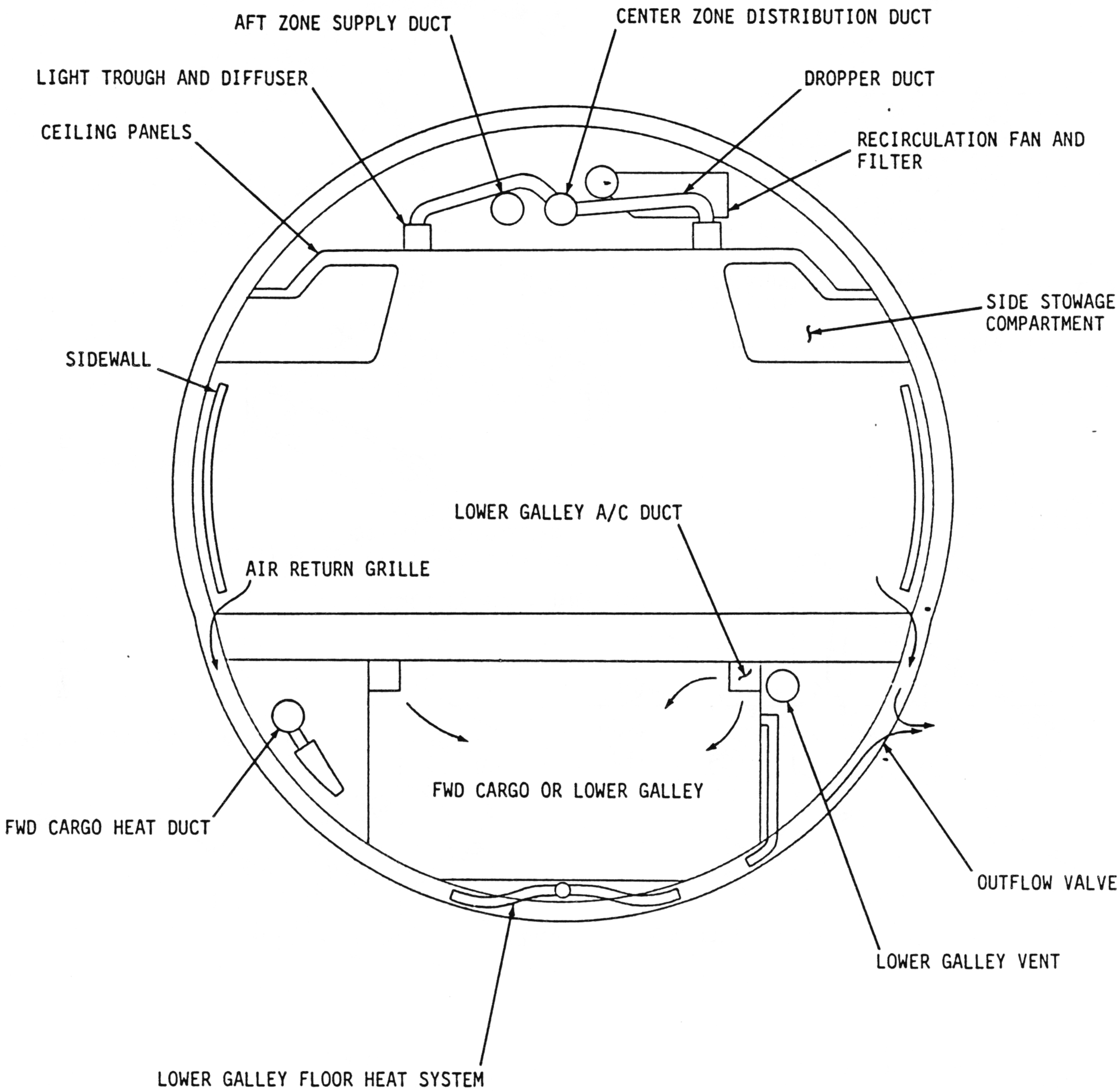


FIGURE 9-12. DC-10 PASSENGER CABIN CROSS SECTION

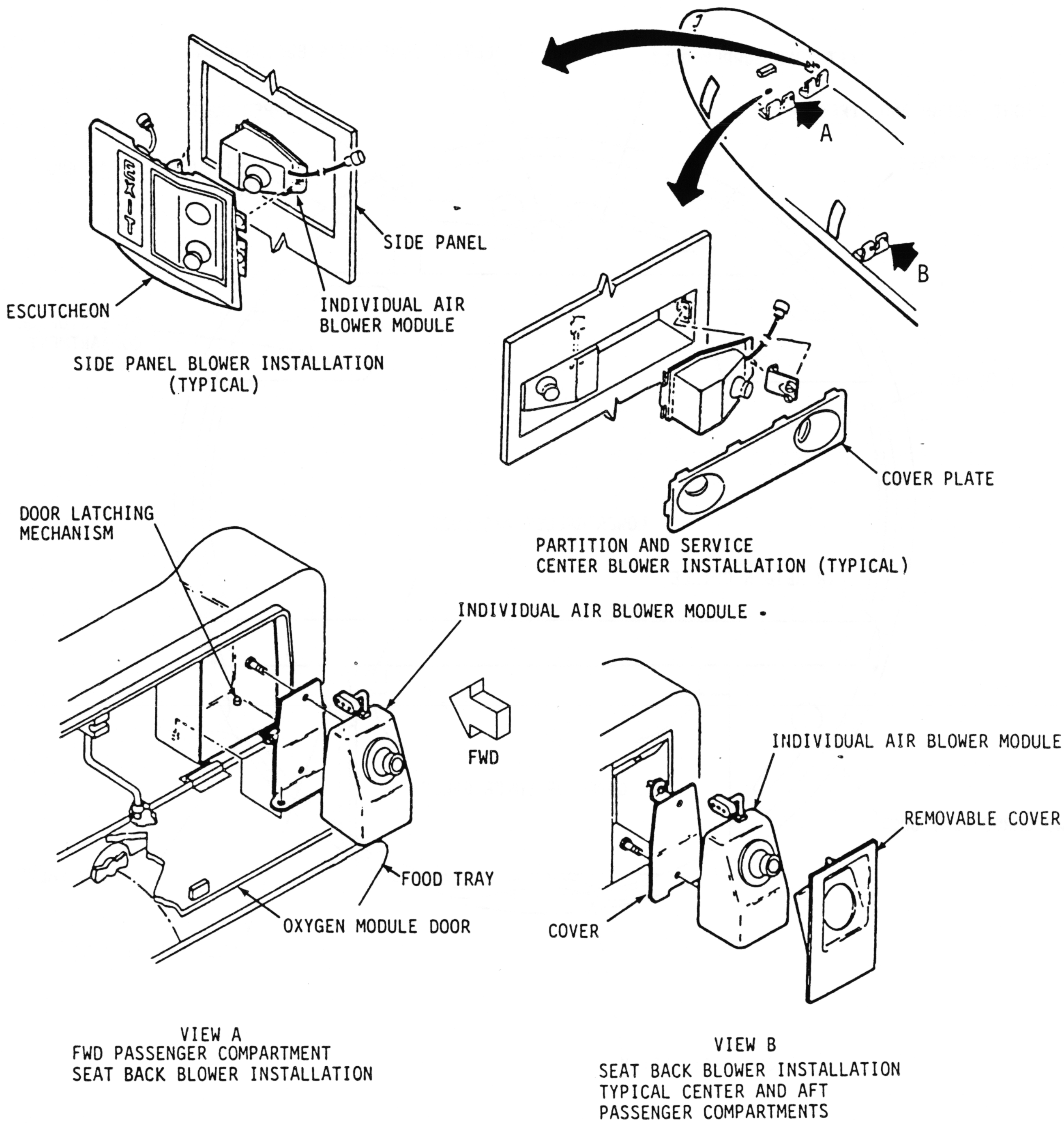


FIGURE 9-13. DC-10 INDIVIDUAL AIR BLOWERS

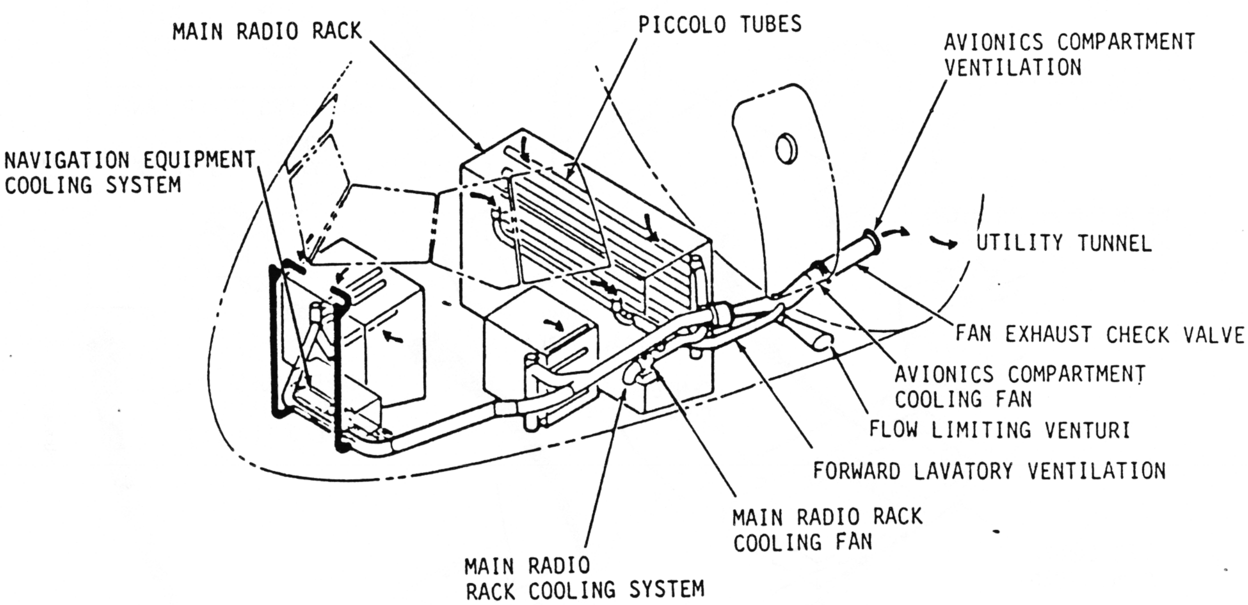
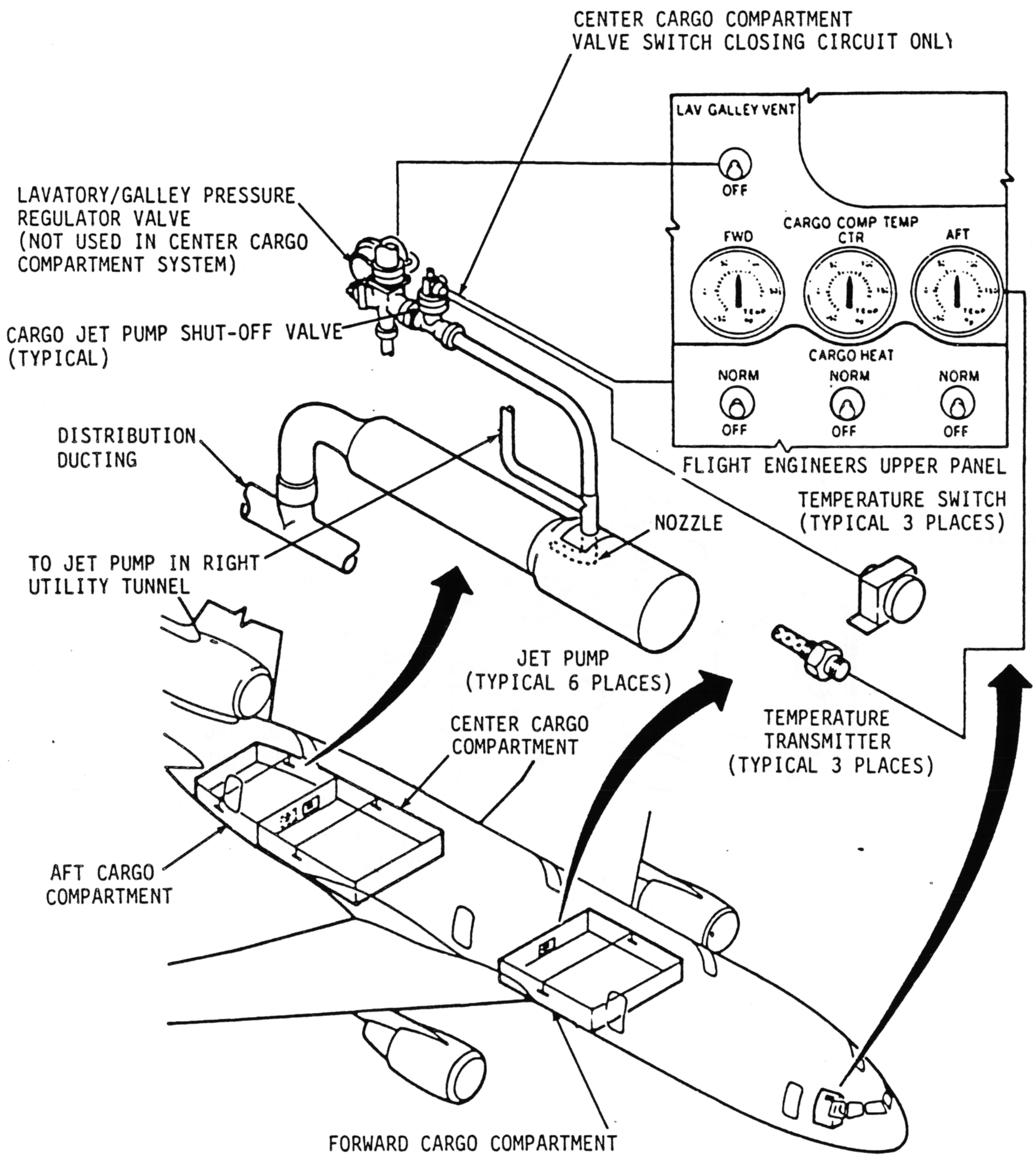


FIGURE 9-14. DC-10 EQUIPMENT COOLING



NOTE: CARGO COMPARTMENT HEATING SYSTEM
IS TYPICAL FOR ALL CARGO COMPARTMENTS
EXCEPT AS NOTED

FIGURE 9-15. DC-10 CARGO COMPARTMENT HEATING SYSTEMS

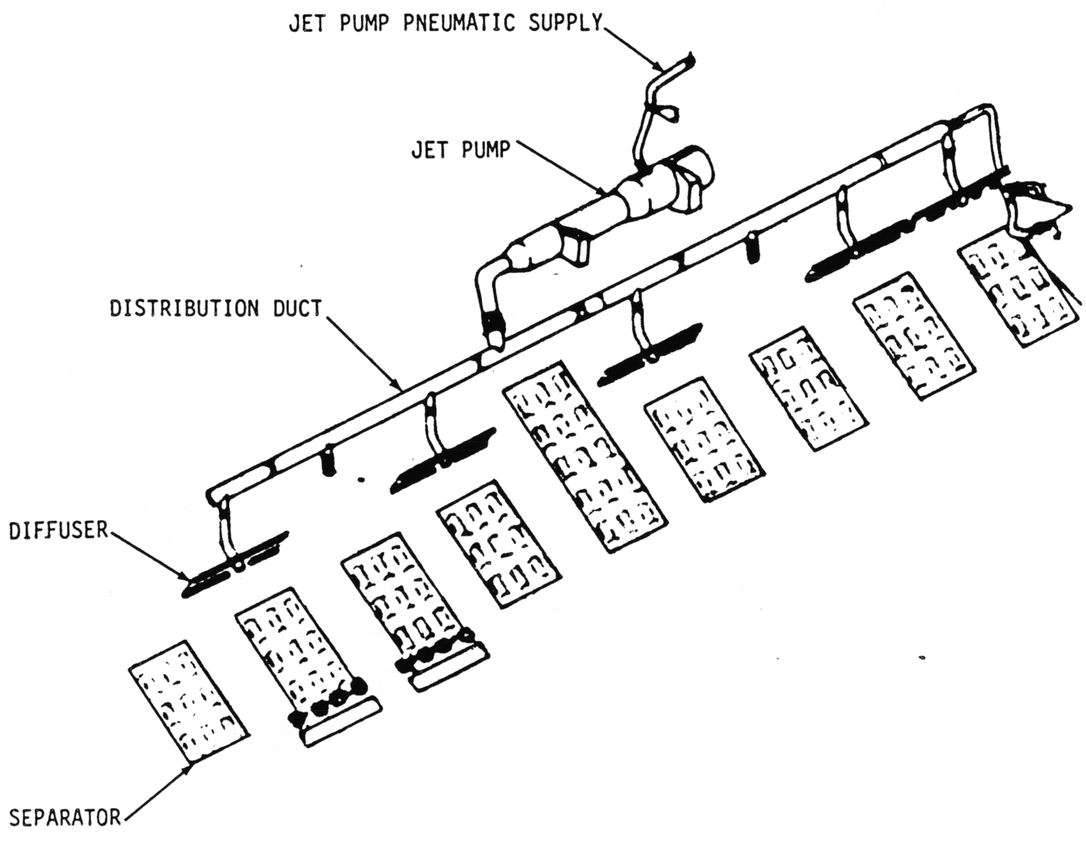


FIGURE 9-16. DC-10 TYPICAL CARGO HEAT DUCTING

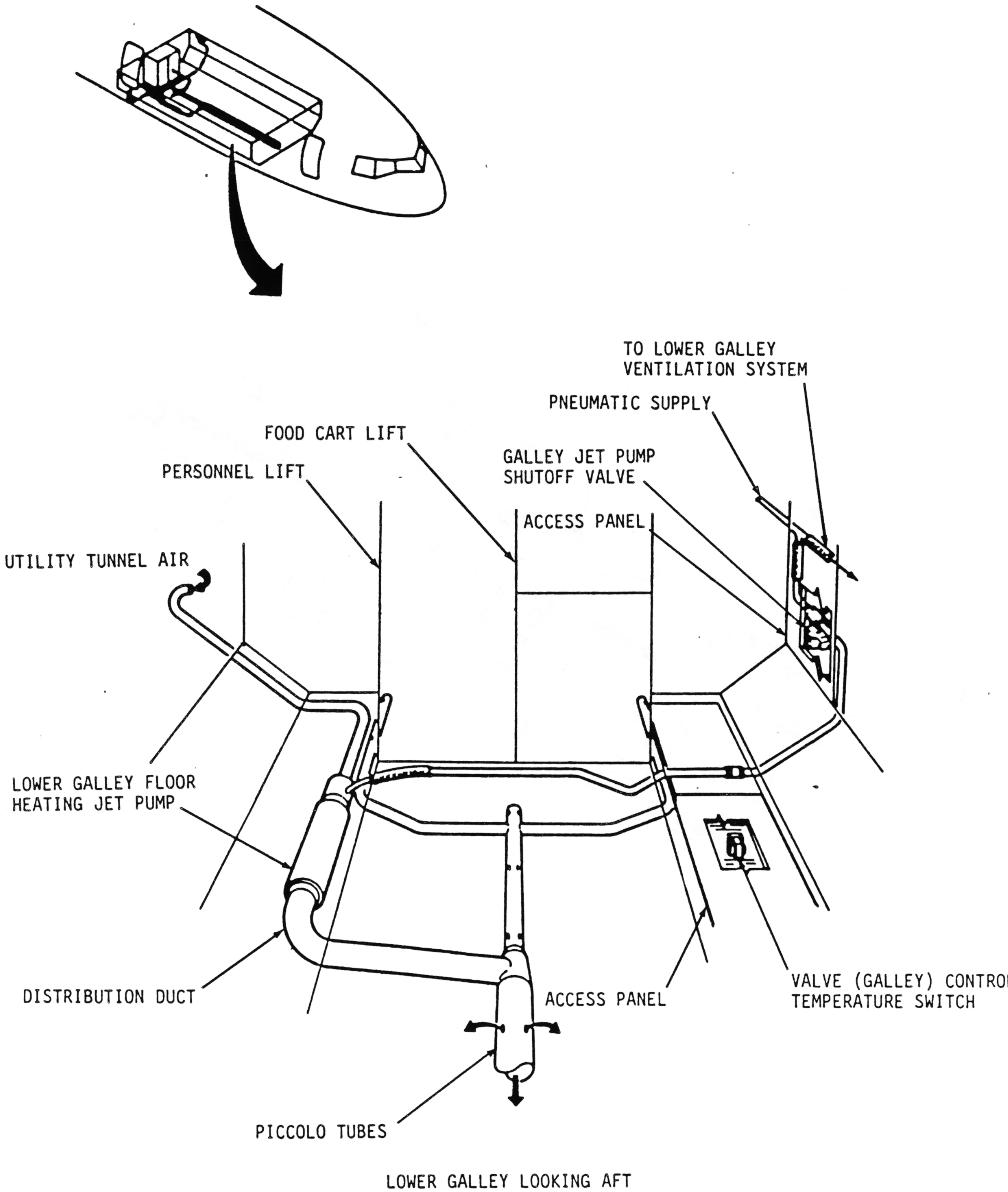


FIGURE 9-17. DC-10 LOWER GALLEY FLOOR HEATING

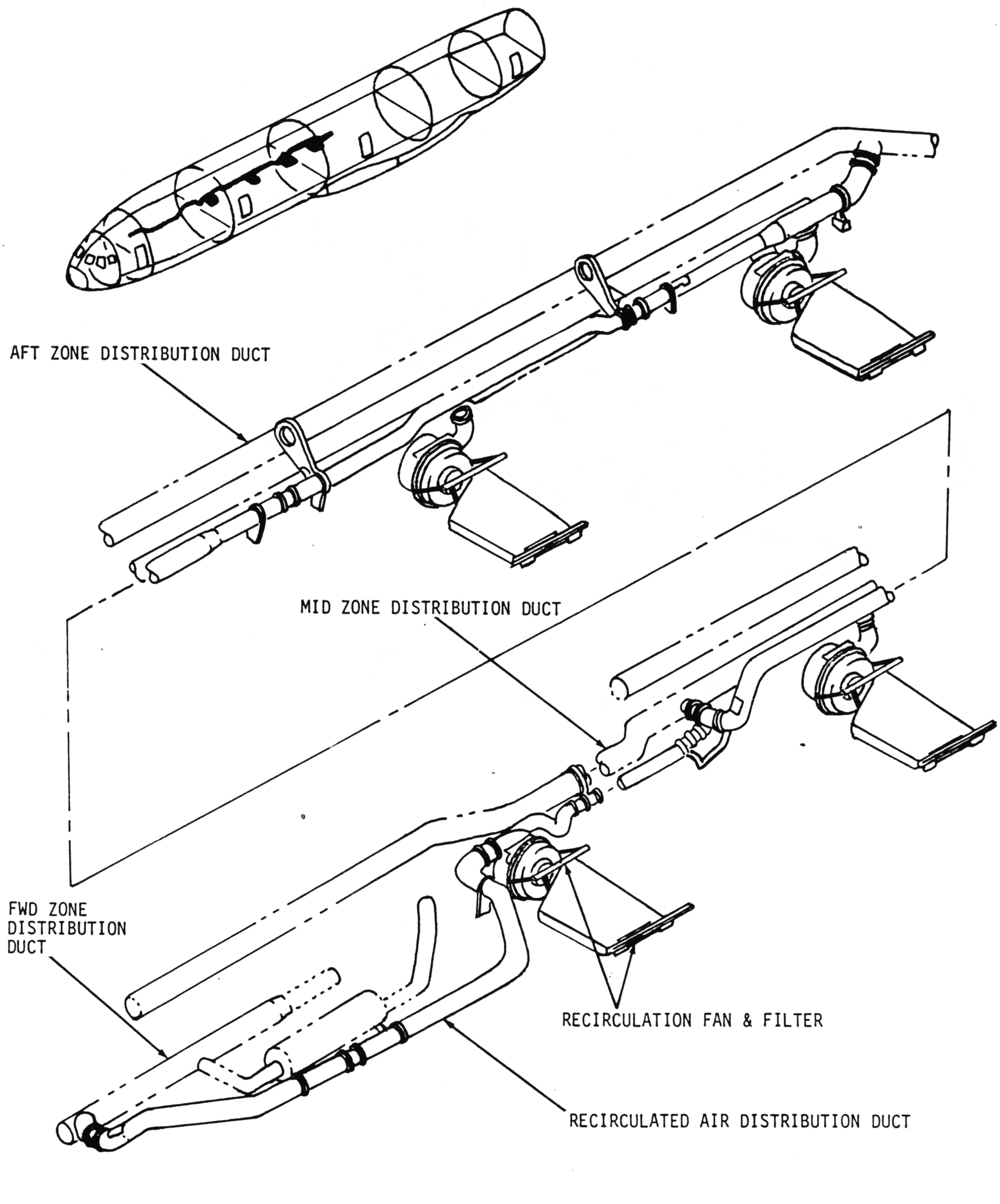


FIGURE 9-18. DC-10 PASSENGER CABIN RECIRCULATION SYSTEM

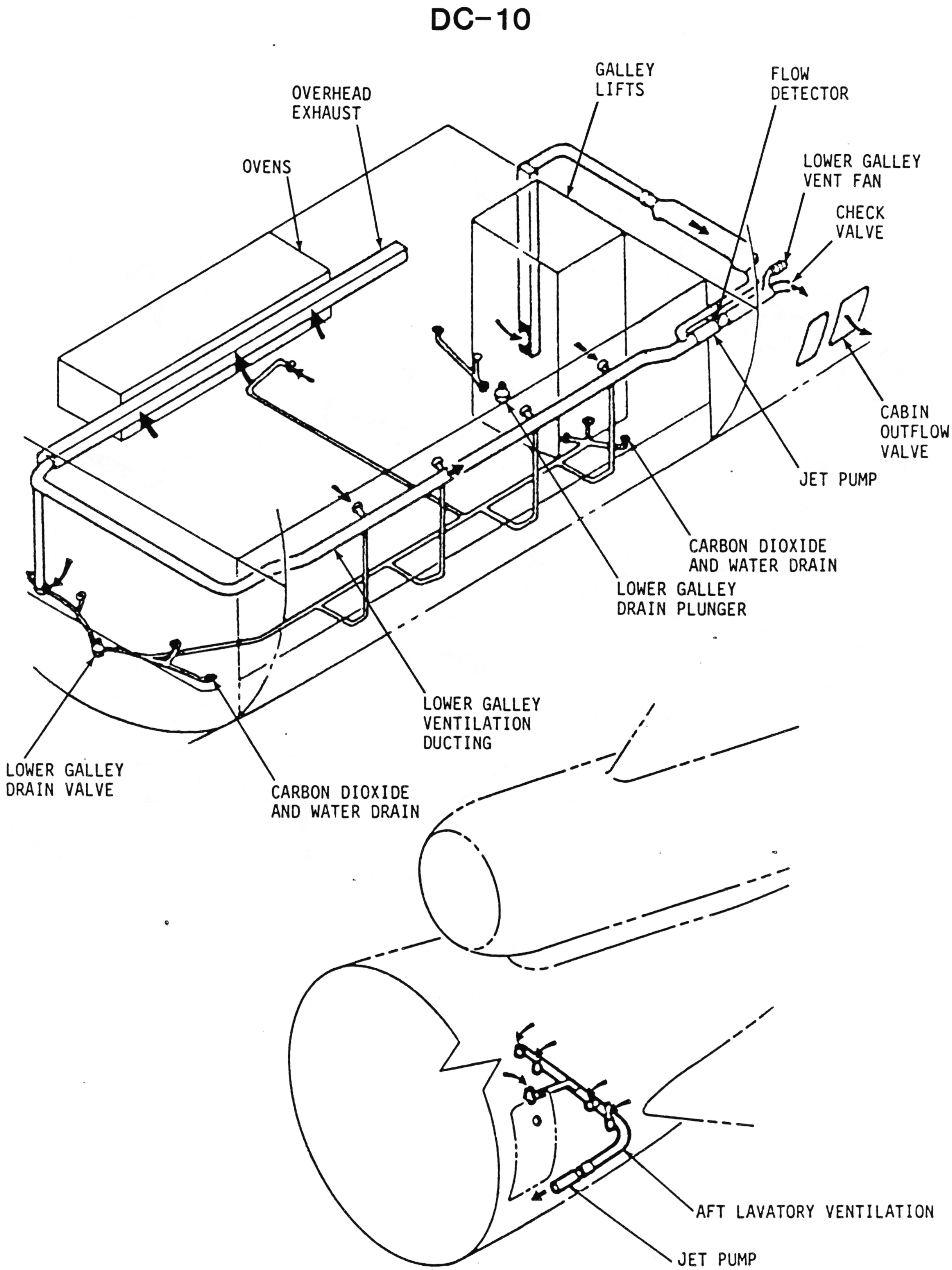


FIGURE 9-19. DC-10 LOWER GALLEY AND AFT LAVATORY VENT

DC-10

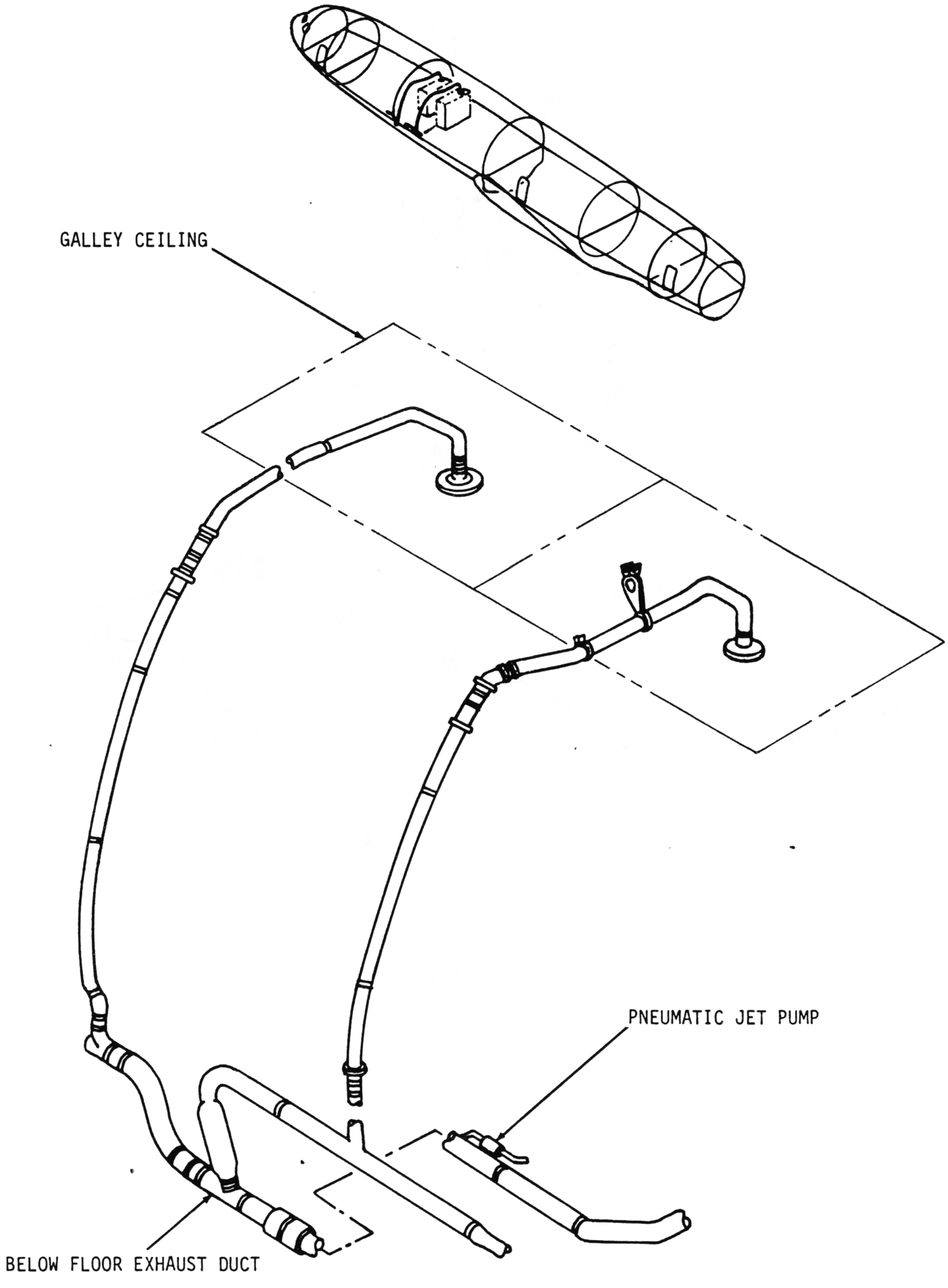


FIGURE 9-20. DC-10 CENTER GALLEY VENT

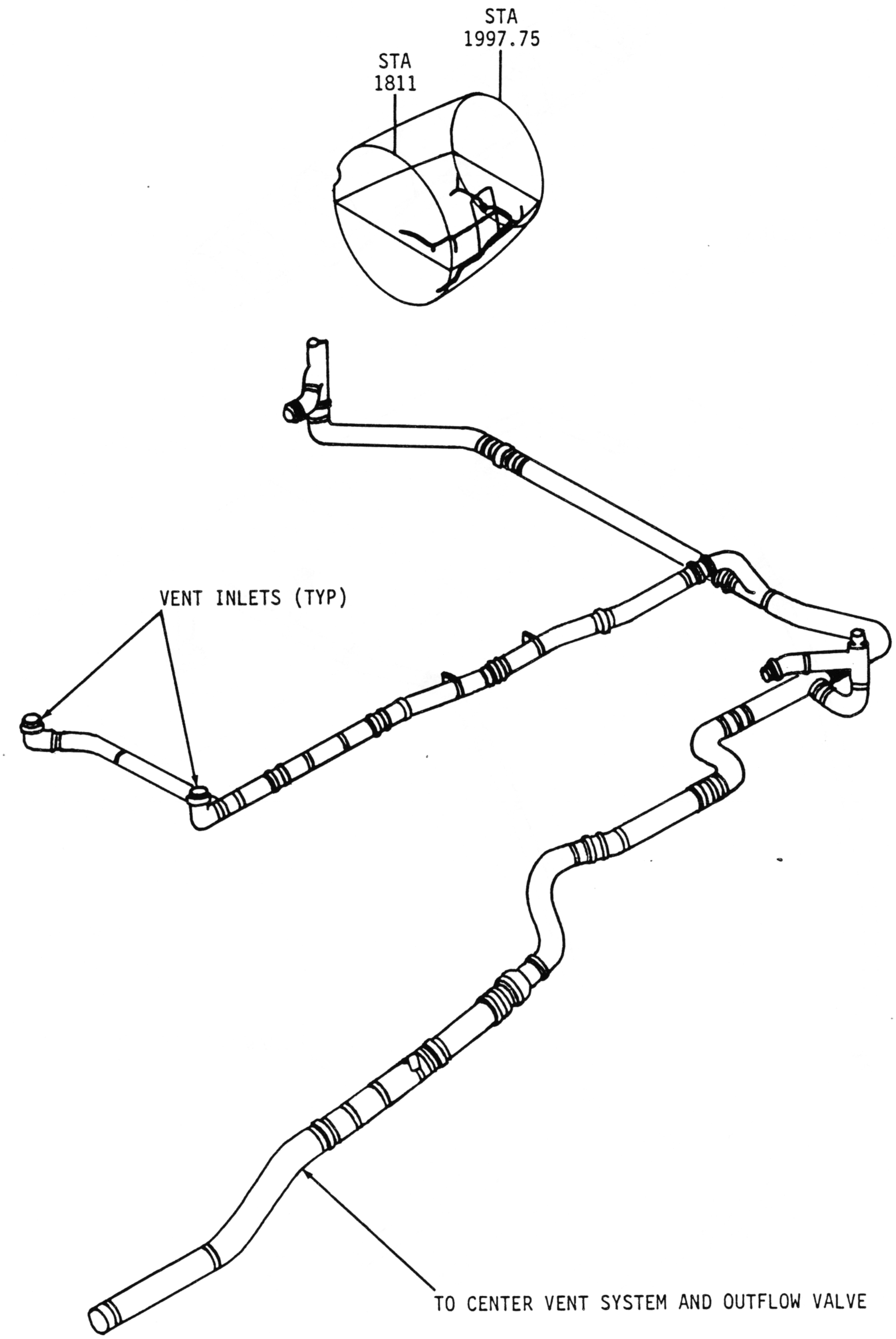
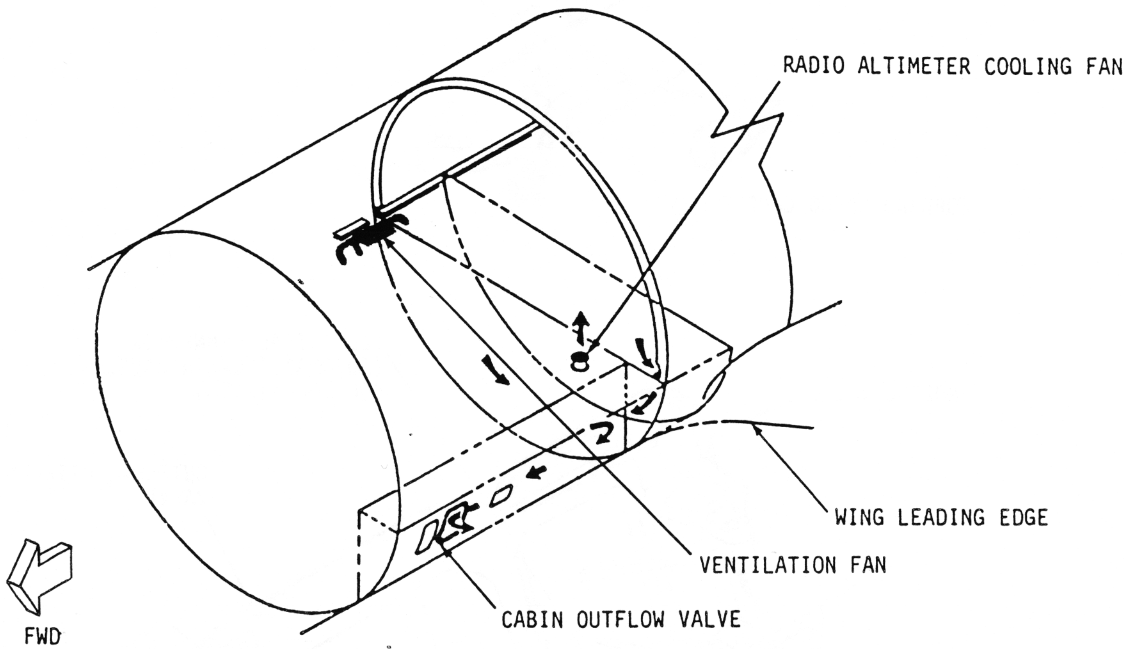


FIGURE 9-21. DC-10 AFT LAVATORY VENTING



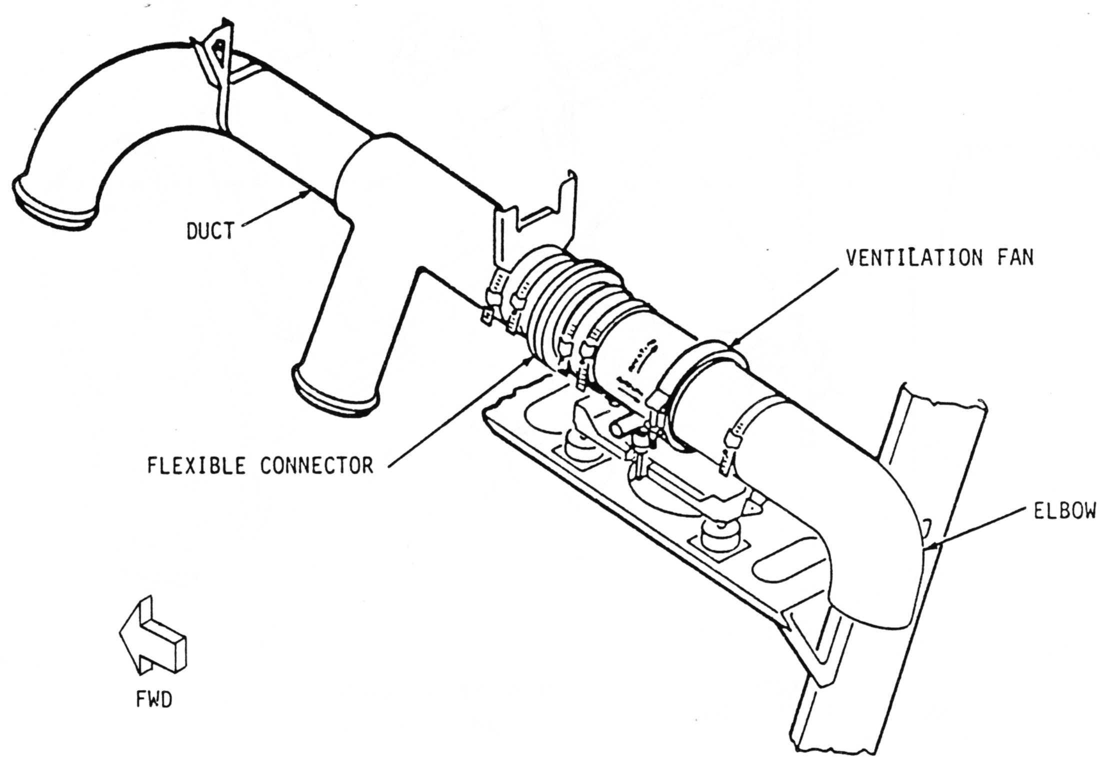
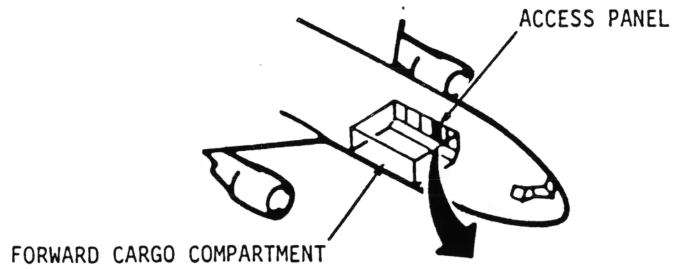


FIGURE 9-22. DC-10 CENTER ACCESSORY COMPARTMENT VENTILATION



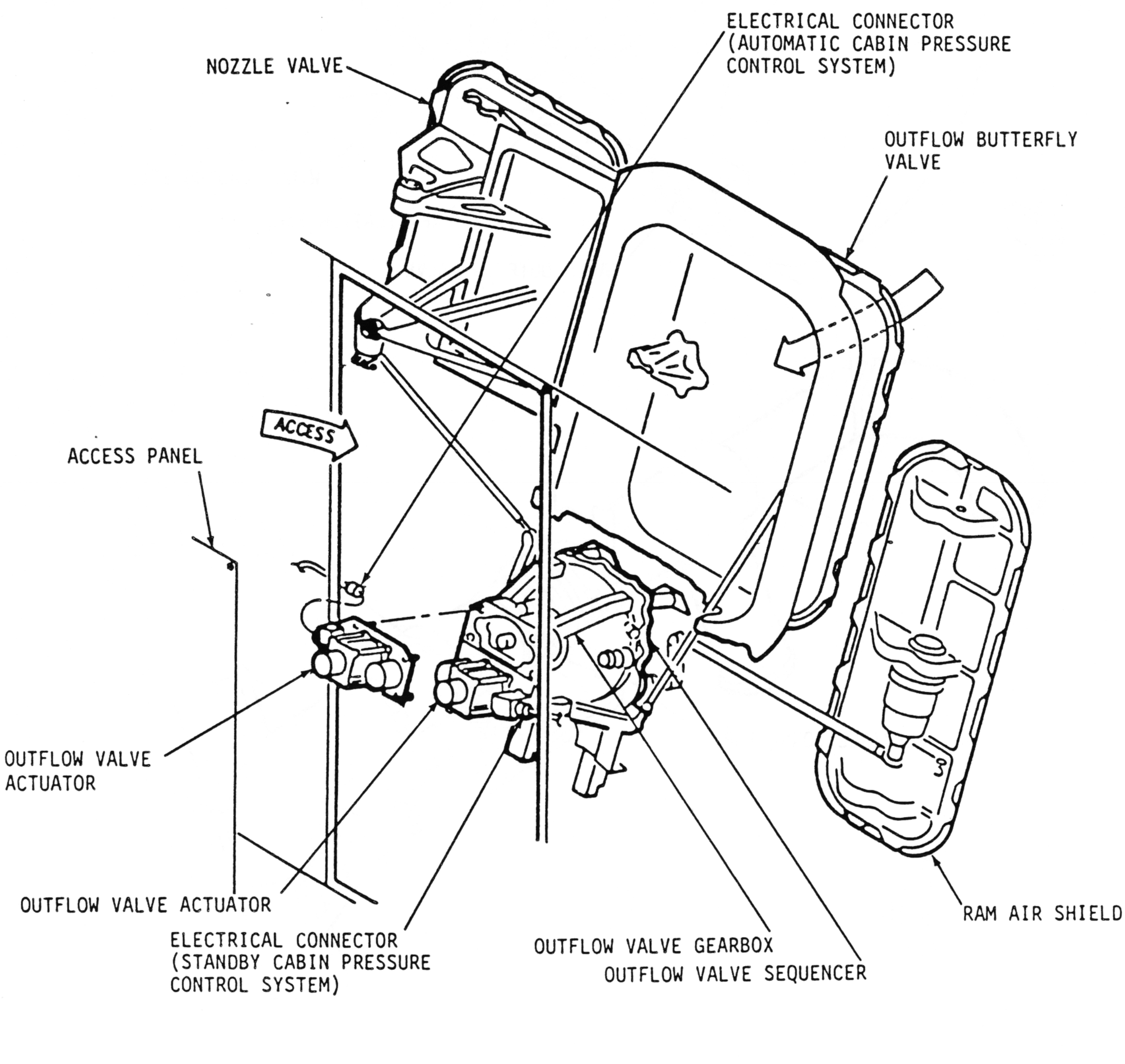


FIGURE 9-23. DC-10 PRESSURIZATION OUTFLOW VALVES

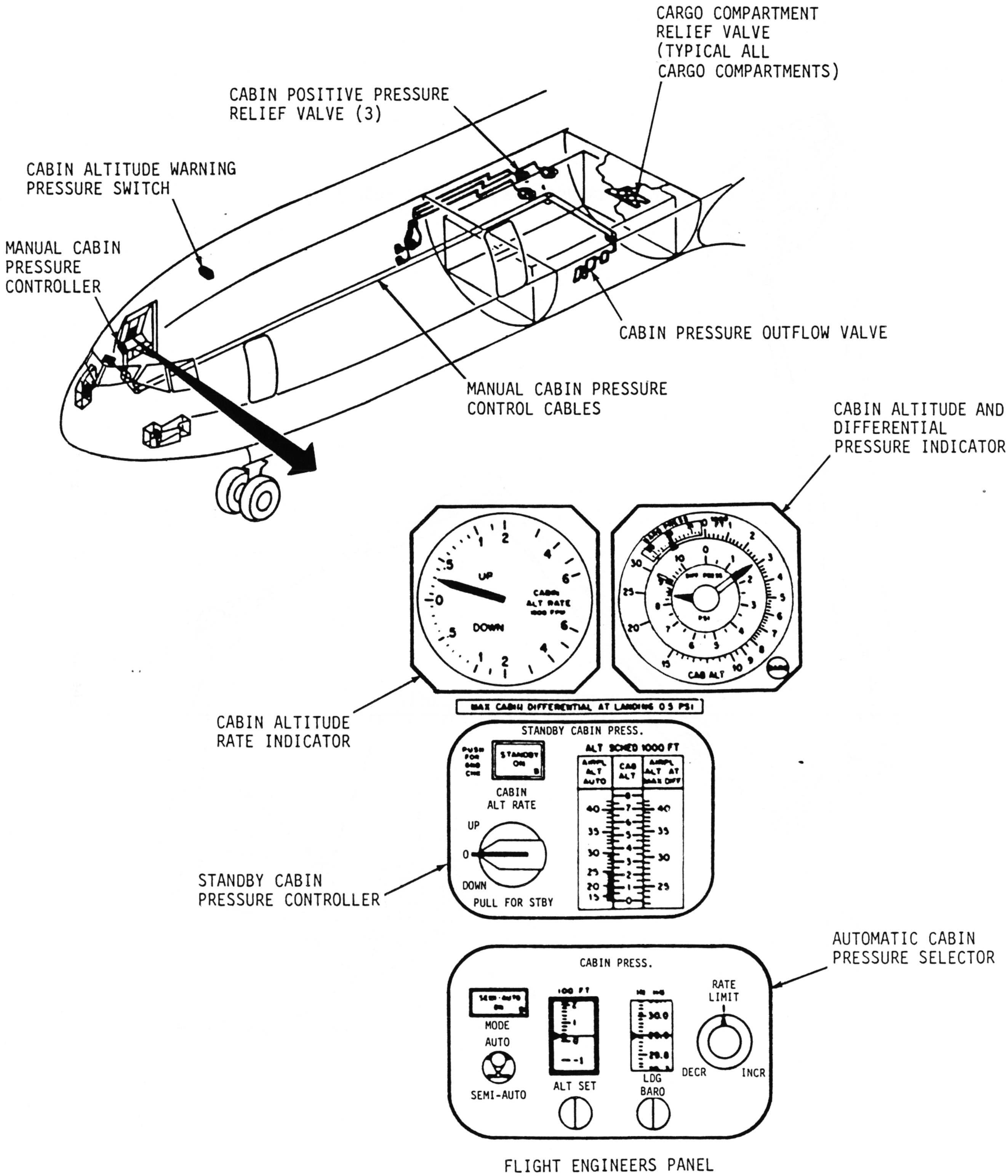


FIGURE 9-24. DC-10 PRESSURIZATION CONTROL PANEL

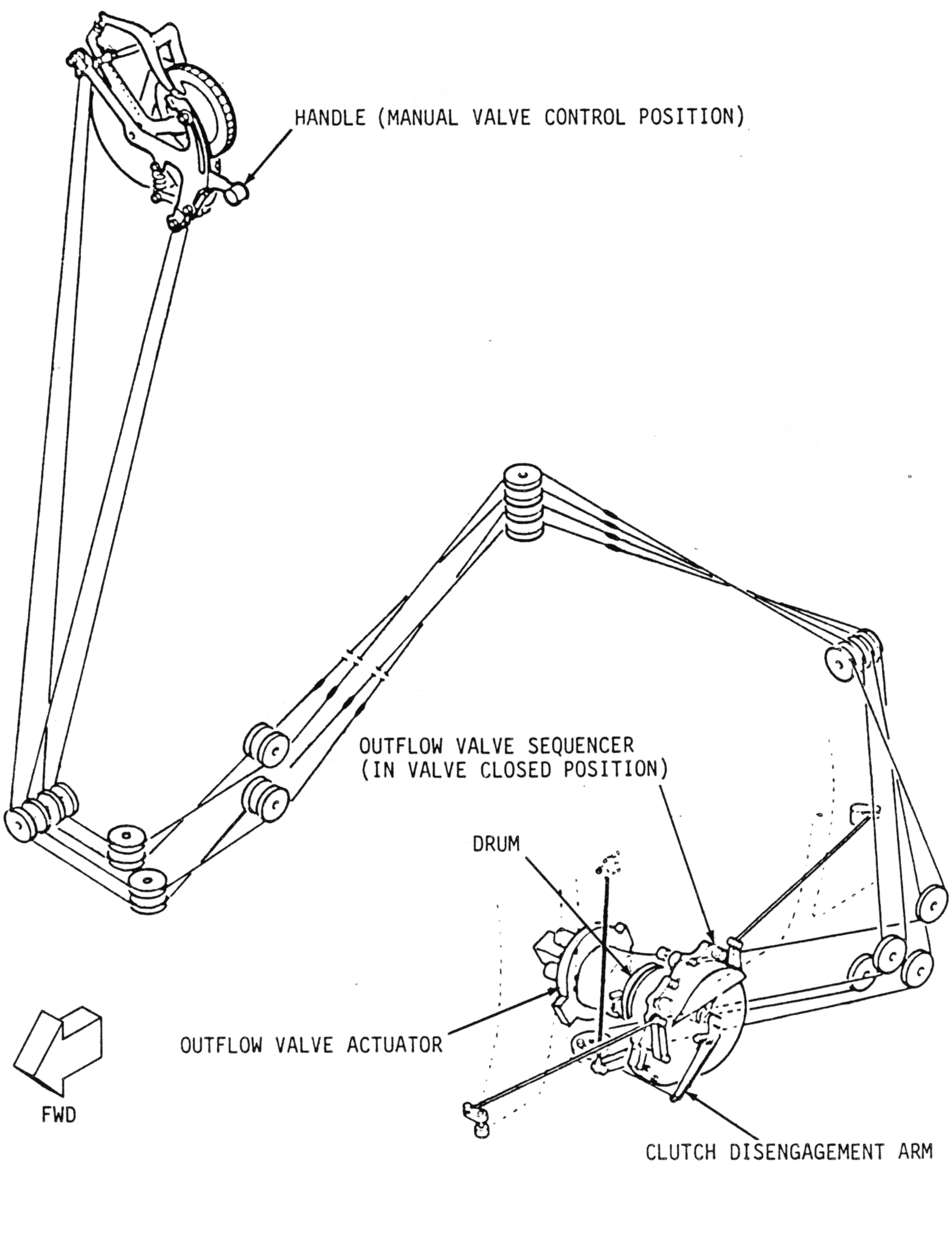
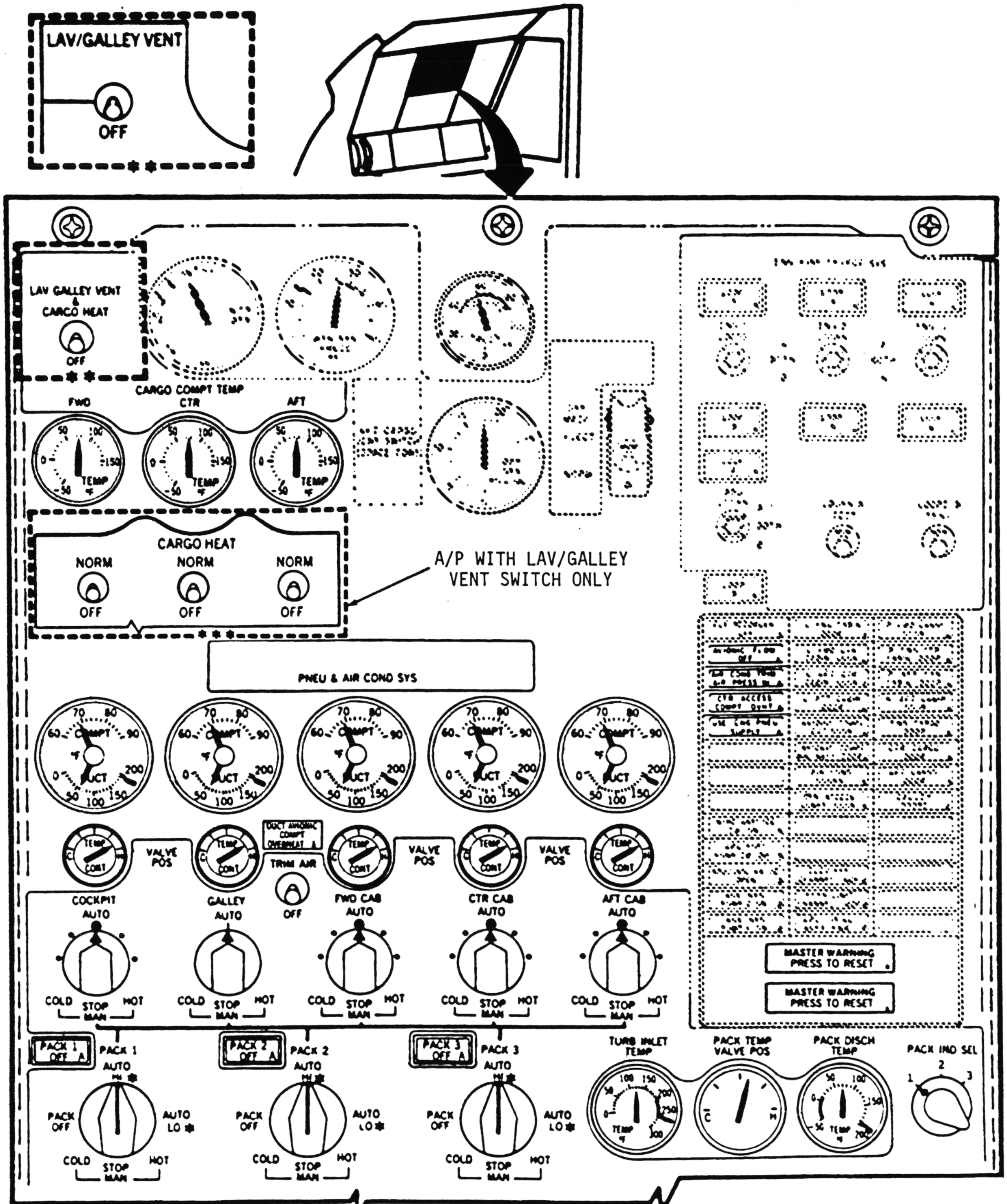


FIGURE 9-25. DC-10 MANUAL OUTFLOW VALVE CONTROL



*RECIRCULATION SYSTEM AIRPLANES ONLY

FIGURE 9-26. DC-10 ECS CONTROL PANEL

SECTION 10

AIRBUS INDUSTRIE A300

Model Variation

Airbus Industrie was formed in 1970, as a result of negotiations over the previous five years, to bring together four of Europe's leading aircraft manufacturers. This resulted in the most cost-effective technologically efficient method for the European manufacturers to compete with larger American companies.

Early discussions between the member companies revealed that about 60% of the world's airline traffic flies routes of less than 2,500 miles. It was recognized that this short-to-medium range market was not being served well by current aircraft types, and short-range-optimized wide-body aircraft were virtually nonexistent.

The A300 was, therefore, sized and configured to serve high density short-to-medium range markets. The A300 was produced in six models, the major variation being gross weight and engine choice. A summary of first flight dates and number produced for A300 variants is shown in Table 10-1. The air conditioning and pressurization systems are the same for all models, with the exception of the -600 model. The -600 model was fitted with a new Environmental Control System (ECS) that has two significant differences; recirculation capability, and adjustable flow-control valves. Due to the limited numbers of -600 models in service, the information on this model was generally unavailable. All available information is included herein.

A300 Environmental Control System (ECS)

The A300 ECS is a two pack air cycle system that uses bleed-air as the air source. A schematic of the system is shown in Figure 10-1. The air-conditioning packs are located below the wing in an unpressurized area of the fuselage just forward of the wheel well. The air-conditioning packs utilize engine bleed-air from the intermediate and high-pressure compressor stages of both engines as an air source. During ground operations, the APU or a pneumatic ground cart may be used as the air source. A schematic of the pack is shown in Figure 10-2. Pressures and temperatures at Points A through E on Figures 10-2 and 10-3 are listed in Table 10-2 for -100, -200, and -300 models, and Table 10-3 for -600 models.

The hot bleed-air temperature and pressure are regulated by the pneumatic system before being supplied to the flow-control valve. The flow-control valve is an electrically controlled pneumatically operated valve that acts to minimize variation in volumetric flow rate in response to changing cabin and pneumatic system pressures. The rate control valve allows the flow-control valve to respond to rapid fluctuations in supply pressure without affecting downstream conditions.

Air leaving the flow-control valve is routed to the trim air system, air cycle machine (ACM) compressor, anti-ice valve, and compressor bypass valve. The trim air system adds a controlled amount of hot air to the supply ducting of each zone to adjust the supply temperature as required by the zone temperature control system. The anti-ice valve allows a small amount of hot air to bypass the ACM to prevent ice formation in the turbine outlet and water separator. The valve is controlled by differential pressure (indicating ice formation) across the anti-ice screen. The compressor bypass valve allows air to bypass the compressor when the cooling demands are low (and hence the turbine is rotating slowly) to increase system efficiency.

The ACM compressor is driven by air expanding in the ACM turbine, and raises the supply air to higher temperatures and pressures. Air leaving the compressor is routed to the heat exchanger where it is cooled by ram air. The air is expanded in the ACM turbine to produce cold air at the turbine outlet. The turbine bypass valve regulates the amount of air bypassing the turbine to regulate the temperature and quantity of cold air supplied to the cabins. Cold air leaving the turbine is routed to the water separator. The water separator removes entrained moisture droplets from the turbine discharge air to regulate the relative humidity in the cabin within acceptable limits. Air leaving the water separator is routed to the cold air manifold for distribution to the various compartments. The cold and hot air distribution manifolds are shown in Figure 10-3.

Distribution

Air entering the cold air manifold is divided and routed to the flight deck, passenger cabin and individual air distribution systems.

The passenger cabin is divided into three zones; forward, mid, and aft. Each zone has separate supply and distribution ducting.

The forward cabin distribution system is shown in Figure 10-4. The distribution system is supplied from the cold air manifold by a riser located behind the right sidewall just aft of the number 2 passenger door. The riser supplies conditioned air to the distribution ducting located above the ceiling and stowage compartments. The forward cabin distribution supplies air outlets located above the stowage compartments, in the forward lavatories and galleys, and over the forward and mid passenger doors. A typical stowage compartment outlet is shown in Figure 10-5. The outlets are configured so that air exhausted above the stowage compartment draws air from below the compartment, up behind the compartment, mixes it with the fresh air, and exhausts the mixture above the compartment.

The mid and aft cabin distribution systems are shown in Figure 10-6. The mid cabin distribution system is supplied by a riser located behind the left sidewall aft of the mid passenger door. The mid cabin distribution ducting is located above the ceiling and stowage compartments, and supplies outlets located above the stowage compartments. The mid cabin zone extends from the mid cabin passenger door to just aft of the trailing edge of the wing. The aft cabin distribution ducting is supplied by a riser located behind the right-hand sidewall just aft of the mid cabin passenger door. The distribution ducting is located above the ceiling, and supplies the same types of outlets as the forward and mid cabin distribution systems; outlets located above the aft passenger doors, and in the lavatories and galleys.

The flight deck distribution system is shown in Figure 10-7. The flight deck distribution system is supplied from the cold air manifold by a duct running forward below the left-hand floor. The supply duct also routes air to the electronics racks to provide blow-through ventilation. The distribution system supplies windshield outlets, instrument panel outlets for the captain, and first officer, an underseat outlet for the captain and overhead outlets for the flight engineer and observer. Airflow from the overhead and instrument panel outlets can be adjusted for flow and direction. In addition, the airflow regulating valve can be used to regulate the flow from the supply duct to the distribution system. The airflow valve is controlled by a switch located on the flight engineer's upper panel.

The air conditioning distribution systems in the forward and aft cabins also supply supplemental air to the forward, mid, and aft lavatories and galleys. The forward system has a fan that draws air from the forward zone air-conditioning system ducts, and exhausts air into the forward lavatories, and the forward and mid cabin galleys.

The aft system works in the same manner, and supplies additional air to the aft cabin lavatories and galleys.

The fans are controlled from the cabin attendant panels, and are used at the flight attendant's discretion. The supplemental system is shown in Figure 10-8.

In addition to conditioned air, the distribution system has provisions for admitting ram air into the cold air manifold. The inlet may be opened when the air-conditioning packs are operating, but only when the cabin differential pressure is less than one psi. Opening the ram air inlet automatically causes the four pressurization outflow valves to fully open. The ram air inlet is shown in Figure 10-9.

A cross-section view showing ducting arrangement is shown in Figure 10-10. airflow patterns produced in the passenger cabin are shown in Figure 10-11.

Airflow rates entering the respective compartments are shown in Table 10-4 and 10-5, and air change rates are shown in Table 10-6 and 10-7. Compartment volumes are listed in Table 10-8.

Individual (Gasper) Air Distribution

The individual air system provides each passenger with a source of cold fresh air that may be used to further ventilate the passenger's personal space.

The gasper system is supplied with air at the pack discharge temperature, and is somewhat cooler than air supplied to the air-conditioning system. The gasper system is supplied by a riser located behind the left sidewall just aft of the mid cabin passenger door. The distribution system consists of a main duct located above the ceiling to the left of centerline, and running the length of the passenger cabin. This main duct supplies air to branch ducts located behind the stowage compartments which, in turn, route air to outlets located below the stowage compartments. The gasper distribution system is shown in Figure 10-12.

The flight deck does not have a separate gasper air system, but is provided with gasper style outlets supplied by the air conditioning ducting.

Equipment Cooling

The A300 uses blow-through and draw-through methods of equipment cooling. The equipment cooling system is shown in Figures 10-13 and 10-14.

The blow-through cooling system supplies air from the flight deck air-conditioning supply line to the forward instrument panels, and left and right electronic equipment racks. On some airplanes, the flow from the supply duct is regulated by a valve that is controlled from the flight engineer's panel, and is designated as the rack valve. On others, this valve is replaced by a check valve. These valves prevent flow of air from the electronics rack into the supply duct when the blower is used to supply blow-through cooling. The equipment cooling blower is used to draw cabin exhaust air into the blow-through system during ground maintenance, or when the packs are not operating. The blower is controlled from the flight engineer's panel.

The draw-through system functions as a part of the forward extraction system. The forward instrument panels, flight engineer's panels, and circuit breaker panels are ventilated by the forward extraction system. The forward extraction system uses an extractor fan or cabin differential pressure to draw cabin exhaust air through the equipment and electronics racks, and into the extractor manifolds. The extractor fan is used to draw in air when cabin-to-ambient pressure differential is between zero and one psi. Above one psi, the fan shuts off, and flow is driven through the system by differential pressure. The fan may also be controlled by a switch on the flight engineer's panel. Selecting the switch to on causes the fan to operate regardless of the pressure differential.

Cooling is also supplied to the auxiliary battery boxes. At differential pressures of less than one psi, a small fan draws air from the passenger cabin, and exhausts it through the battery boxes and then overboard through a flow limiting nozzle. At differential pressures greater than one psi, flow is driven by the differential pressure. The fan is controlled by a switch on the flight engineer's upper panel marked battery fan. In the auto position, the fan responds to differential pressure. If selected to on, the fan operates continuously. The battery cooling system is shown in Figure 10-15.

Cargo Heating

The A300 cargo compartments are classified as FAR Part 25 Class C compartments. They are required to have fire detection and suppression systems, adequate means to control ventilation and drafts within the compartment, and to exclude hazardous quantities of smoke from entering the occupied areas of the airplane. The A300 has three cargo compartments; forward, aft, and bulk. All cargo compartments are heated in part by exhausting cabin air between the cargo lining and fuselage skin; in addition, the forward and bulk compartments have supplemental heating systems.

The forward and bulk cargo compartments are heated in the same manner. The cargo compartment heating systems use the aft extraction system to draw air through outlets in the right-hand cargo lining. This causes air to be drawn into the compartment through inlet ducting outlets in the left-hand lining. The inlet duct draws in cabin exhaust air, and adds hot air from the pneumatic system to adjust the air temperature. The bulk system also exhausts hot pneumatic air below the compartment to heat the floor.

The compartment temperature can be controlled automatically or manually. When using the auto mode, the desired compartment temperature is selected, then automatic controls add the correct amount of hot air to maintain the set temperature. The forward system can be set between 41-72 °F, and the bulk system can be set between 41-79 °F. When using the manual mode, the temperature selector can only adjust the temperature to be colder or warmer by adjusting the pneumatic air valve position. Gauges are provided to indicate compartment temperature and position of the temperature control valve. The forward and bulk cargo heating systems are shown in Figures 10-16 and 10-17.

The aft cargo compartment is heated only by passenger cabin exhaust. The aft extraction system aids the flow of air between the cargo lining and fuselage skin by removing air from below the cargo floor. The aft cargo heating provisions are shown in Figure 10-18.

In the event of smoke detection in the forward or bulk compartments, isolation valves in the supply and exhaust ducting close to isolate the cargo compartment. Overheat sensors shut off the heating system if the inlet temperature sensor reaches 165 °F.

Ventilation

Compartment ventilation is accomplished by the forward and aft extraction systems.

The forward extraction system is located below the forward cargo compartment and uses a fan or cabin differential pressure to draw air from the electronics racks, forward instrument panels, forward lavatories and galley, and mid cabin lavatory and galleys. The forward and mid galley extraction ducting is shown in Figure 10-19, and the electronics racks extraction is shown in Figures 10-13 and 10-14. The forward extraction system exhausts air into a small compartment that also contains the forward pressurization outflow valves.

The aft extraction system uses a fan or cabin differential pressure to draw air from the forward and bulk cargo compartments, and from below the aft cargo compartment. The aft system also provides ventilation to the aft galley and lavatories. The aft galley and lavatory extraction ducting is shown in Figure 10-20. The aft extraction system exhausts air into a small compartment that also contains the aft pressurization control valves.

The extraction fans are controlled by a switch on the flight engineer's panel. The switch has two operating positions; on and auto. When selected to auto, the fans respond to the differential pressure. Fans will operate when the differential pressure is less than one psi, and shut off for pressures greater than one psi. If the switch is selected to on, the fans run continuously.

Air is also vented overboard through the toilet bowl. Flow is driven overboard by differential pressure, and controlled by a flow limiting venturi. Flow through the venturi is non-adjustable. The toilet tank vent is shown in Figure 10-21.

Pressurization outflow valves are the primary means of venting air overboard. The A300 is equipped with four outflow valves; two mounted forward of the wing and two mounted aft of the bulk cargo compartment. A typical outflow valve is shown in Figure 10-22. The outflow valves are mounted in a small compartment that receives air from the extraction system, and provides a low pressure source to draw air into the extraction system when the fans are not operating. The outflow valves respond to signals generated in the pressure controller to vary the amount of air passing overboard, and maintain cabin pressure within acceptable limits.

One safety relief valve is also mounted in each outflow valve compartment. The safety relief valve prevents cabin differential pressure from exceeding 8.9 psi.

Pressurization Control

A schematic of the pressurization control system is shown in Figure 10-23. The pressurization control system modulates the outflow valves to maintain cabin pressure and altitude change rates within acceptable limits. The system has two identical controllers.

To operate the system, the crew selects which system is to be used, (designated 1 and 2). The crew inputs the desired cabin altitude, cabin altitude rate of change, and a landing barometric correction factor. The pressure controller modulates the outflow valves to avoid reaching the preset limits and ensure that the cabin is depressurized at landing. The system also provides for selection of outflow valve operating mode. The system can be set to use the two forward valves, the two aft valves, or all four outflow valves.

Indicators are provided to show cabin altitude, differential pressure and outflow valve position.

Environmental Control System (ECS) Controls

The ECS controls consist of pack operation and zone temperature controls.

The pack controls are shown in Figure 10-24. Operation of the pack is either on or off - there is no provision for varying the system flow rate. Gauges are provided to indicate the pack discharge temperature, turbine inlet temperature, and the turbine bypass valve position. Control of the pack discharge temperature can be automatic or manual. When using automatic control, the outlet temperature is determined by the zone temperature control system. When using manual control, the pack discharge temperature can be directly controlled by positioning the turbine bypass valve. Commanding colder causes the bypass valve to close, commanding hot causes the bypass valve to open.

On -600 models, the pack flow-control valve has two operating modes, economy and max cooling. Economy mode reduces the demands on the bleed-air system (and therefore increases fuel economy) to 68% of nominal full flow schedule at cruise altitudes. Selection of maximum cooling causes the pack to operate at 100% of full flow schedule.

The zone temperature controls regulate the trim air system and pack discharge temperature when the packs are operated in the auto mode. The zone temperature controls are shown in Figure 10-24. All zone controls have an automatic and manual mode. When using the auto mode, the desired cabin temperature is set on the dial and the zone temperature controller and pack temperature controller work in conjunction with the zone temperature sensors to maintain the selected temperature. When using the manual mode, the selector controls the position of the respective trim air valve. Gauges are provided to indicate the zone temperature, duct temperature and position of the trim air valve.

Electrical energy requirements of ECS components and control systems are shown in Table 10-9.

TABLE 10-1. AIRBUS A-300 PRODUCTION DATA

	FIRST FLIGHT (REF 1)	CERTIFICATION (US)	NO. PRODUCED (REF 3)
A-300 B2-100	6-28-73		32
A-300 B2-200			25
A-300 B2-300	4-28-79		4
A-300 B4-100	12-26-74		67
A-300 B4-200	12-21-79		114
A 300 B4-600	8-7-83		15

TABLE 10-2. AIRBUS A-300-100,-200,-300 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(^{o}F DRY BULB AND PSIA)

FLIGHT REGIME	A FLOW CONTROL VALVE INLET		B FLOW CONTROL VALVE OUTLET		C WATER SEPARATOR OUTLET		D FLIGHT DECK SUPPLY		E PASS. CABIN SUPPLY		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	59	346	51	346	15.5	53	14.8	52	14.8	52	14.8	75	14.7	100
5,000 FT CLIMB					DATA NOT AVAILABLE									
20,000 FT CLIMB	51	346	48	346	15.5	50	14.7	52	14.7	51	14.7	75	6.7	28
25,000 FT CRUISE					DATA NOT AVAILABLE									
30,000 FT CRUISE	42	345	39	345	12.4	50	11.7	54	11.7	51	11.7	75	4.4	-8
35,000 FT CRUISE	37	345	37	345	12.4	51	11.7	56	11.7	51	11.7	75	3.5	-26
43,000 FT CRUISE					DATA NOT AVAILABLE									
25,000 FT DESCENT	38	344	38	344	13.3	47	12.8	51	12.8	47	12.8	75	5.5	10
15,000 FT DESCENT					DATA NOT AVAILABLE									

MAXIMUM SUPPLY TEMP 145

MINIMUM SUPPLY TEMP 20

TABLE 10-3. AIRBUS A-300B4-600 SYSTEM TEMPERATURES AND PRESSURES (REF 7)

(°F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	60	341	49	341	15.0	39	14.7	43	14.7	52	14.7	75	14.7	100
5,000 FT CLIMB					DATA NOT AVAILABLE									
10,000 FT CLIMB					DATA NOT AVAILABLE									
25,000 FT CRUISE	40	339	38	339	13.0	43	12.7	63	12.7	59	12.7	75	5.5	10
31,000 FT CRUISE (68% FCV)	37	337	27	337	12.2	31	12.0	69	12.0	58	12.0	75	4.1	-11
35,000 FT CRUISE (68% FCV)	33	337	21	337	11.7	35	11.5	74	11.5	60	11.5	75	3.5	-26
35,000 FT CRUISE (100% FCV)	31	338	31	338	11.8	48	11.5	74	11.5	62	11.5	75	3.5	-26
25,000 FT DESCENT	33	339	33	339	12.7	34	12.5	62	12.5	58	12.5	75	5.4	10
15,000 FT DESCENT	35	339	35	339	13.3	34	13.1	48	13.1	60	13.1	75	8.3	46

MAXIMUM SUPPLY TEMP 145

MINIMUM SUPPLY TEMP 20

TABLE 10-4. AIRBUS A-300-100,-200,-300 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	176	4,051	NOT APPLICABLE	526	NOT APPLICABLE
5,000 FT CLIMB	DATA NOT AVAILABLE				
20,000 FT CLIMB	175	4,080		530	
25,000 FT CRUISE	DATA NOT AVAILABLE				
30,000 FT CRUISE	146	4,281		556	
35,000 FT CRUISE	142	4,142		538	
43,000 FT CRUISE	DATA NOT AVAILABLE				
25,000 FT DESCENT	135	3,609		469	
15,000 FT DESCENT	DATA NOT AVAILABLE				

TABLE 10-5. AIRBUS A-300B4-600 VOLUME FLOW (CFM) (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	159	5,796	41	375	0
5,000 FT CLIMB	DATA NOT AVAILABLE				
10,000 FT CLIMB	DATA NOT AVAILABLE				
25,000 FT CRUISE	142	5,942	41	414	0
31,000 FT CRUISE (68% FCV)	92	4,972	53	326	0
35,000 FT CRUISE (68% FCV)	89	4,972	53	335	0
35,000 FT CRUISE (100% FCV)	131	5,990	41	442	0
25,000 FT DESCENT	107	5,198	49	345	0
15,000 FT DESCENT	109	5,130	50	328	0

TABLE 10-6. AIRBUS A-300-100,-200,-300 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	18.0	NOT APPLICABLE	74.5
5,000 FT CLIMB	N/A*		N/A*
20,000 FT CLIMB	18.1		75.0
25,000 FT CRUISE	N/A*		N/A*
30,000 FT CRUISE	19.0		78.7
35,000 FT CRUISE	18.4		76.2
43,000 FT CRUISE	N/A*		N/A*
25,000 FT DESCENT	16.0		66.4
15,000 FT DESCENT	N/A*		N/A*

*NOT AVAILABLE

TABLE 10-7. AIRBUS A-300-600 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	14.5	24.5	53.1
5,000 FT CLIMB	N/A*	N/A*	N/A*
20,000 FT CLIMB	N/A*	N/A*	N/A*
25,000 FT CRUISE	14.8	25.1	58.6
31,000 FT CRUISE (68% FCV)	9.8	21.0	46.2
35,000 FT CRUISE (68% FCV)	9.8	21.0	47.4
35,000 FT CRUISE (100% FCV)	14.9	25.3	62.6
25,000 FT DESCENT	11.2	22.0	48.8
15,000 FT DESCENT	10.8	21.7	46.4

*NOT AVAILABLE

TABLE 10-8. AIRBUS A-300 VENTILATION PARAMETERS

VOLUMES (CU FT)		-100,-200,-300	-600
TOTAL PRESSURIZED			
PASSENGER CABIN		13,490	14,196
FLIGHT DECK		423.8	423.8
FORWARD CARGO		2,649	
AFT CARGO		1,650	
BULK CARGO		565	
PRESSURIZATION CAPABILITIES			
MAX ΔP (PSI)			
CONTROLLER LIMITED		8.26	
SAFETY VALVE LIMITED		8.9	
CABIN ALTITUDE CHANGE RATES (FT/MIN)			
CONTROLLER SELECTED	MAX	2,000	
	MIN	50	

TABLE 10-9. AIRBUS A-300 ELECTRICAL ENERGY REQUIREMENTS (REF 28)

EQUIPMENT	POWER REQD	LOADS	SOURCE
Eng 1 Bleed Air Warning Lights	28 VDC	7W	3PP
Pack & Cross Bleed Auto Closure	28 VDC	19W	3PP
Outflow Valves Closure Sys 1	28 VDC	56W	3PP
Sys 2	28 VDC	56W	3PP
Cabin Pressure Warning Light	28 VDC	5W	3PP
Bulk Cargo Isolation Valves	28 VDC	20W	3PP
Forward Cargo Isolation Valves	28 VDC	20W	3PP
Ram Air Emergency Inlet Indicator	28 VDC	1W	3PP
Outflow Valves Opening Sys 1	28 VDC	56W	3PP
Sys 2	28 VDC	56W	3PP
Toilet Vent	115 VAC	160VA	104XP
Avionics Vent, Battery Fan	115 VAC	57VA	104XP
Avionics Vent, Main Fan	115 VAC	3840VA	104XP
	115 VAC	2VA	131XP
Pack 1 Flow Meter	115 VAC	8VA	131XP
Temp Control Valve Position Pack 1	115 VAC	13VA	131XP
Flt Decr & Mid Cab Trim Air Valve Position	115 VAC	26VA	131XP
Pack 2 Flow Meter	115 VAC	8VA	231XP
Temp Control Valve Position Pack 2	115 VAC	13VA	231XP
Fwd & Aft Cabin Trim Air Valve Position	115 VAC	26VA	231XP
Flt Deck & Mid Cabin Manual Temp Control	115 VAC	69VA	301XP
Fwd & Aft Cabin Manual Temp Control	115 VAC	69VA	301XP
Bulk Cargo Temp Control	115 VAC	60VA	302XP
Manual Temp Control Pack 1	115 VAC	115VA	302XP
Manual Temp Control Pack 2	115 VAC	115VA	302XP
Fwd Cargo Temp Control	115 VAC	60VA	302XP
Bulk Cargo Temp Control Valve Position	115 VAC	13VA	331XP
Fwd Cargo Temp Control Valve Position	115 VAC	13VA	331XP
Pack 1 Shutoff Valve	115 VAC	35VA	Bus 402XP
Pack 2 Shutoff Valve	115 VAC	35VA	Bus 402XP
Cabin Pressure Selector, Sys 1	115 VAC	17VA	Bus 402XP
Cabin Pressure Selector, Sys 2	115 VAC	17VA	Bus 402XP
Ram Air Emergency Inlet Control	115 VAC	290VA (12 sec)	Bus 402XP

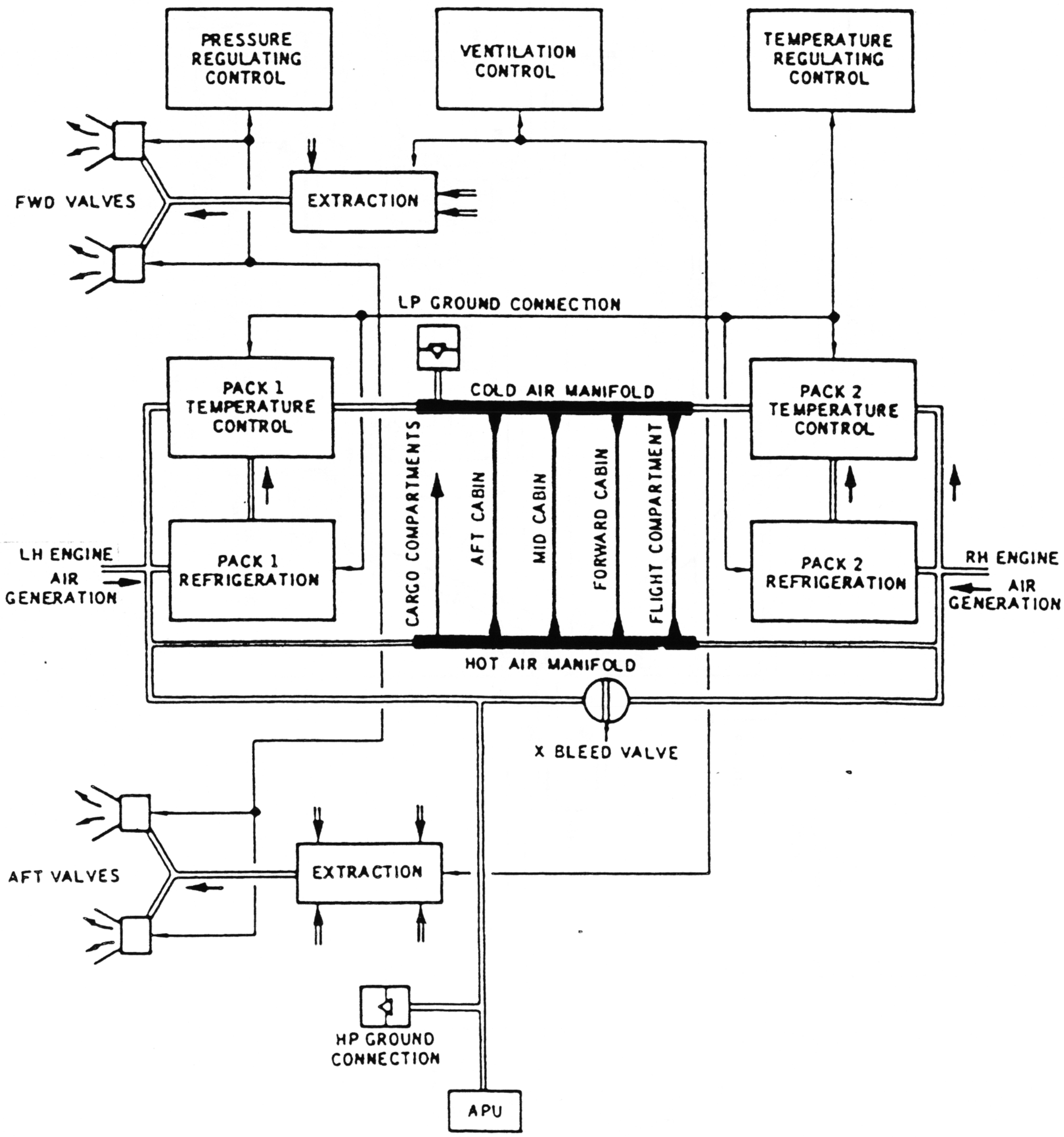


FIGURE 10-1. AIRBUS A-300 AIR CONDITIONING AND PRESSURIZATION CONTROL SCHEMATIC

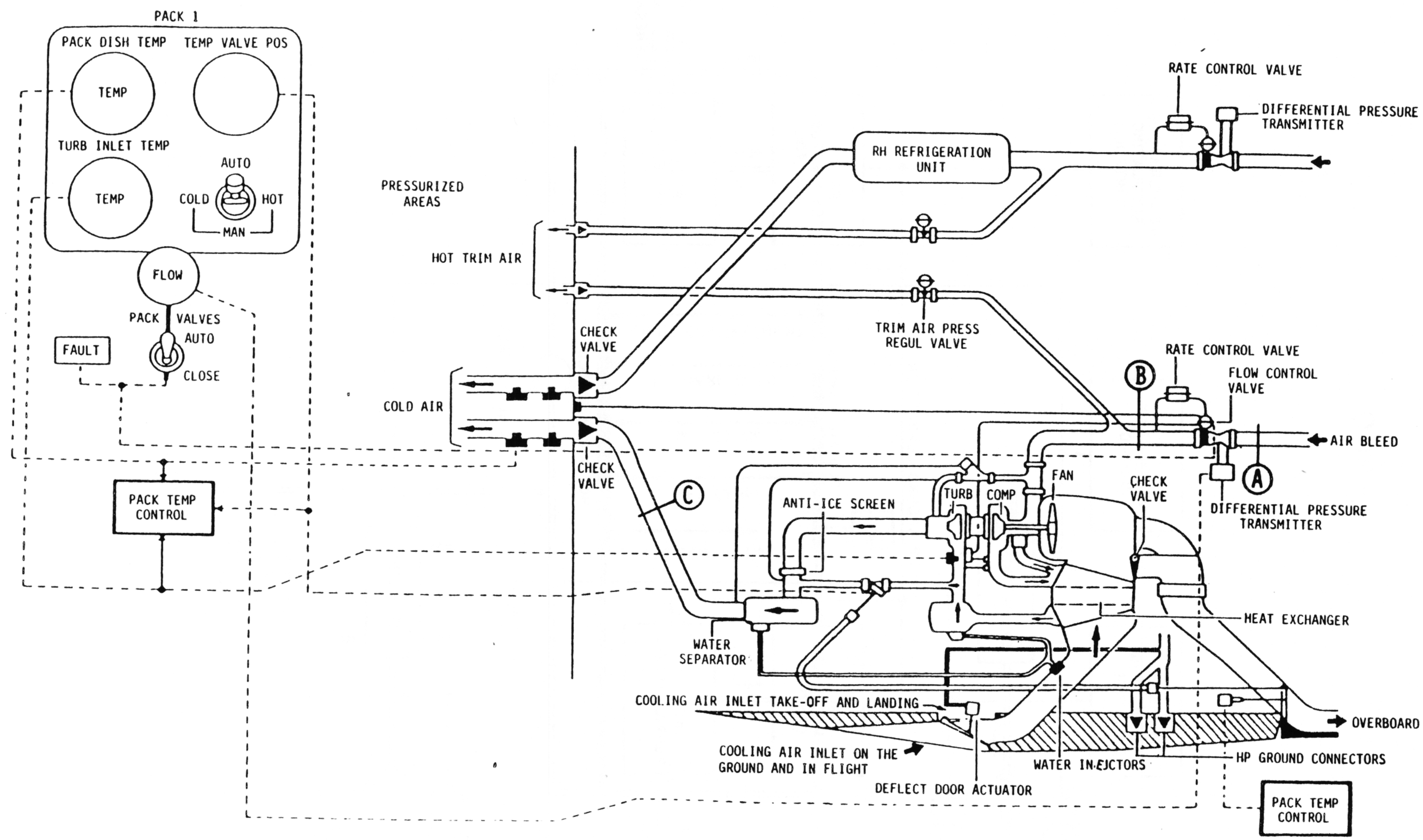


FIGURE 10-2 AIRBUS A-300 AIR CONDITIONING PACK SCHEMATIC

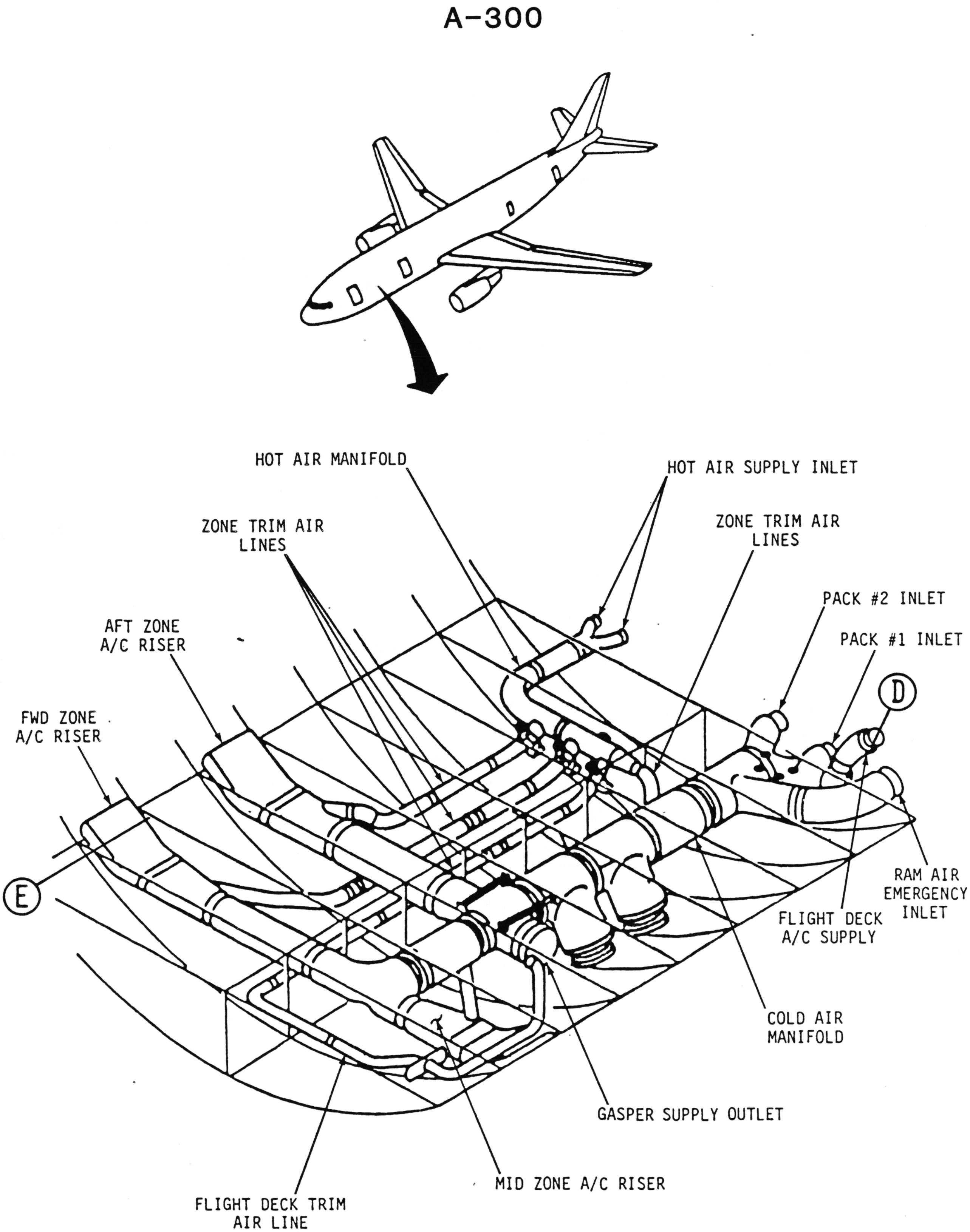


FIGURE 10-3. AIRBUS A-300 HOT AND COLD AIR DISTRIBUTION MANIFOLDS

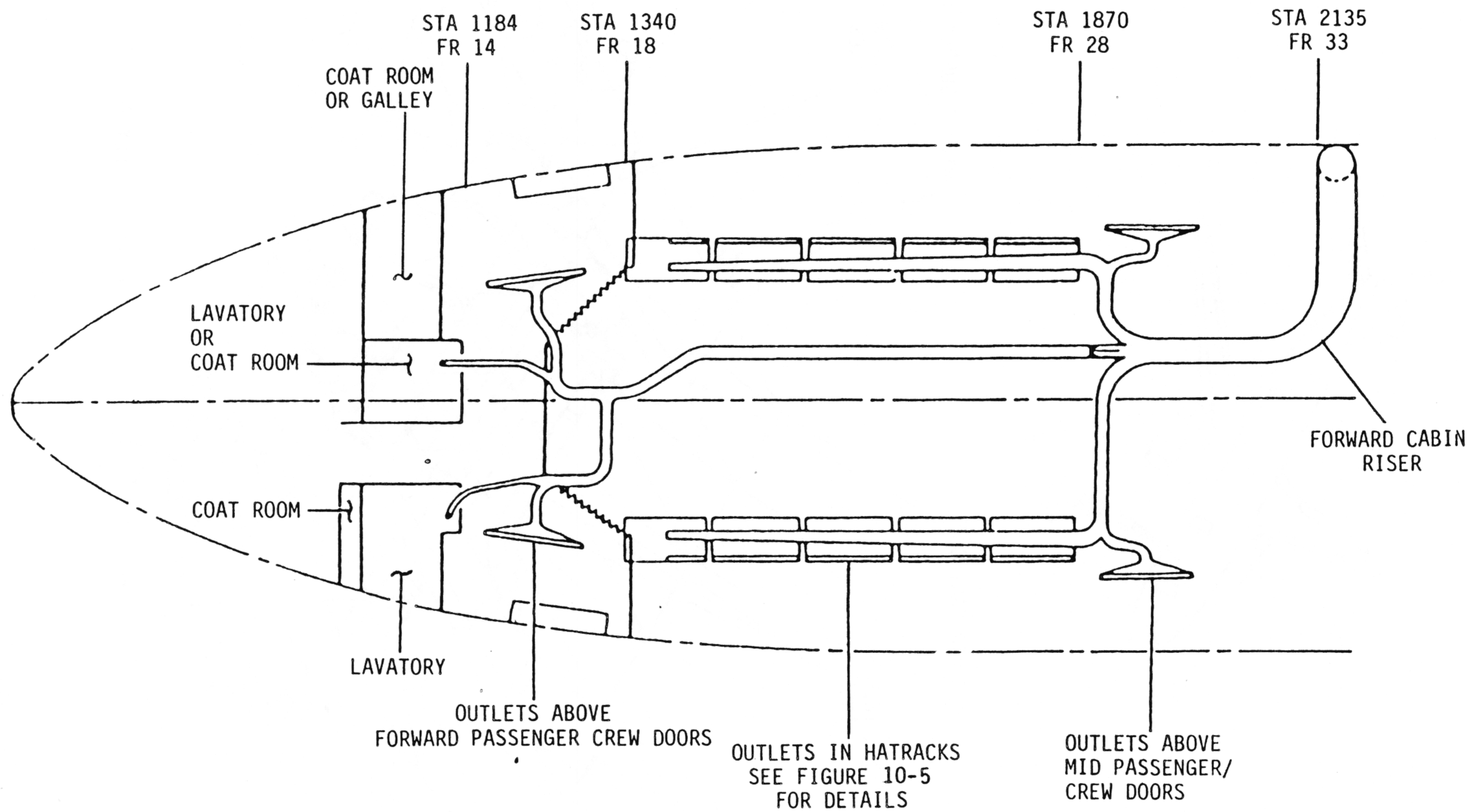


FIGURE 10-4. AIRBUS A-300 FORWARD CABIN AIR DISTRIBUTION

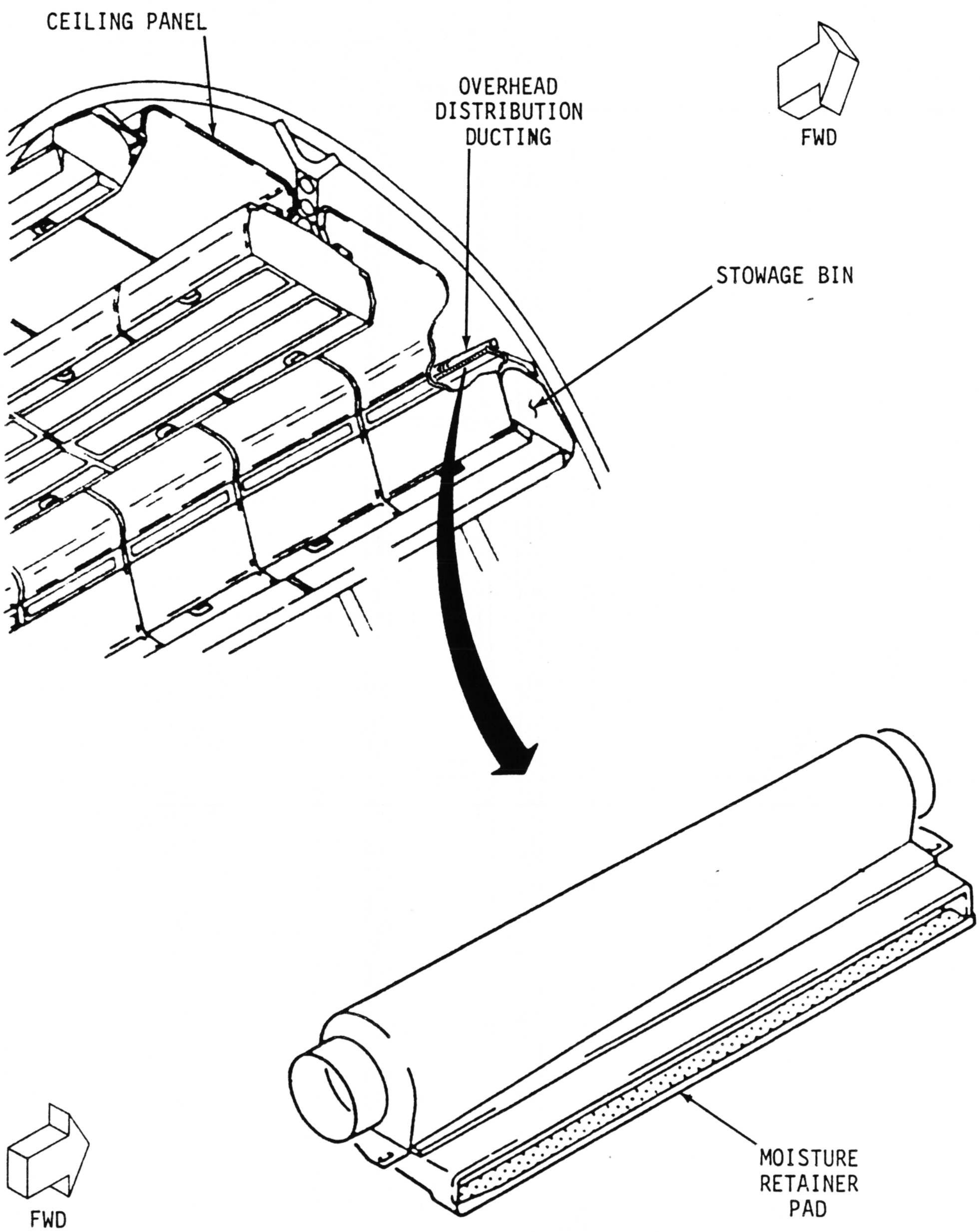


FIGURE 10-5. AIRBUS A-300 STOWAGE RACK AIR OUTLET

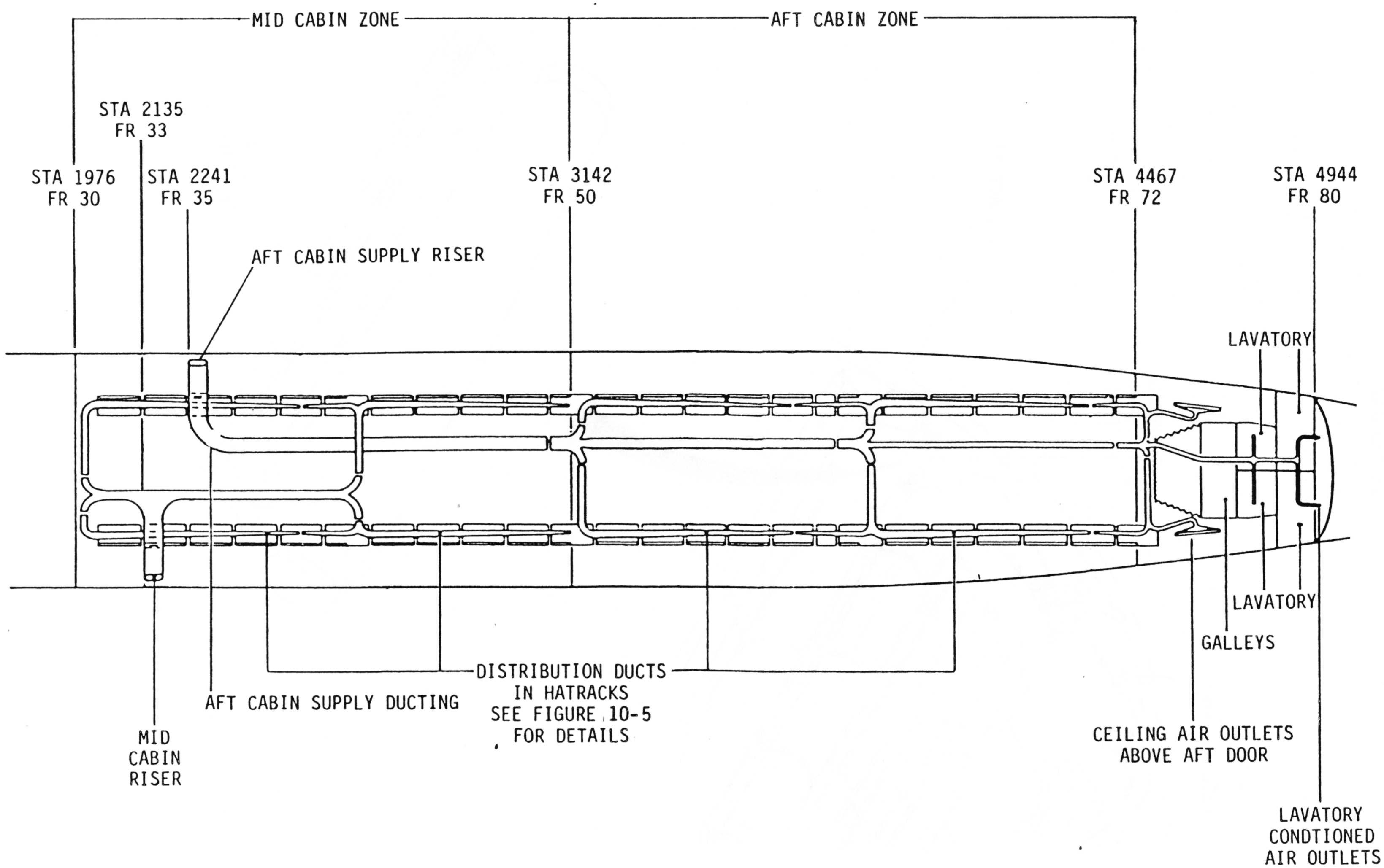


FIGURE 10-6. AIRBUS A-300 MID AND AFT CABIN AIR DISTRIBUTION

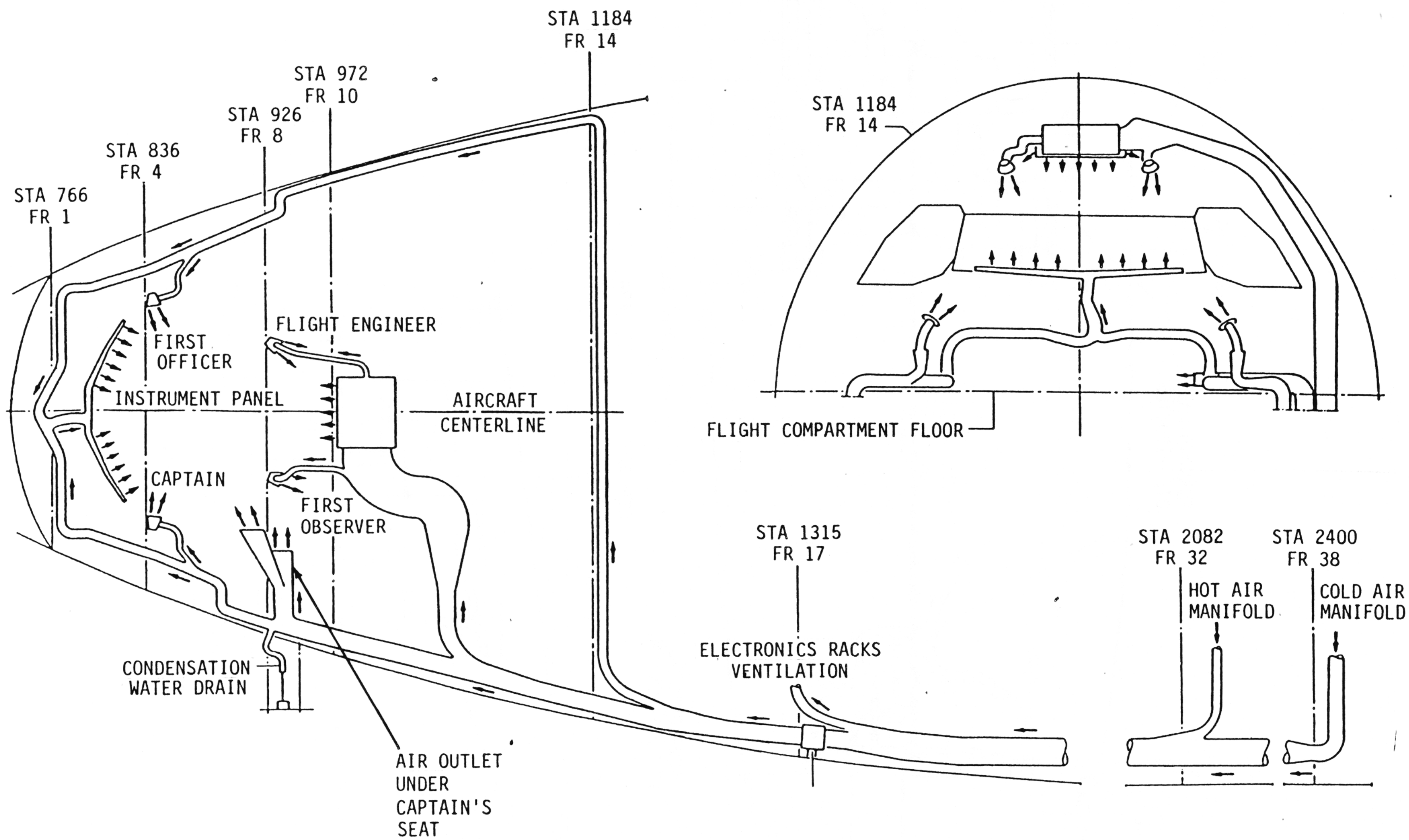


FIGURE 10-7. AIRBUS A-300 FLIGHT DECK AIR DISTRIBUTION

A-300

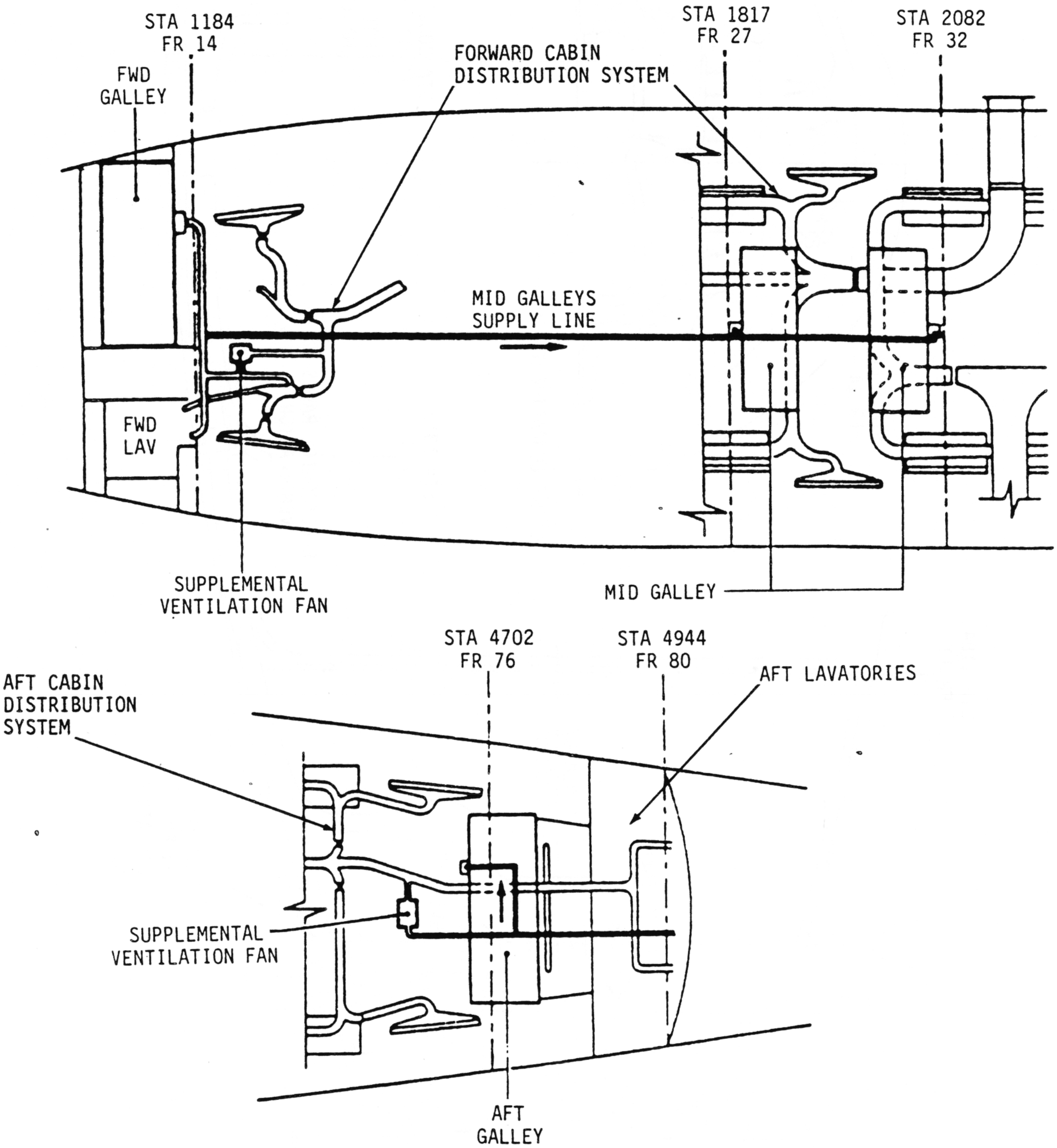


FIGURE 10-8. AIRBUS A-300 LAVATORY AND GALLEY SUPPLEMENTAL AIR

A-300

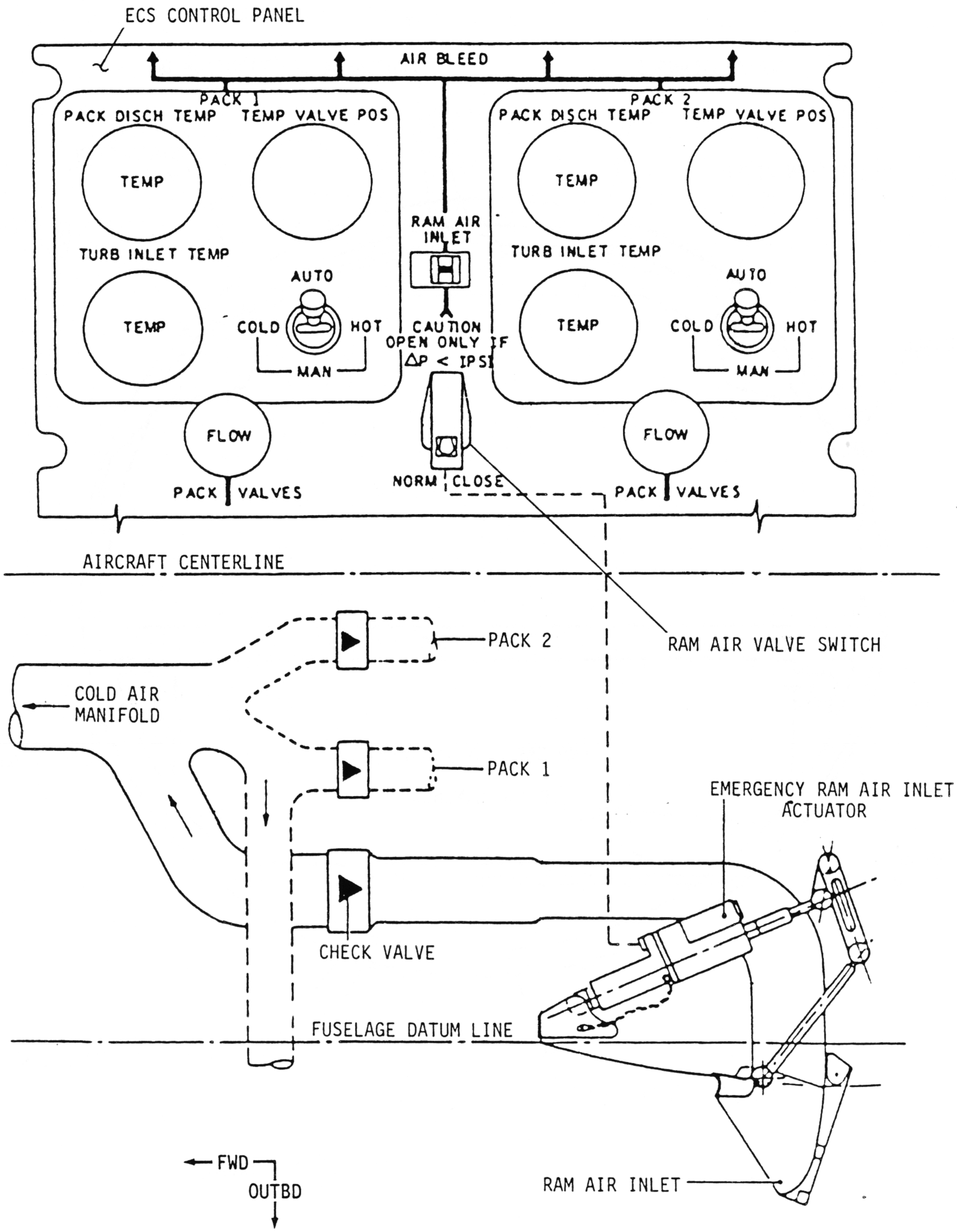


FIGURE 10-9. AIRBUS A-300 EMERGENCY RAM AIR INLET

A-300

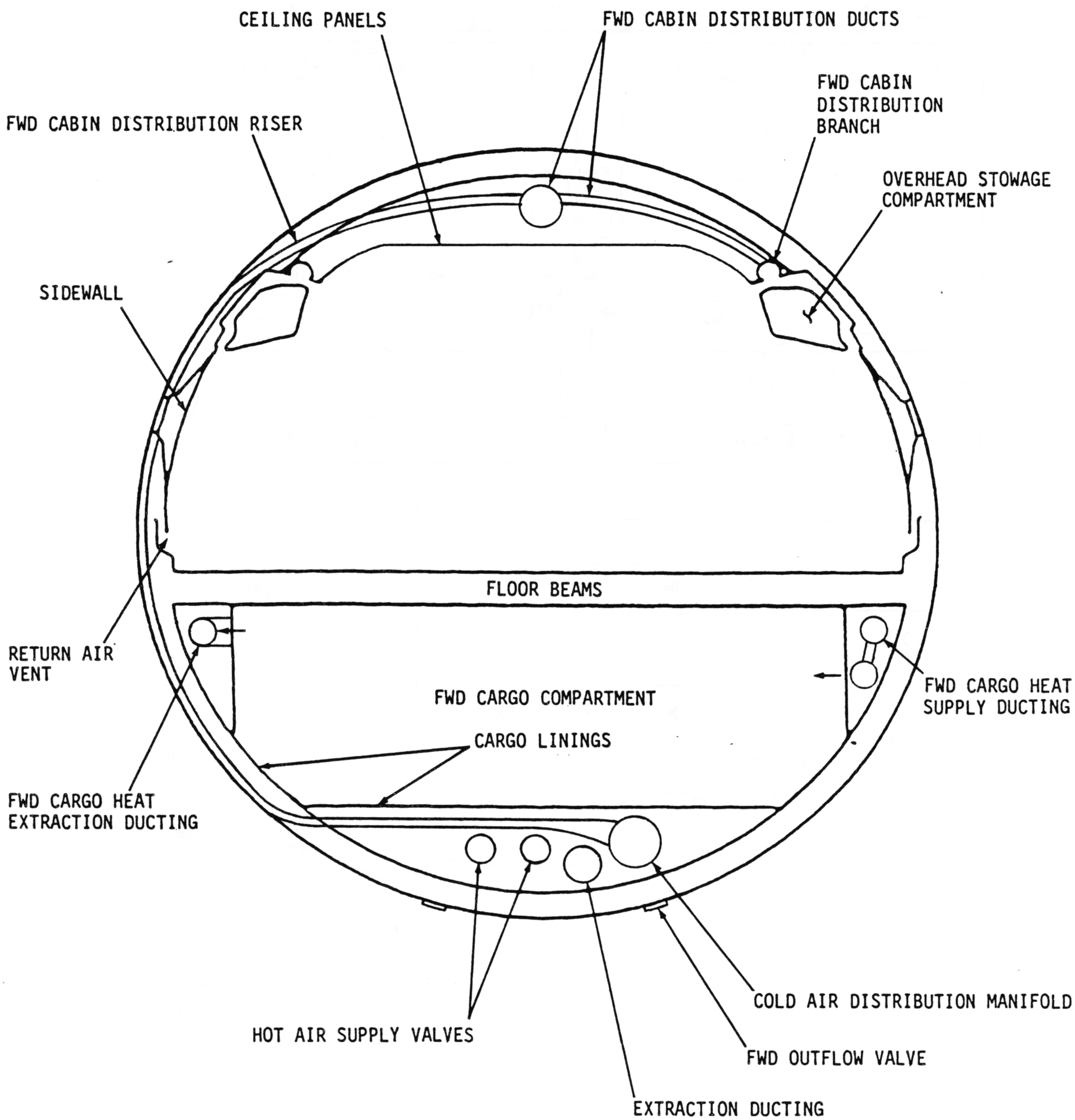
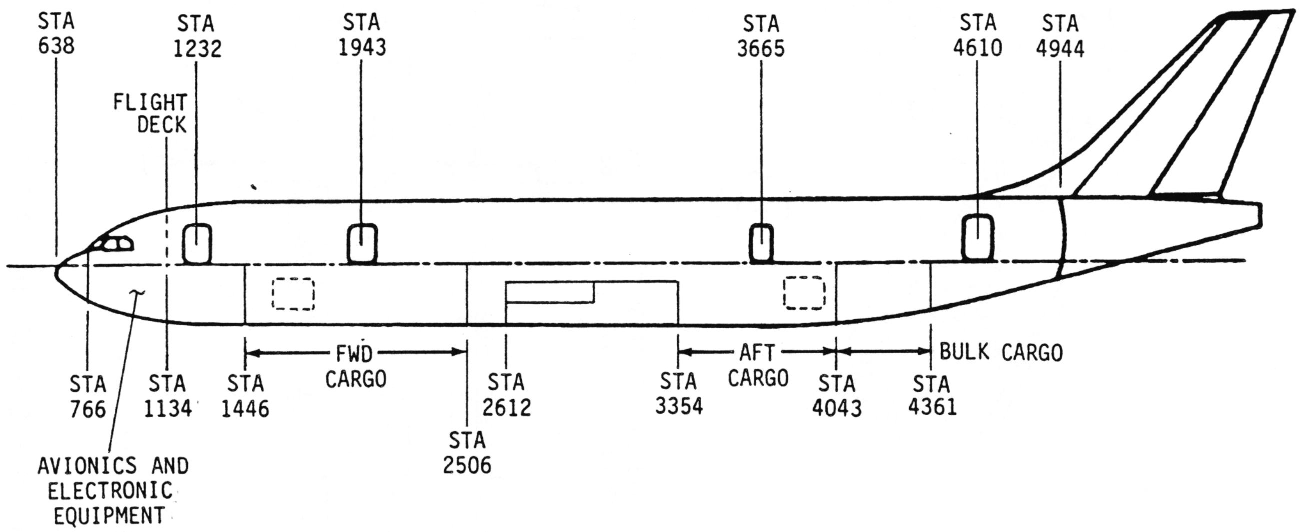


FIGURE 10-10. AIRBUS A-300 PASSENGER CABIN CROSS SECTION



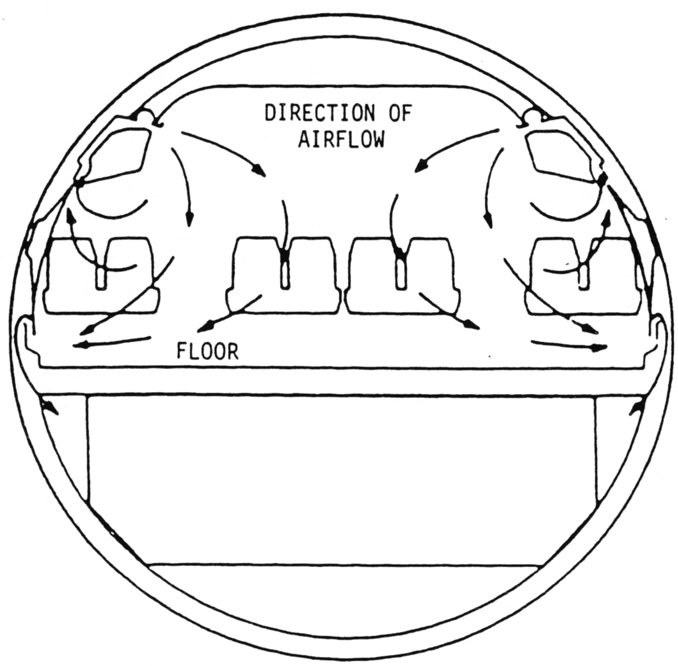


FIGURE 10-11. AIRBUS A-300 CABIN AIR FLOW PATTERNS

A-300

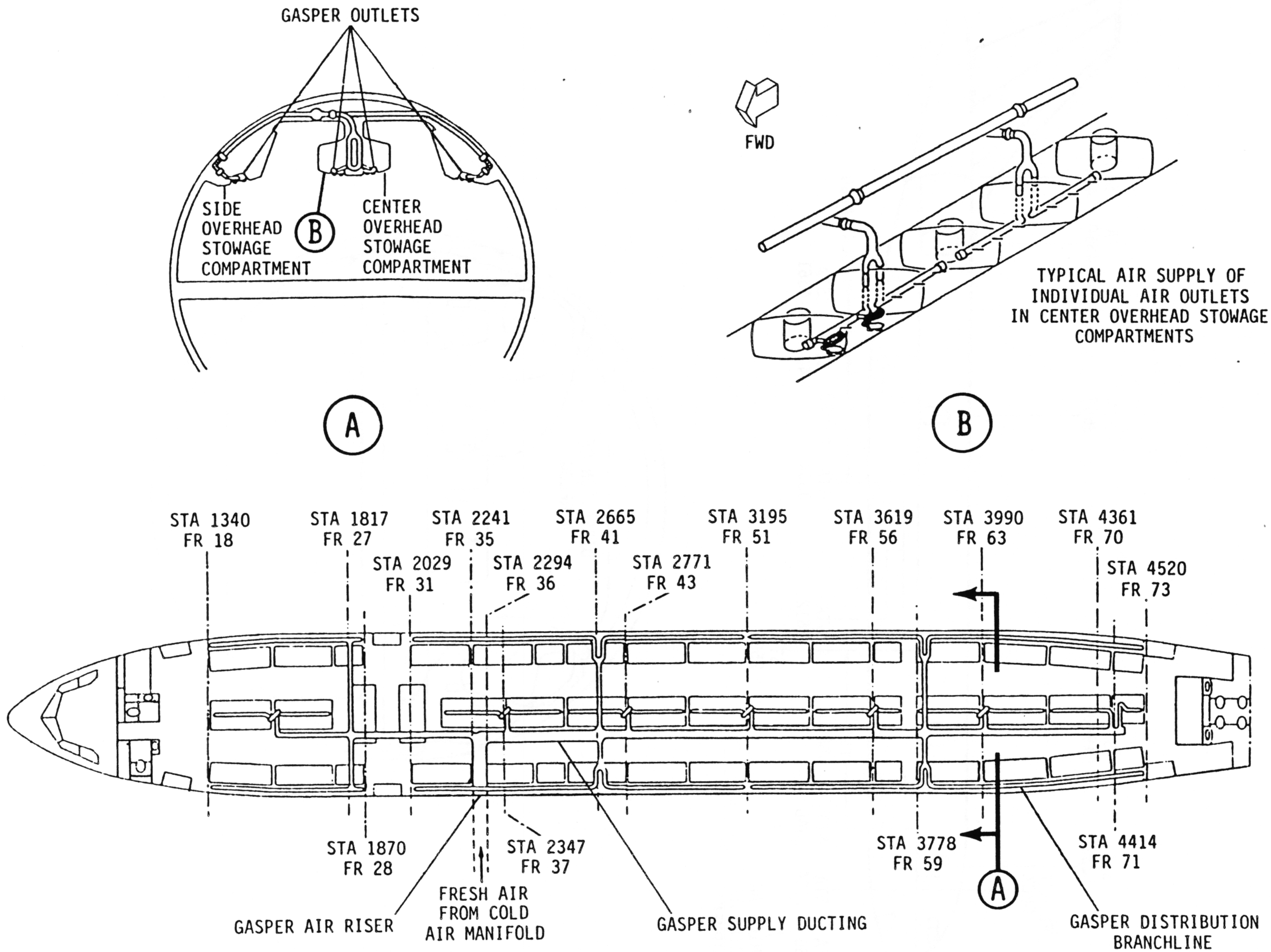


FIGURE 10-12. AIRBUS A-300 INDIVIDUAL (GASPER) AIR DISTRIBUTION

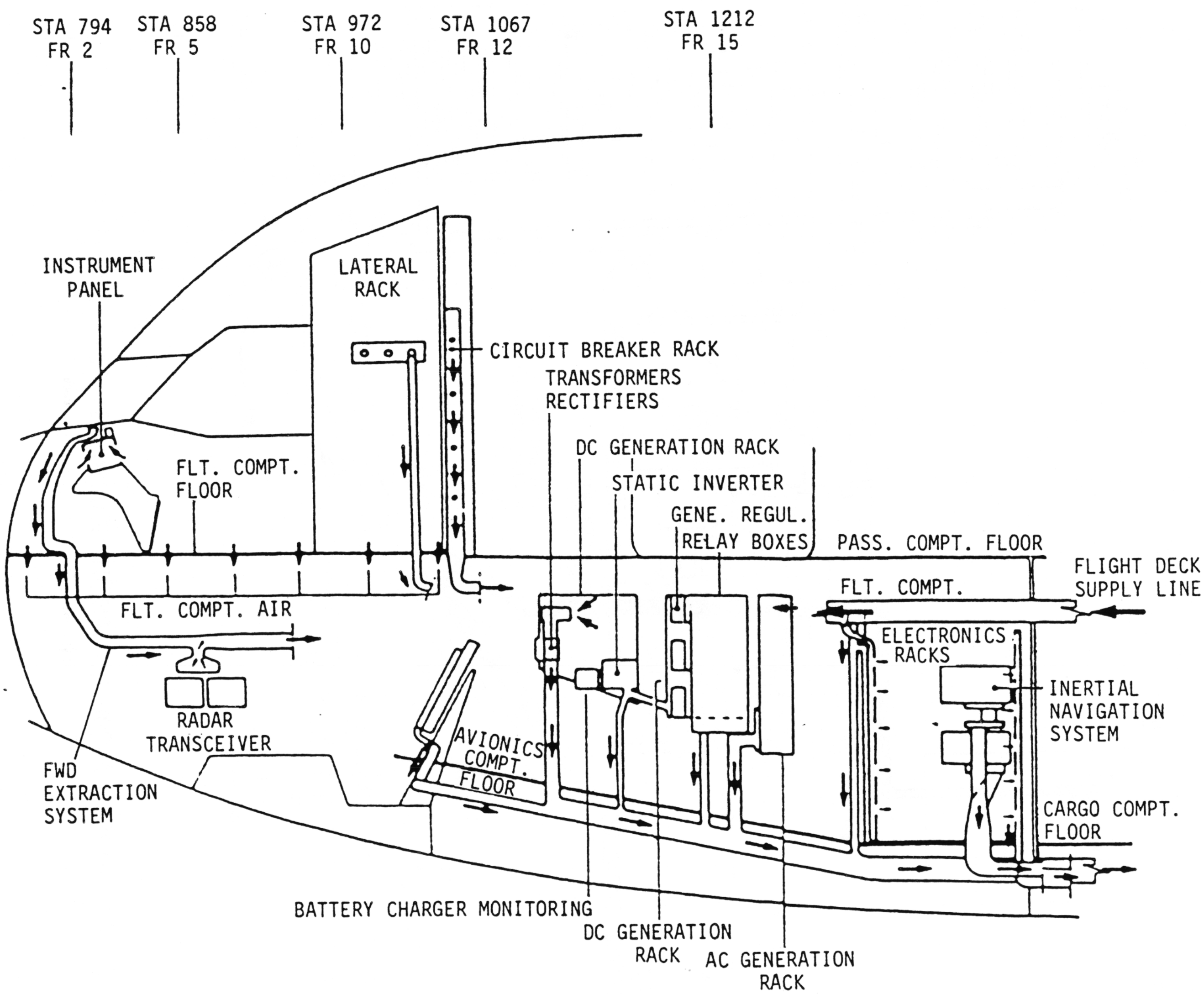


FIGURE 10-13. AIRBUS A-300 EQUIPMENT COOLING SIDE VIEW

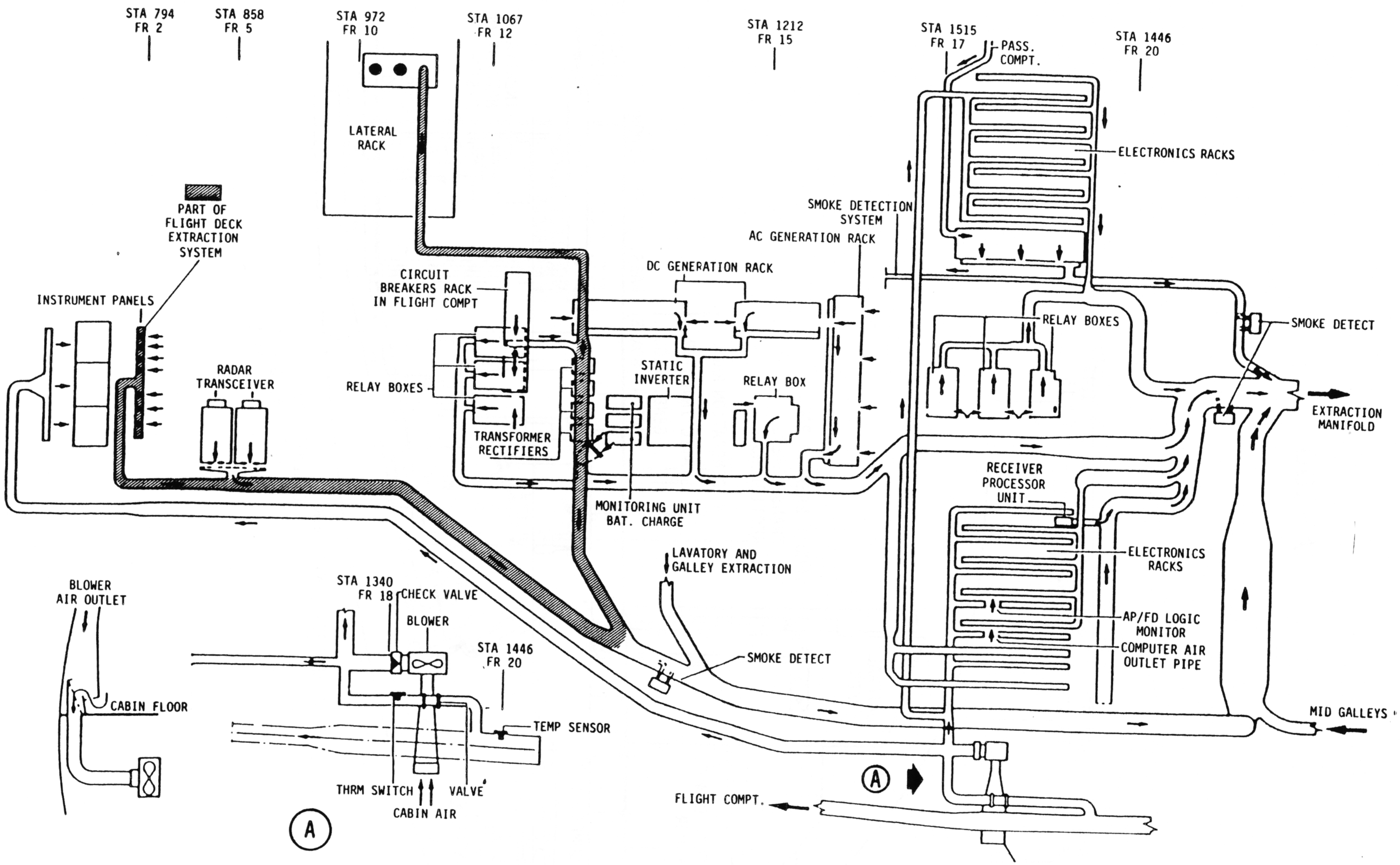


FIGURE 10-14. AIRBUS A-300 EQUIPMENT COOLING SYSTEM SCHEMATIC

A-300

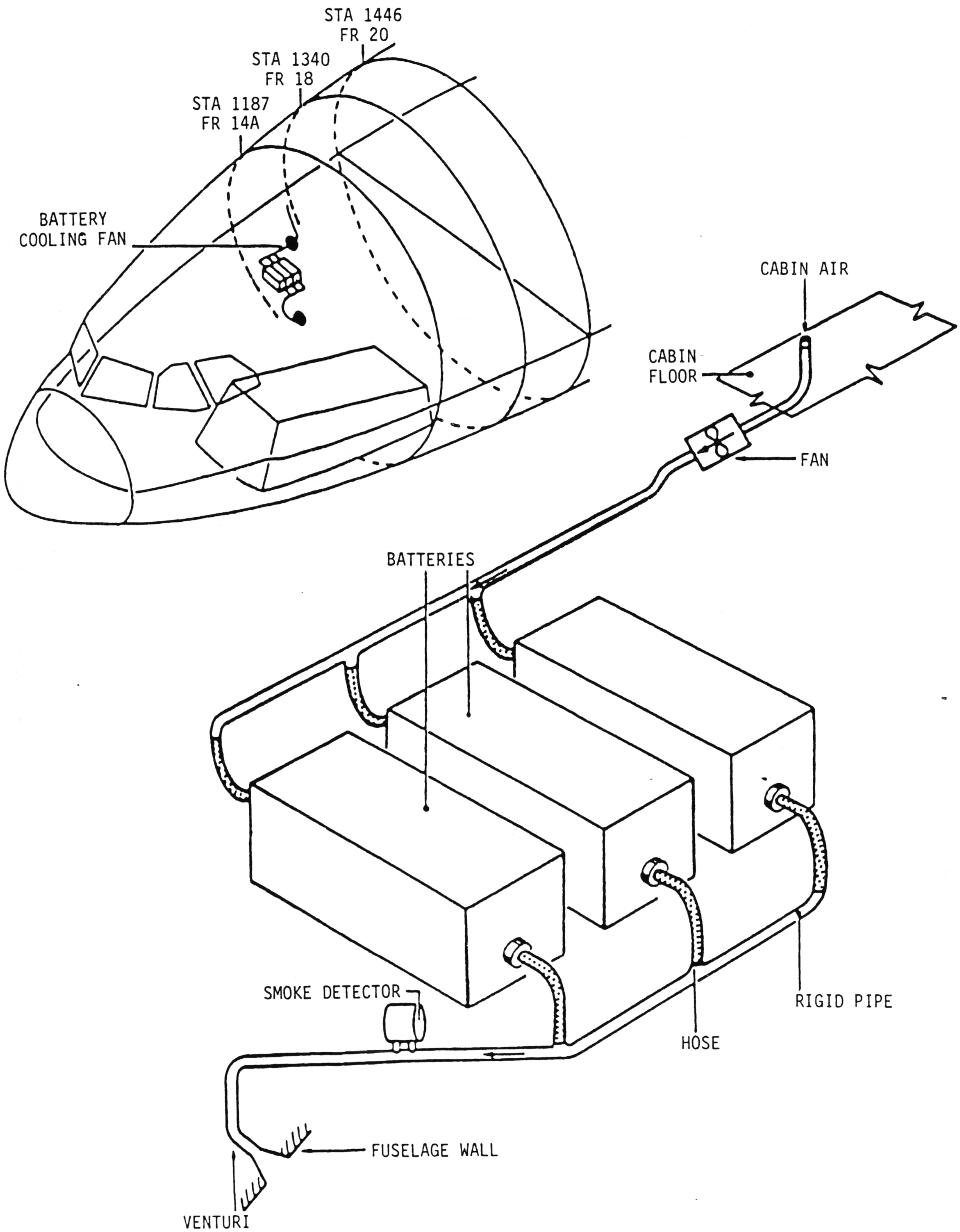


FIGURE 10-15. AIRBUS A-300 BATTERY COOLING

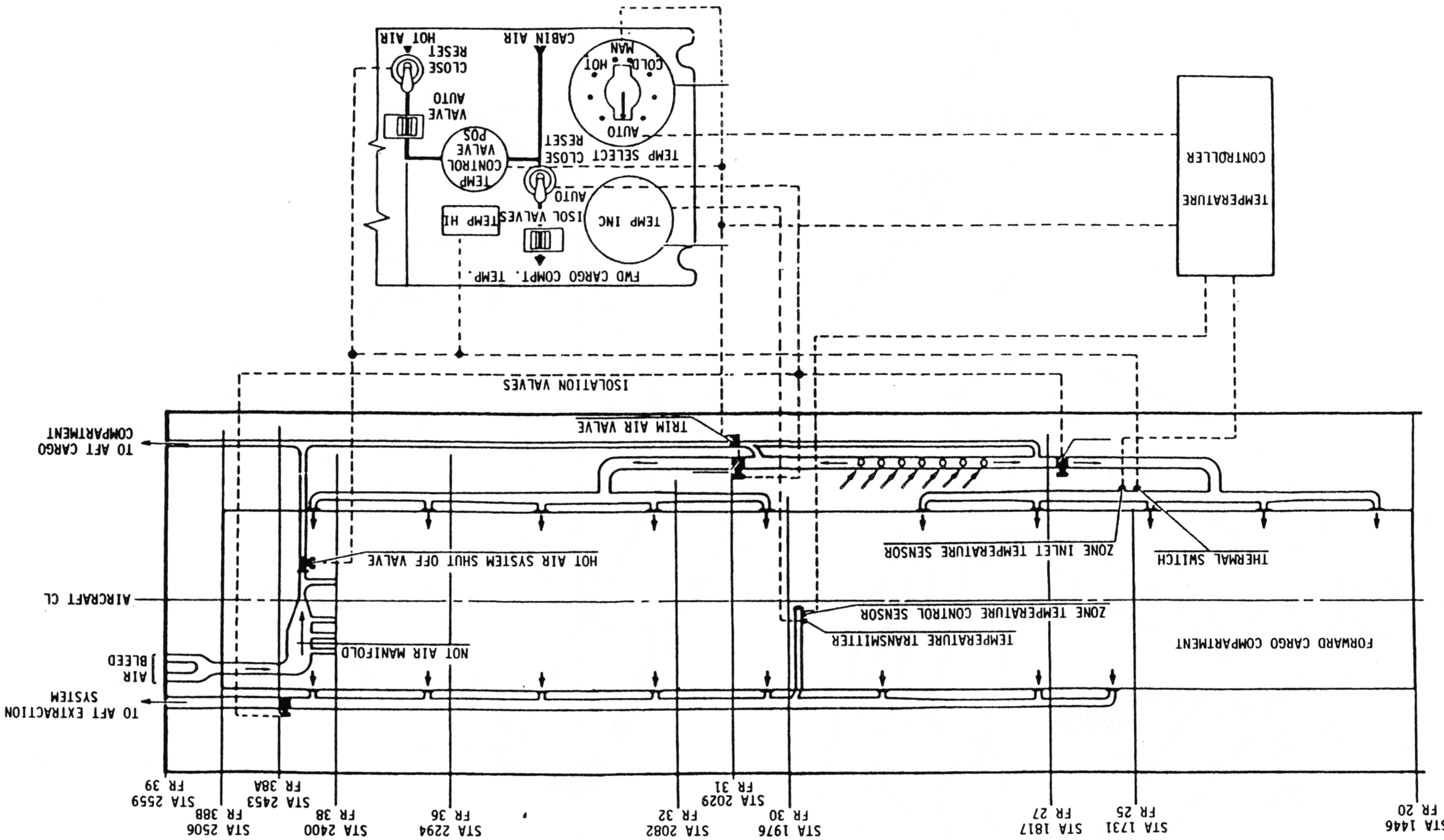


FIGURE 10-16. AIRBUS A-300 FORWARD CARGO HEATING

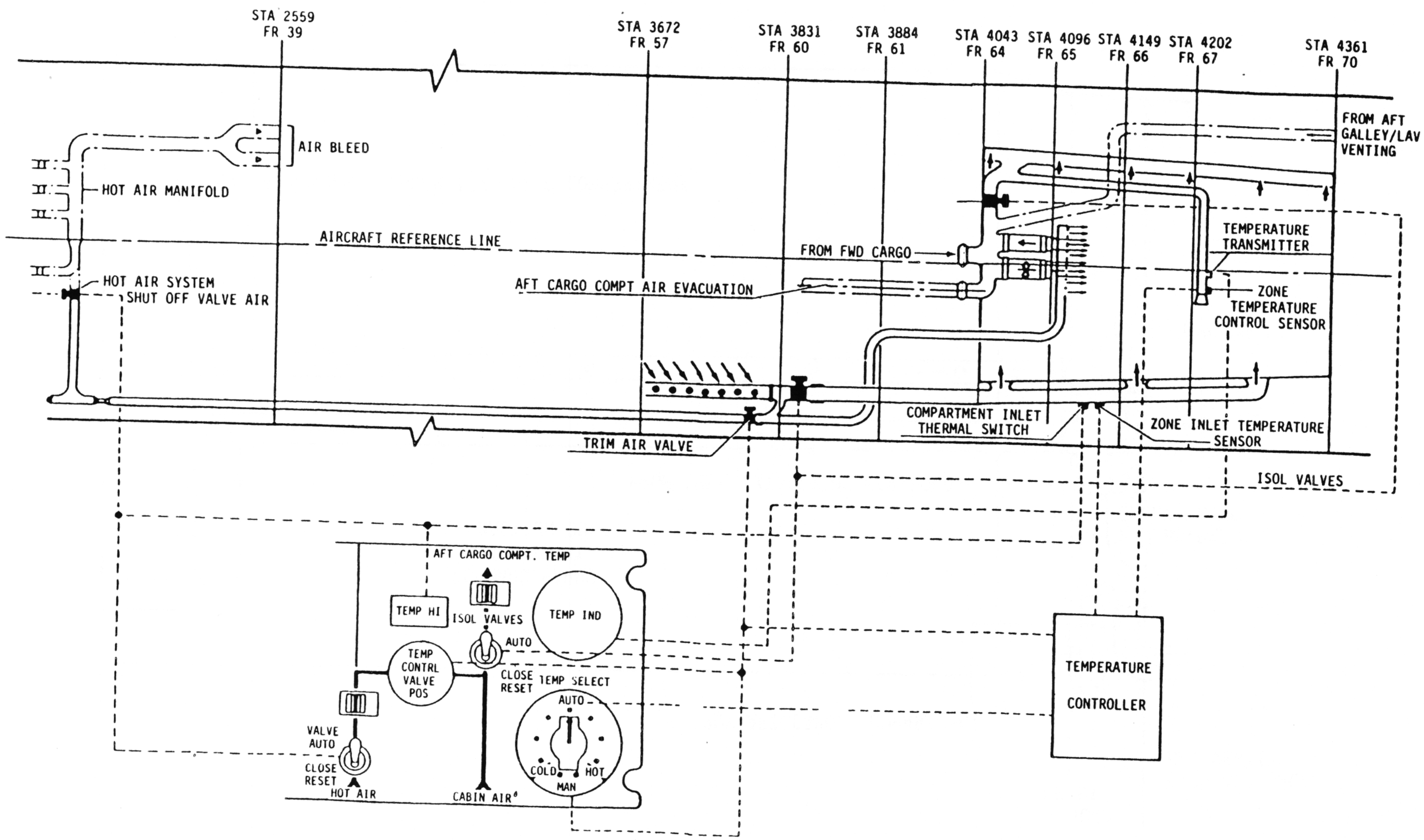


FIGURE 10-17. AIRBUS A-300 BULK CARGO HEATING

A-300

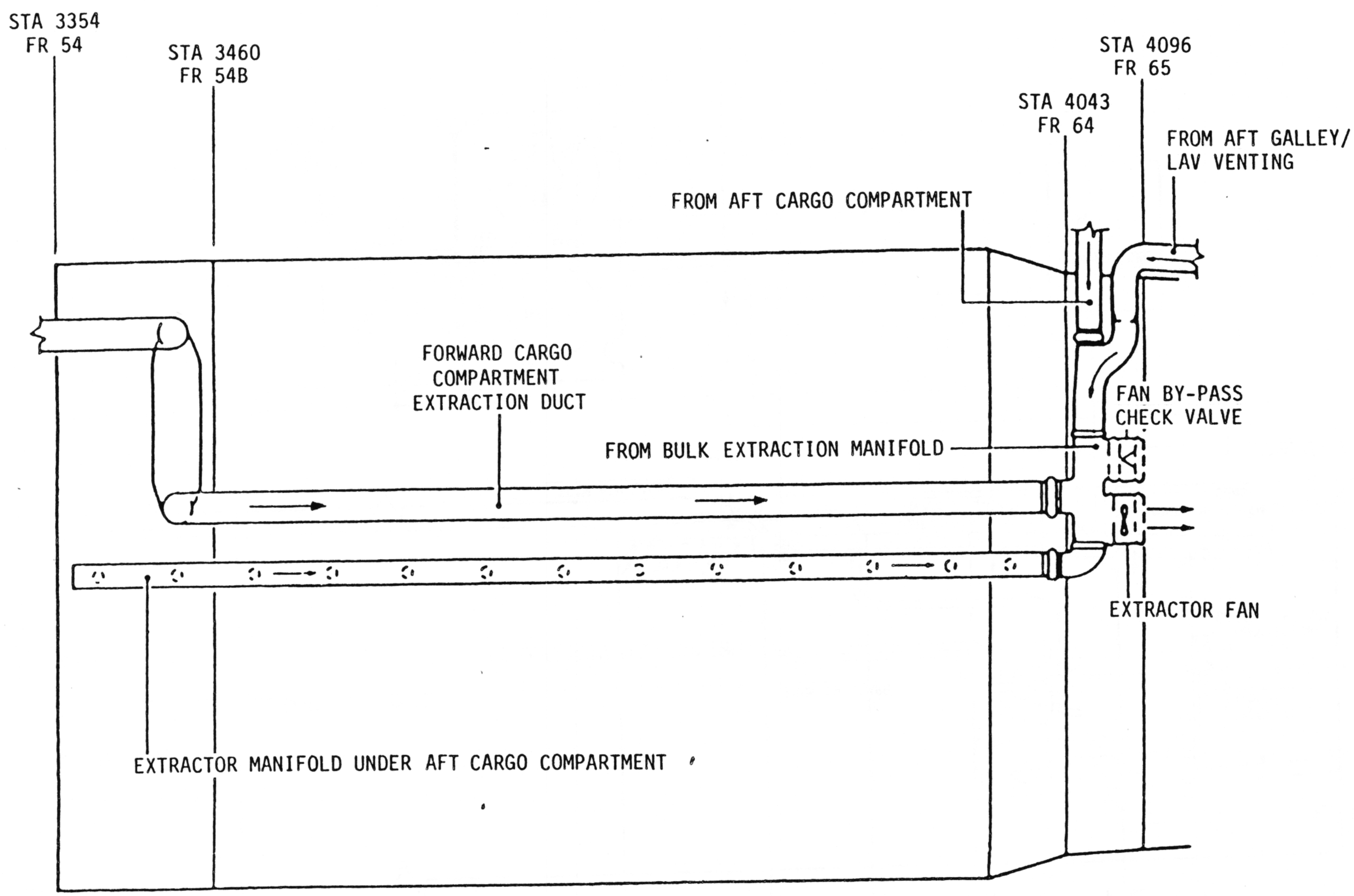


FIGURE 10-18. AIRBUS A-300 AFT CARGO HEATING

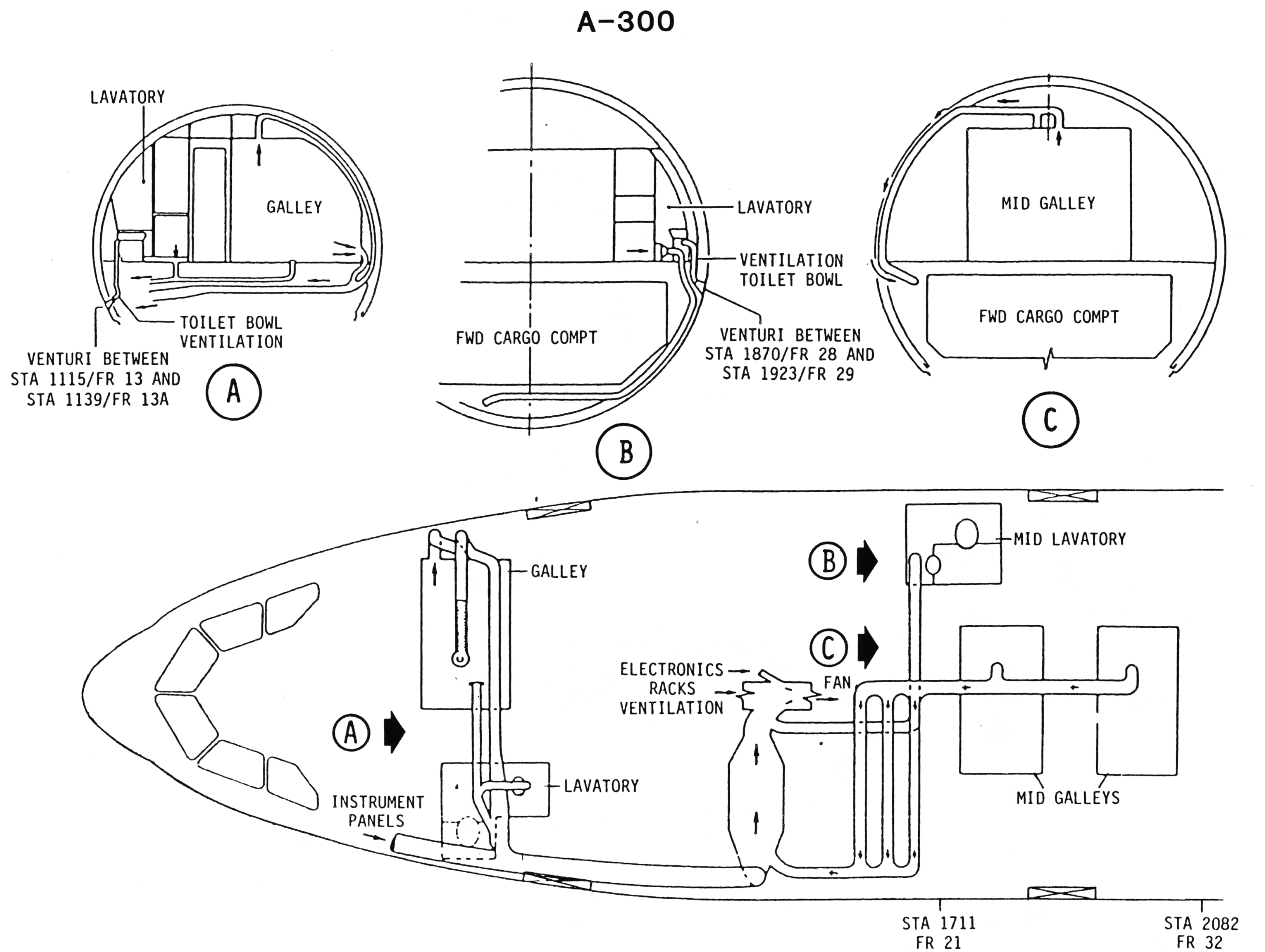


FIGURE 10-19. AIRBUS A-300 FORWARD AND MID LAVATORY AND GALLEY EXTRACTION

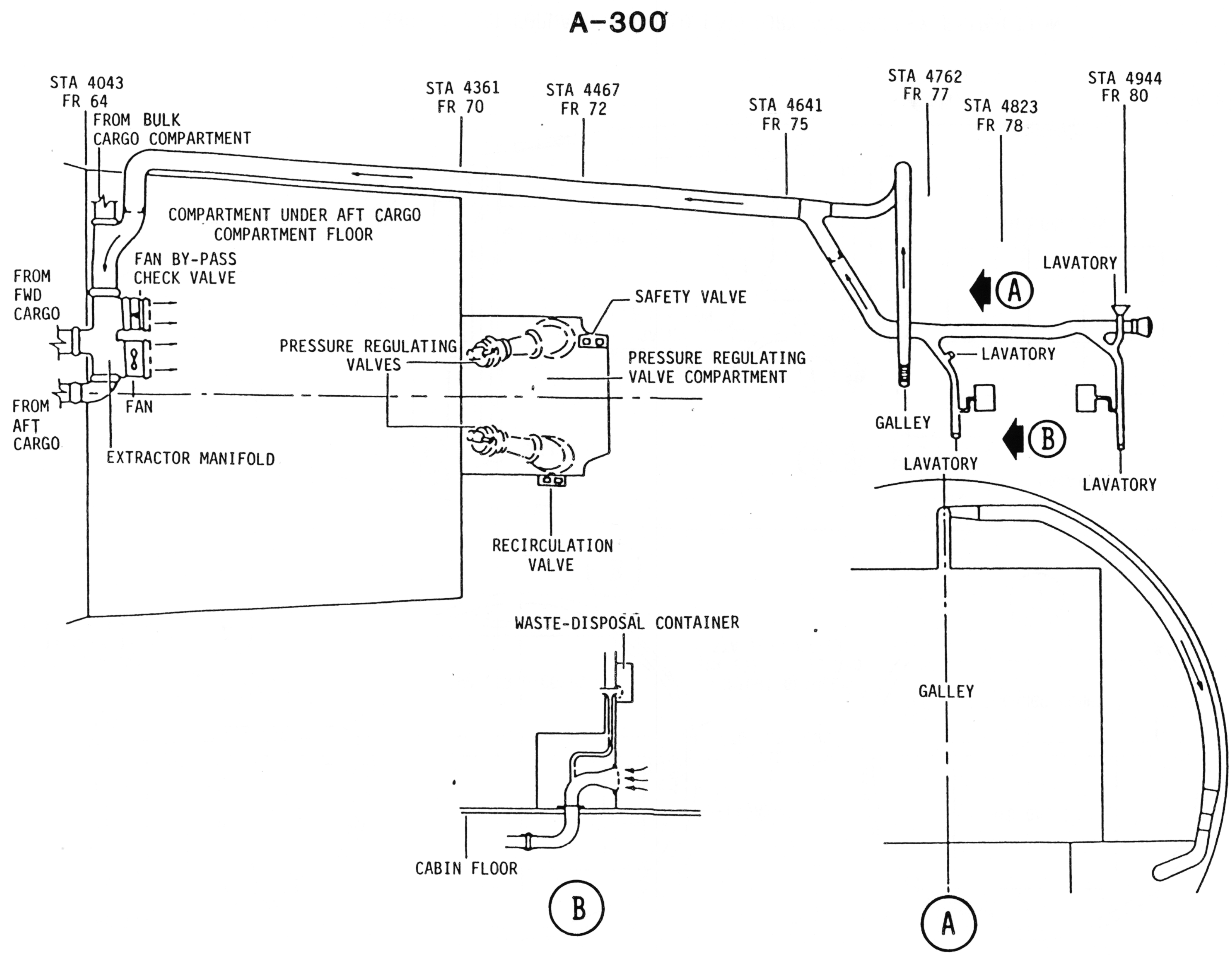


FIGURE 10-20. AIRBUS A-300 AFT LAVATORY AND GALLEY EXTRACTION

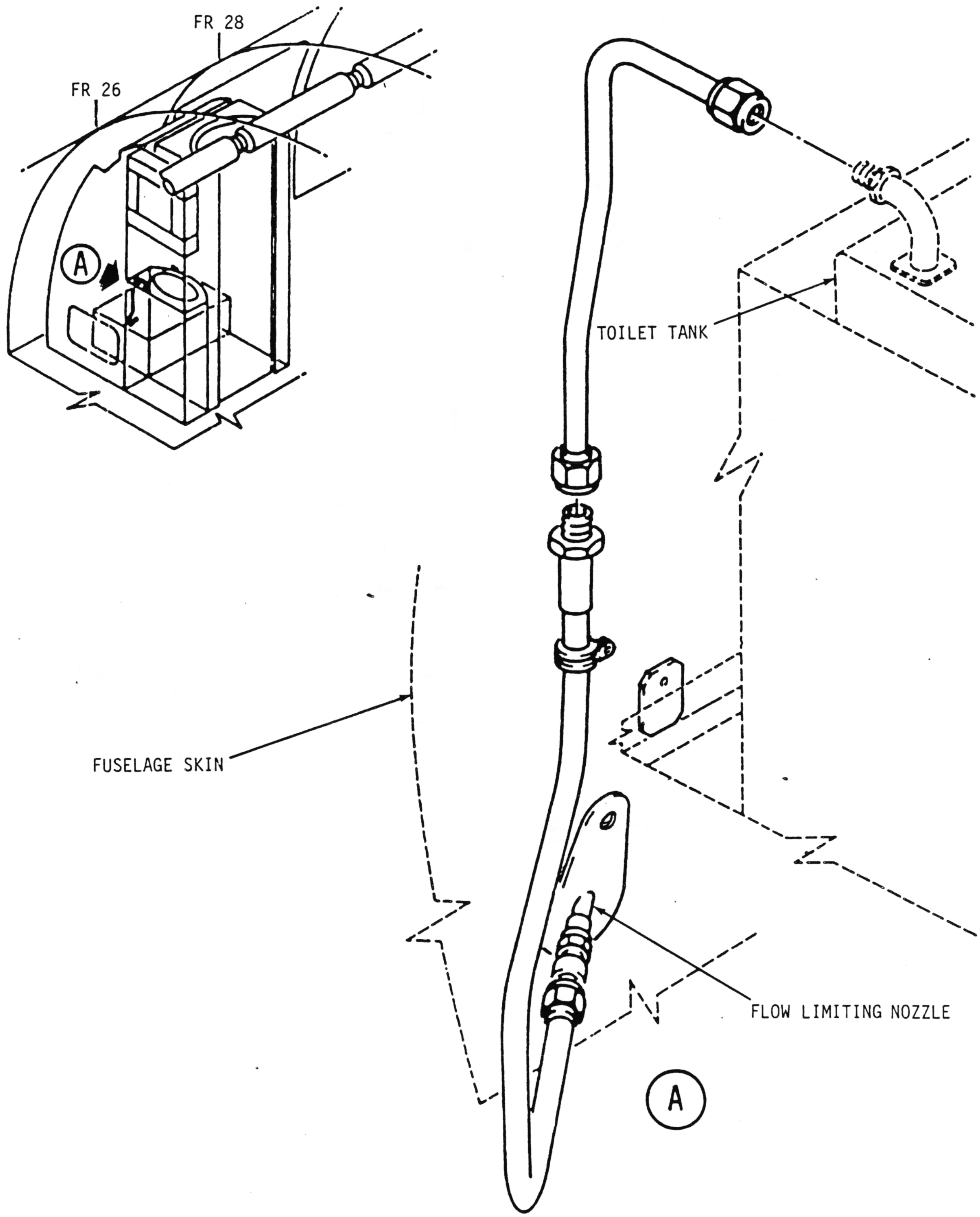


FIGURE 10-21. AIRBUS A-300 TOILET TANK VENT

A-300

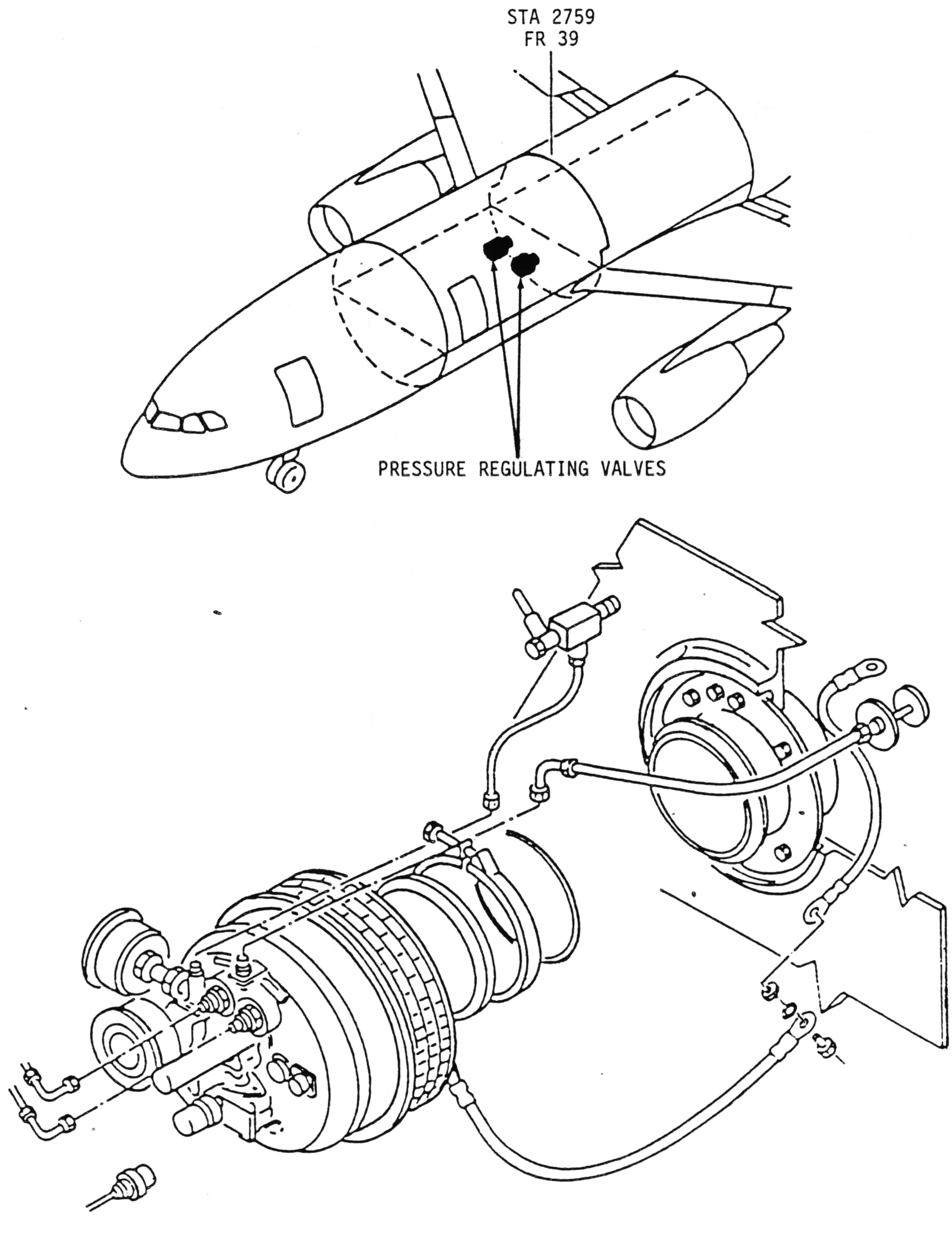


FIGURE 10-22. AIRBUS A-300 TYPICAL PRESSURIZATION OUTFLOW VALVE

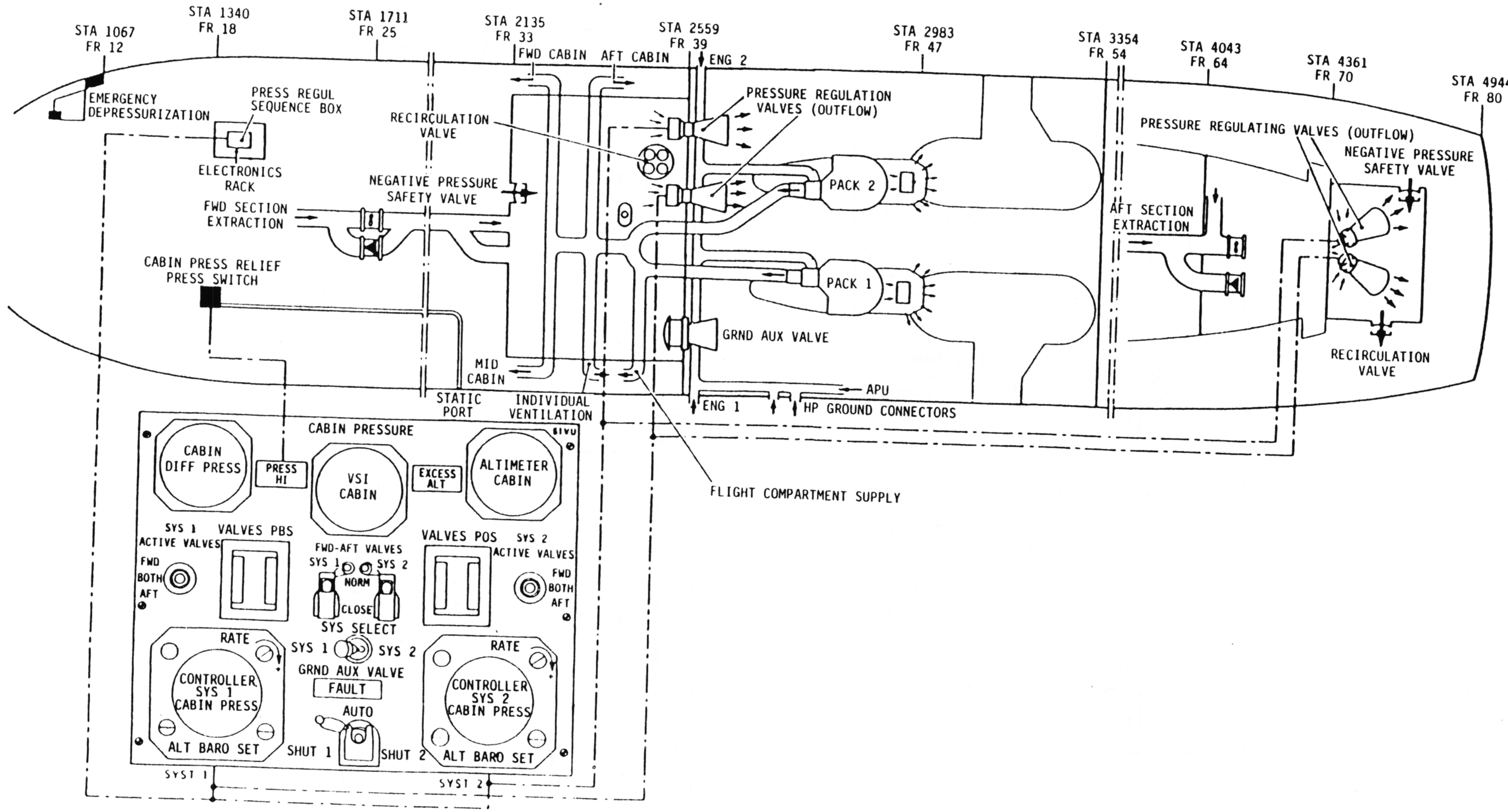
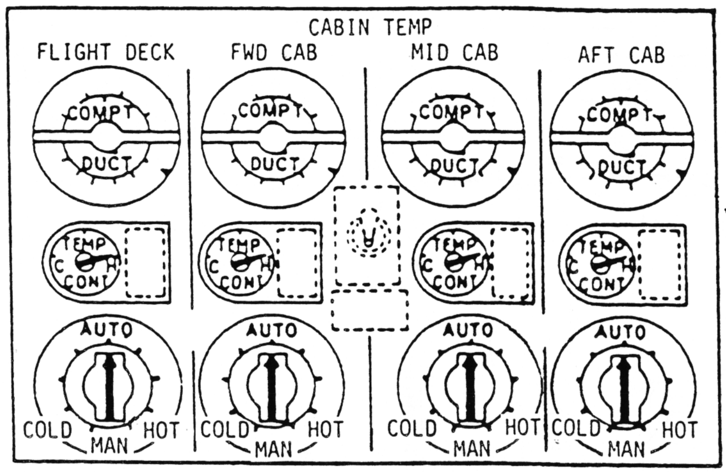


FIGURE 10-23. AIRBUS A-300 PRESSURIZATION CONTROL SCHEMATIC

A-300



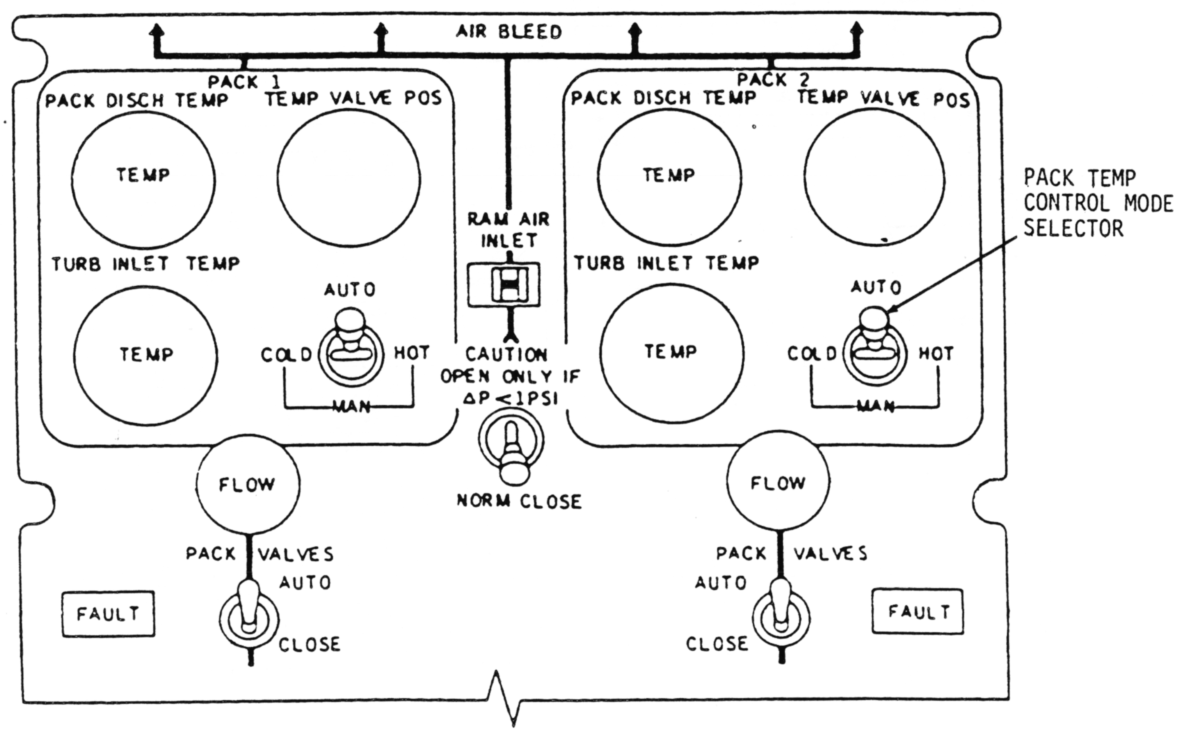


FIGURE 10-24. AIRBUS A-300 ECS AND ZONE TEMPERATURE CONTROLS

SECTION 11

AIRBUS INDUSTRIE A310

Model Variation

The A310 series was introduced in April 1982 as a smaller wide body twin jet alternative to the A300. The A310 offers the maturity and experience gained in A300 production in a smaller airplane suited to short range low-density markets.

The A310 fuselage has the same cross section as A300, but is fitted with a new wing optimized to the A310 size and mission. Currently, the A310 is offered in two models, the -200 and -300. The -200 first flew in April 1982 and entered service in April of 1983. The -300 is an increased gross weight version, incorporating a fuel tank in the horizontal stabilizer that allows for greater range and center of gravity control. The -300 completed its first flight on July 8, 1985 and is scheduled to enter service with Swissair in late 1985.

A310 ECS

The A310 ECS is a two pack air cycle system that uses bleed-air as the air source. A schematic of the system is shown in Figure 11-1. The air-conditioning packs are located below the wing in an unpressurized area of the fuselage just forward of the wheel well. The air-conditioning packs utilize engine bleed-air from the intermediate and high-pressure compressor stages of both engines as an air source. During ground operations, the APU or a ground cart may be used as the air source. A schematic of the pack is shown in Figure 11-2.

The hot bleed-air pressure and temperature are regulated by the pneumatic system before being supplied to the flow-control valve. The flow-control valve is an electronically controlled pneumatically operated valve that acts to minimize variation in volumetric flow rate in response to changing cabin and pneumatic system pressures. The A310 flow-control valve has provisions for operation on two flow schedules, max cool and economy. Switches on the control panel control the operational mode. Economy mode reduces system flow rates to 68% of the max cooling flow rate. Economy mode operation is available only when both packs are operating.

Air leaving the flow-control valve is routed to the trim air system, air cycle machine (ACM) compressor, anti-ice valve, and compressor bypass valve. The trim air system adds a controlled amount of hot air to the supply ducting of each zone to adjust the supply temperature as required by the zone temperature control system. The anti-ice valve allows a small amount of hot air to bypass the ACM to prevent ice formation in the turbine outlet and water separator. The valve is controlled by differential pressure (indicating ice formation) across the anti-ice screen. The compressor bypass valve allows air to bypass the compressor when cooling demands are low (and, hence, the turbine is rotating slowly) to increase system efficiency.

The ACM compressor is driven by air expanding in the ACM turbine, and raises the supply air to higher temperature and pressure. Air leaving the compressor is routed to the heat exchanger and cooled by ram air. The air is then expanded in the ACM turbine to produce cold air at the outlet. The turbine bypass valve regulates the amount of air passing through the turbine to regulate the temperature and quantity of cold air supplied to the distribution systems. Cold air leaving the turbine is routed to the water separator. The water separator removes entrained moisture droplets from the turbine discharge air to regulate the relative humidity in the cabin within acceptable limits.

Air leaving the water separator is routed to the cold air manifold for distribution to the various compartments. The cold and hot air distribution manifolds are shown in Figure 11-3.

Distribution

Air entering the distribution manifolds is divided, then routed to the flight deck and passenger cabin distribution systems.

The passenger cabin is divided into three zones, forward, mid, and aft cabin, each zone having its own separate supply and distribution ducting. The passenger cabin distribution ducting is shown in Figure 11-4.

The zone distribution systems are supplied from the cold air manifold by risers located behind the sidewall on both sides of the cabin. The risers supply distribution ducting located above the ceilings and stowage compartments. The outlets are designed so that the air entering the cabin from the top draws air into an outlet below the compartment. The air drawn in from the bottom rises through a duct behind the stowage bin, mixes with the fresh air, and re-enters the cabin. The distribution system also supplies air to the overdoor outlets.

The flight deck distribution system is shown in Figure 11-5. The flight deck distribution system is supplied from the cold air manifold by a duct running forward below the left-hand floor. The supply duct also provides air to the electronics racks to provide blow-through ventilation. The distribution system supplies windshield outlets, instrument panel outlets for the captain and first officer, an underseat outlet for the captain, and overhead outlets for the flight engineer and observers station. The instrument panel and overhead outlets are gasper style outlets, adjustable for flow and direction. The flow through the windshield and captain's floor outlets can be varied by means of flaps in the inlet ducts.

Conditioned air is also supplied to the lavatories and galleys by tapping air from the main distribution ducting. Air enters the galleys and lavatories through gasper style adjustable outlets. Most of the ventilating air in these areas is cabin air drawn into the lavatories and galleys by the extraction system.

In addition to conditioned air, the distribution system also has provisions for admitting ram air from the heat exchanger cooling duct into the cold air manifold. The inlet may be opened while the air-conditioning packs are operating, but only if cabin differential pressure is less than one psi. Opening the ram-air inlet automatically causes the four pressurization outflow valves to fully open. The ram air inlet is shown in Figure 11-6.

A cross section of the passenger cabin showing airflow patterns is shown in Figure 11-7. Compartment volumes are listed in Table 11-1. Airflow rates entering the compartments are listed in Table 11-2. System temperatures and pressures at various points, as depicted in Figure 11-1, are listed in Table 11-3. Air change rates for various flight regimes are listed in Table 11-4.

Individual (Gasper) Air

The A310 does not have a passenger cabin gasper system. Gasper style outlets, supplied from the conditioned air distribution system, are installed in the flight deck and lavatories.

Equipment Cooling

The A310 uses blow-through and draw-through methods of cooling. The equipment cooling system is shown in Figure 11-8.

The blow-through cooling system uses a blower to draw air from the lower portion of the avionics bay into the equipment cooling ducts. The blower exhausts air into the overhead panels, forward instrument panels, and left and right electronic equipment racks. The system uses two identical blowers, with only one blower operating at a time. If the operating blower fails, switch over to the backup is automatic. If the backup blower fails, air from the flight deck conditioned air supply duct is bled into the system.

The draw-through system uses the forward extraction blower or cabin differential pressure to draw air from the flight deck through the instrument panels and electronics racks. During normal operation, the extraction blower operates, and extracted air is discharged below the forward cargo compartment if the airplane is in flight. During ground operations, extracted air is vented overboard through the overboard extraction valve.

If the extraction blower fails, the crew can select the overboard mode. This causes the overboard extraction valve to open, and airflow is driven by cabin differential pressure. The overboard extraction valve can also be opened manually in the event of total loss of electrical power.

The equipment cooling controls are located on the overhead panel. The system has smoke detection and low flow warning capabilities.

Cooling air is also supplied to the auxiliary battery boxes from the electronics racks blow-through supply duct. Air supplied to the battery boxes is vented overboard through a flow limiting venturi. The battery cooling ducting is shown in Figure 11-9.

Cargo Heating

The A310 cargo compartments are classified as FAR Part 25 Class C compartments; as such, they are required to have fire detection and suppression systems, adequate means to control ventilation and drafts within the compartment, and to exclude hazardous quantities of smoke from entering the occupied areas of the airplane. All cargo compartments are heated in part by exhausting cabin air between the cargo lining and fuselage skin; in addition, the forward and bulk compartments have supplemental ventilation and heating systems.

The forward cargo compartment heating system provides for compartment heating and cooling. The cooling system allows air from the cold air manifold to enter the distribution ducting to cool the cargo compartment when specific types of temperature sensitive cargo are carried. When using compartment cooling, the packs should be operating in the max cool mode. The heating system heats the cargo compartment by drawing cabin exhaust air into a system of ducts, adjusting the temperature by adding hot air or cold air as required, and exhausting this air into the compartment through outlets in the left-hand wall. Air is taken out of the compartment by an extraction fan drawing air into the extraction ducting through outlets located along right-hand cargo lining. The extraction fan exhausts air below the compartment floor to provide additional heating. The cargo floor is also heated by air exhausted from the forward extraction equipment cooling system. The forward cargo heating system is shown in Figure 11-10.

The bulk cargo heating system functions in the same manner as the forward compartment system with the exception that the floor is heated only by air extracted from the bulk compartment. The bulk cargo heating system is shown in Figure 11-11.

Temperature of the cargo compartments can be controlled manually or automatically. The cargo heat controls are shown in Figure 11-12. When using automatic control, the crew sets the desired temperature and the automatic controls adjust the hot and cold airflow according to the demanded temperature. The manual mode allows the crew to control the position of the hot and cold air valves directly. When using manual mode, the compartment temperature must be monitored on the gauges provided. Separate switches allow the crew to control the flow of hot and cold air to the cargo heating systems.

The cargo compartment smoke detection system closes the hot air valves and cold air valves, and turns off the extraction fans when smoke is detected.

Recirculation Systems

The A310 uses three recirculation systems consisting of a fan and filter, mounted above the ceiling in each passenger cabin zone. The recirculation components are shown in Figure 11-4.

The recirculation fans are controlled by cabin fan switches located on the overhead panel and operate on 115 VAC power. The motors are protected from overheating by thermal switches that will interrupt the power supply if any of the motor windings reaches 194 ^{o}F.

When the fans are operating, air is drawn from the area above the ceiling in each zone, and exhaust the air into the distribution ducting of that zone. When the packs are operating in the economy mode, the amount of recirculated air comprises about 50% of the total flow; when the packs are operated in the max cooling mode, the recirculated air comprises about 40% of the total flow.

Ventilation

Air is vented overboard by the galley and lavatory venting system, battery cooling provisions and pressurization outflow valves. Battery cooling is covered under the equipment cooling system.

The galley and lavatory ventilation system is shown in Figure 11-13. Air is supplied to the galleys and lavatories from the passenger cabin air distribution system. Air enters the galleys and lavatories through adjustable gasper style outlets.

A separate lavatory and galley extraction fan ensures overboard ventilation of air from these compartments. The extraction system removes air from the ceilings of the galleys and from the waste tank of the lavatories, by means of an extraction fan or by cabin differential pressure. Air is vented overboard through a flow limiting venturi. Flow through the system is driven by the lavatory and galley fan when differential pressure is less than one psi, and by differential pressure when greater than one psi.

The pressurization outflow valves are the primary means of venting air overboard. The A310 is equipped with four outflow valves; two mounted just forward of the wing, and two mounted aft of the bulk cargo compartment. A typical outflow valve and its locations are shown in Figure 11-14. The outflow valves respond to signals generated in the pressure controller to control the amount of air vented overboard. The outflow valves also provide safety pressure relief at 8.84 psi. A fifth valve, the depressurization valve, is the main outflow valve when operating in manual pressure control mode. The valve responds to an open or close signal generated by the manual pressure controller. The depressurization valve is shown in Figure 11-15.

Pressurization Control

A schematic of the pressurization control system is shown in Figure 11-16. The pressurization control system consists of two identical automatic systems and a manual system that modulate the outflow valves to maintain cabin pressure and altitude change rate within acceptable limits.

Each automatic system consists of a pressure controller, forward and aft outflow valve, and a forward and aft jet pump. To use either auto system, the crew selects the desired system, the landing altitude, and desired cabin altitude rate of change. The pressure controller then limits cabin altitude to the lowest possible altitude for the flight altitude, minimizes the cabin altitude change rate and ensures that the cabin is unpressurized at landing. Transfer to the backup auto system is automatic if the differential pressure exceeds 8.3 psi cabin altitude exceeds 8,700 feet, or the rate of change exceeds 2,000 feet per minute.

The auto modes are further backed by a manual mode. To use this mode, the crew selects manual on the pressurization control panel. The cabin pressure is now dependent only on the position of the depressurization valve. A switch on the control panel allows the crew to alter the valve position. When using the manual control, the gauges must be monitored to prevent excessive cabin altitude, differential pressure or cabin altitude change rate. A gauge is provided to indicate depressurization valve position.

In the event of total loss of electrical power, the cabin pressure can be controlled by the manual depressurization valve (see Figure 11-17). This valve is controlled via a hand crank and cable from the flight engineer's station.

Environmental Control System (ECS) Controls

The ECS controls consist of pack operation and zone temperature controls. The control panel is shown in Figure 11-18.

The pack controls occupy the lower portion of the panel. The packs can be operated in two modes, economy flow and max cool. When either mode is selected, the flow-control valve opens and the pack starts. If economy flow is selected, the flow-control valve reduces the airflow to 68% of the nominal flow schedule during cruise operation. This can be done when cooling demands are low to reduce the bleed-air requirements and, therefore, increase fuel economy. Selection of the max cool mode causes the pack to maintain a 100% flow-control valve schedule during all phases of flight.

Control of the pack discharge temperature can be automatic or manual. During automatic operation, the pack discharge temperature is controlled by the zone temperature and pack controller control systems. The left pack discharge temperature is controlled by the flight deck temperature selector, or by the lowest cabin zone selector if it is less than the flight deck. The right pack discharge temperature is controlled by the lowest zone temperature selector.

When using manual control, the pack outlet temperature is controlled by directly controlling the position of the turbine bypass valve. A switch allows the flight engineer to select either hotter or colder.

The zone temperature controls regulate the trim air system and pack discharge temperature if the packs are in the auto mode. The zone temperature controls are shown in Figure 11-18. All zone controls have an auto and manual mode. When using the auto mode, the desired cabin temperature is set on the dial, and the zone-temperature controller and pack controller work, in conjunction with the zone-temperature sensors, to maintain the selected temperature. When using the manual mode, the selector controls the position of the trim-air valve. Gauges are provided to indicate zone temperature and duct temperature.

TABLE 11-1. AIRBUS A-310 VENTILATION PARAMETERS

VOLUMES (CU FT)	A 310-200
TOTAL PRESSURIZED	
PASSENGER CABIN	11,795
FLIGHT DECK	424
FWD CARGO	1,780
AFT CARGO	1,218
BULK CARGO	611
PRESSURIZATION CAPABILITIES	
MAX ΔP (PSI)	
CONTROLLER LIMITED	8.4
SAFETY VALVE LIMITED	8.84
CABIN ALTITUDE CHANGE RATES (FT/MIN)	
CONTOLLER — MAX	2,000
CONTOLLER — MIN	0

TABLE 11-2. AIRBUS A-310 VOLUME FLOW (REF 7)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	140	4,652	37	371	0
5,000 FT CLIMB	DATA NOT AVAILABLE				
20,000 FT CLIMB	130	4,784	38	399	0
25,000 FT CRUISE	DATA NOT AVAILABLE				
30,000 FT CRUISE (68% FCV)	82	4,057	53	347	0
37,000 FT CRUISE (68% FCV)	77	4,091	53	367	0
37,000 FT CRUISE (100% FCV)	113	4,944	39	453	0
25,000 FT DESCENT	123	4,806	38	420	0
15,000 FT DESCENT	DATA NOT AVAILABLE				

TABLE 11-3. AIRBUS A-310 SYSTEM TEMPERATURES AND PRESSURES (REV 7)

(^{O}F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	60	341	42	341	14.9	42	14.7	42	14.7	51	14.7	75	14.7	100
5,000 FT CLIMB	DATA NOT AVAILABLE													
20,000 FT CLIMB	52	339	37	399	13.6	42	13.9	57	13.9	55	13.9	75	6.7	15
25,000 FT CRUISE	DATA NOT AVAILABLE													
30,000 FT CRUISE (68% FCV)	32	337	24	337	12.4	31	12.2	68	12.2	55	12.2	75	4.4	-8
37,000 FT CRUISE (68% FCV)	30	336	17	336	11.4	36	11.3	78	11.3	57	11.3	75	3.1	-33
37,000 FT CRUISE (100% FCV)	28	338	25	338	11.5	50	11.3	78	11.3	60	11.3	75	3.1	-33
25,000 FT DESCENT	34	339	34	339	12.7	45	12.5	65	12.5	57	12.5	75	5.5	10
15,000 FT DESCENT	DATA NOT AVAILABLE													

TABLE 11-4. AIRBUS A-310-200 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN (ALL FRESH)	PASS. CABIN (FRESH & RECIRC)	FLIGHT DECK
SEA LEVEL TAKEOFF	14.9	23.7	52.5
5,000 FT CLIMB	N/A*	N/A*	N/A*
10,000 FT CLIMB	15.1	24.3	56.5
25,000 FT CRUISE	N/A*	N/A*	N/A*
30,000 FT CRUISE 68% FCV	9.7	20.6	49.1
37,000 FT CRUISE 68% FCV	9.8	20.8	51.9
37,000 FT CRUISE 100% FCV	15.5	25.4	64.1
25,000 FT DESCENT	15.1	24.4	59.4
15,000 FT DESCENT	N/A*	N/A*	N/A*

*NOT AVAILABLE

A-310

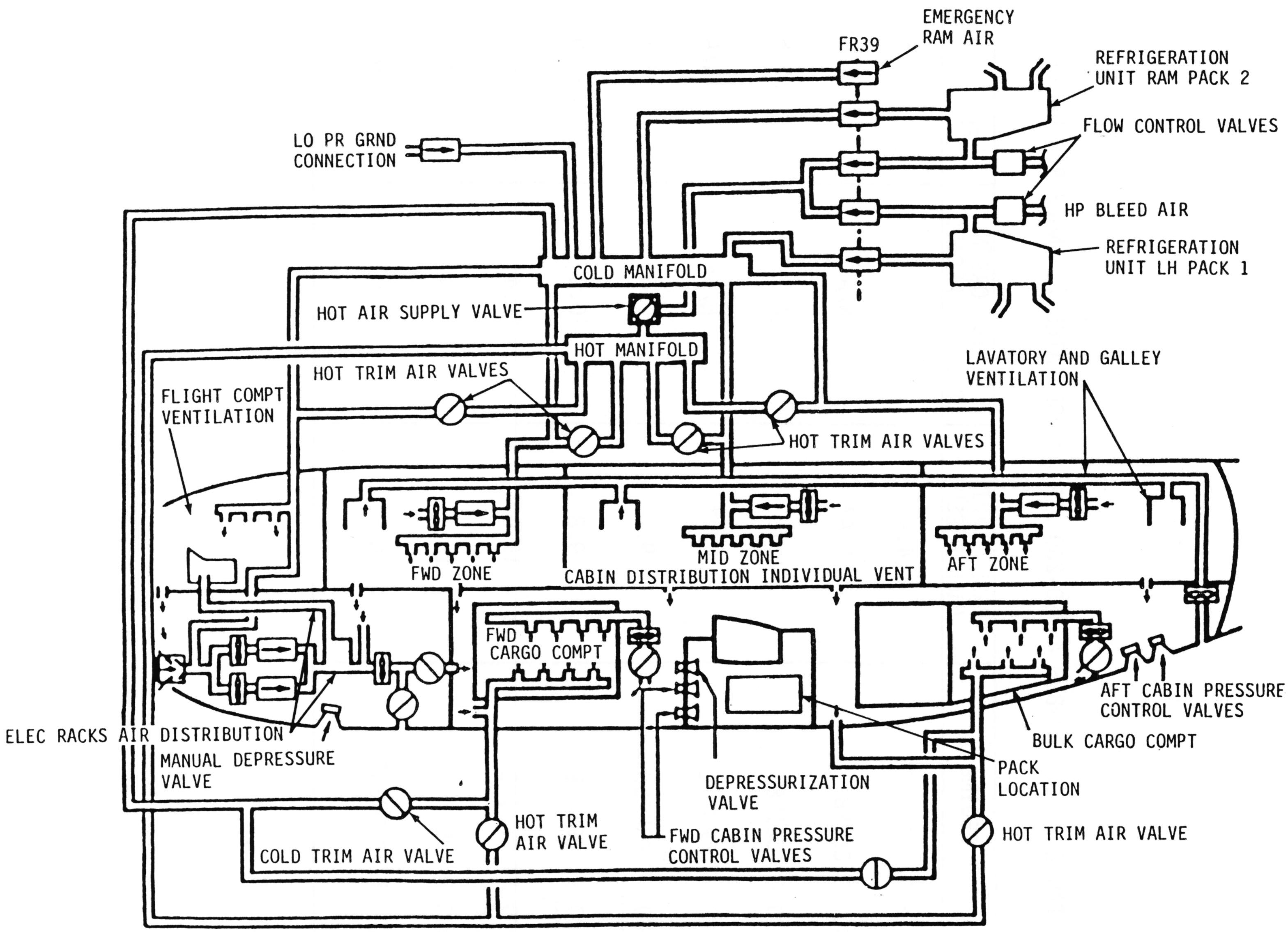


FIGURE 11-1. AIRBUS A-310 AIR CONDITIONING AND PRESSURIZATION SCHEMATIC

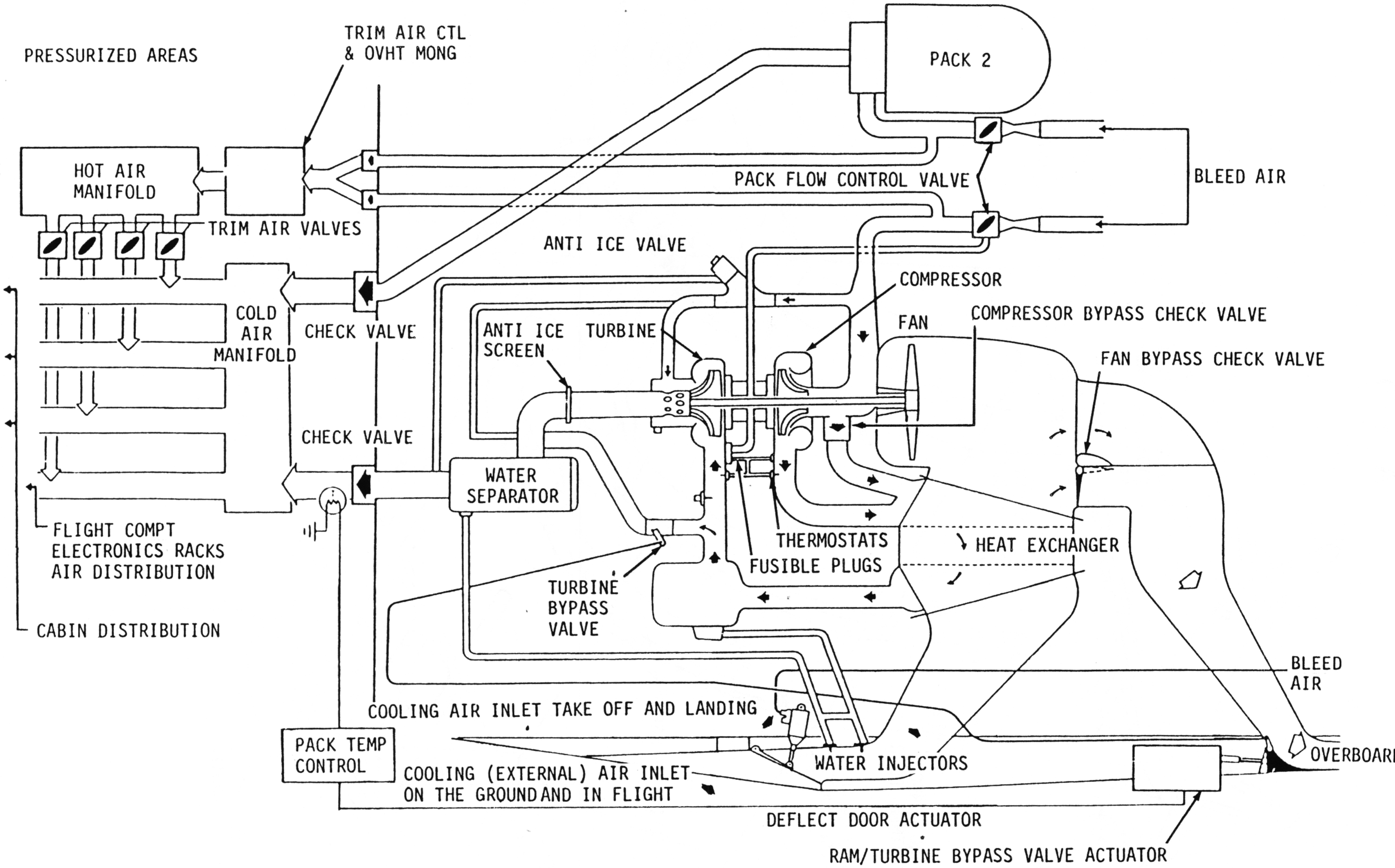


FIGURE 11-2. AIRBUS A-310 AIR CONDITIONING PACK SCHEMATIC

A-310

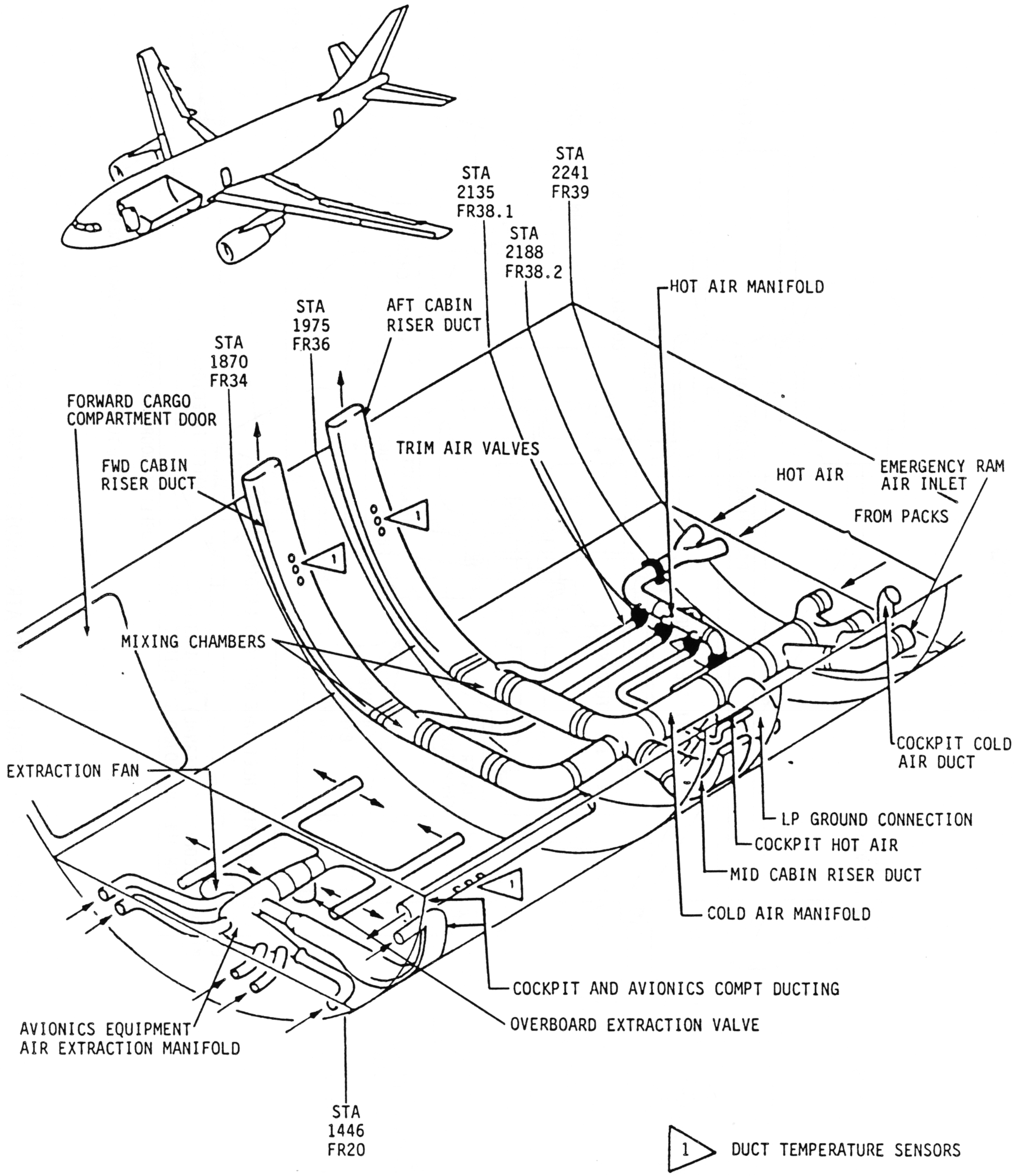


FIGURE 11-3. AIRBUS A-310 MAIN DISTRIBUTION MANIFOLD

A-310

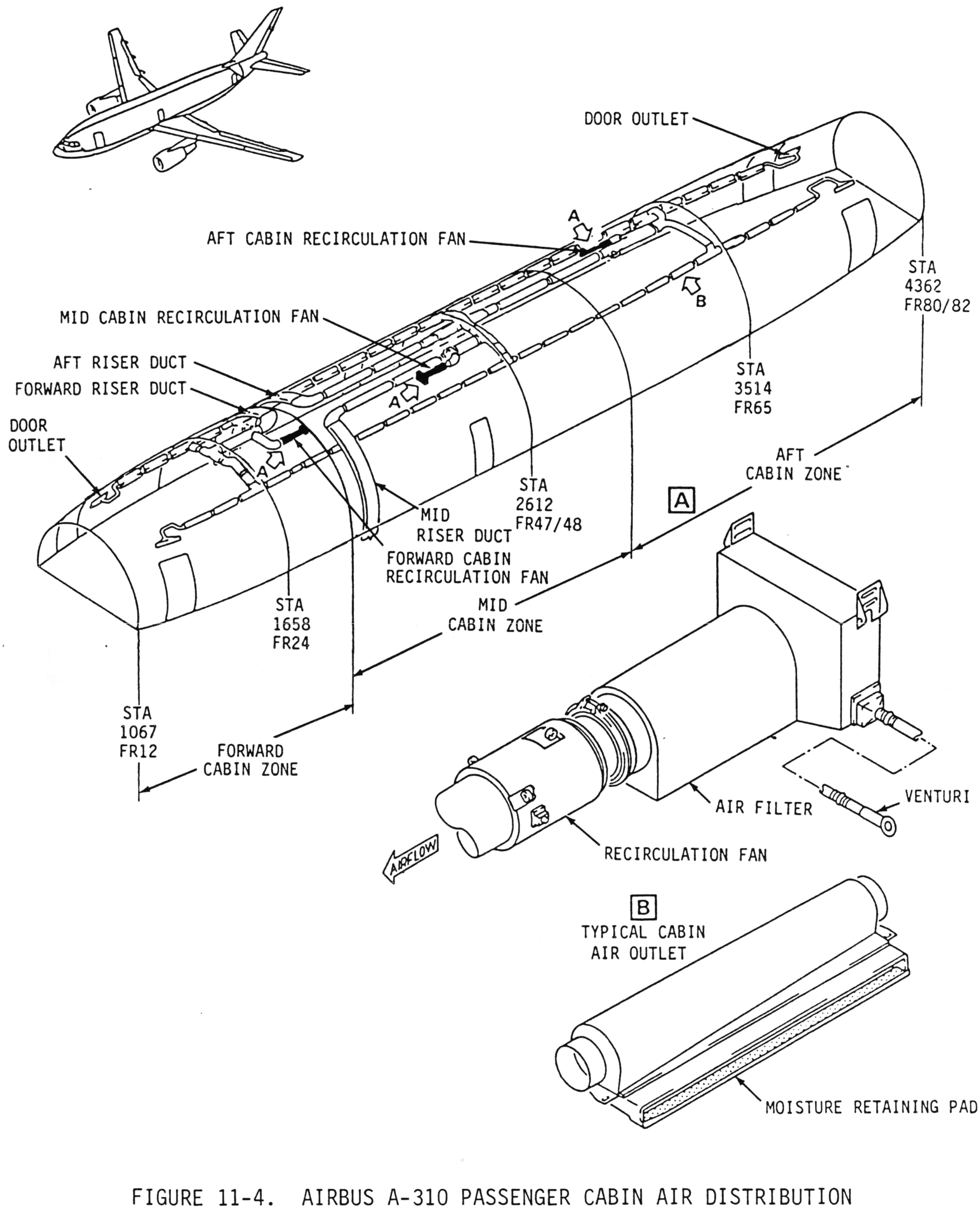


FIGURE 11-4. AIRBUS A-310 PASSENGER CABIN AIR DISTRIBUTION AND RECIRCULATION

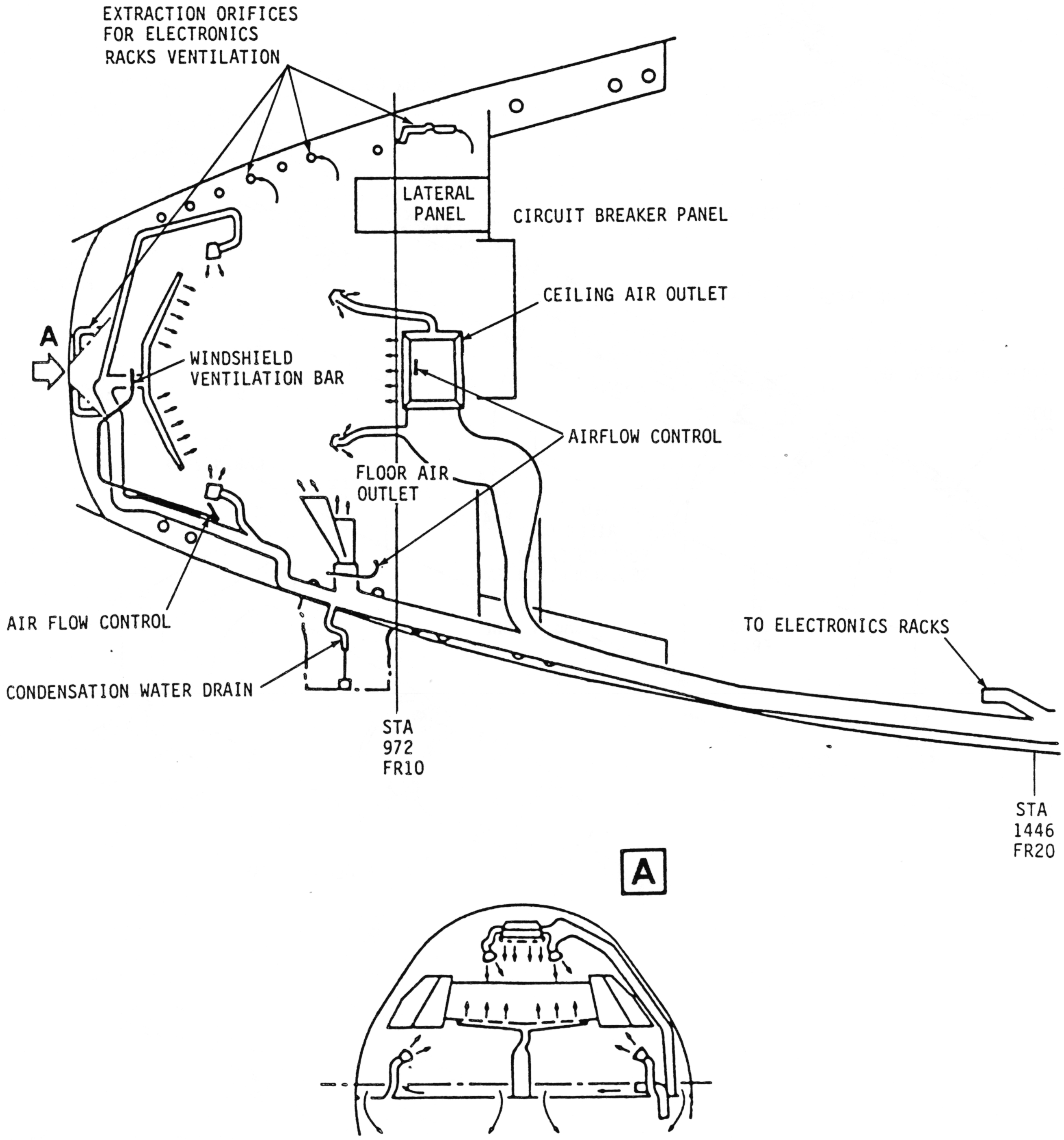


FIGURE 11-5. AIRBUS A-310 FLIGHT DECK DISTRIBUTION

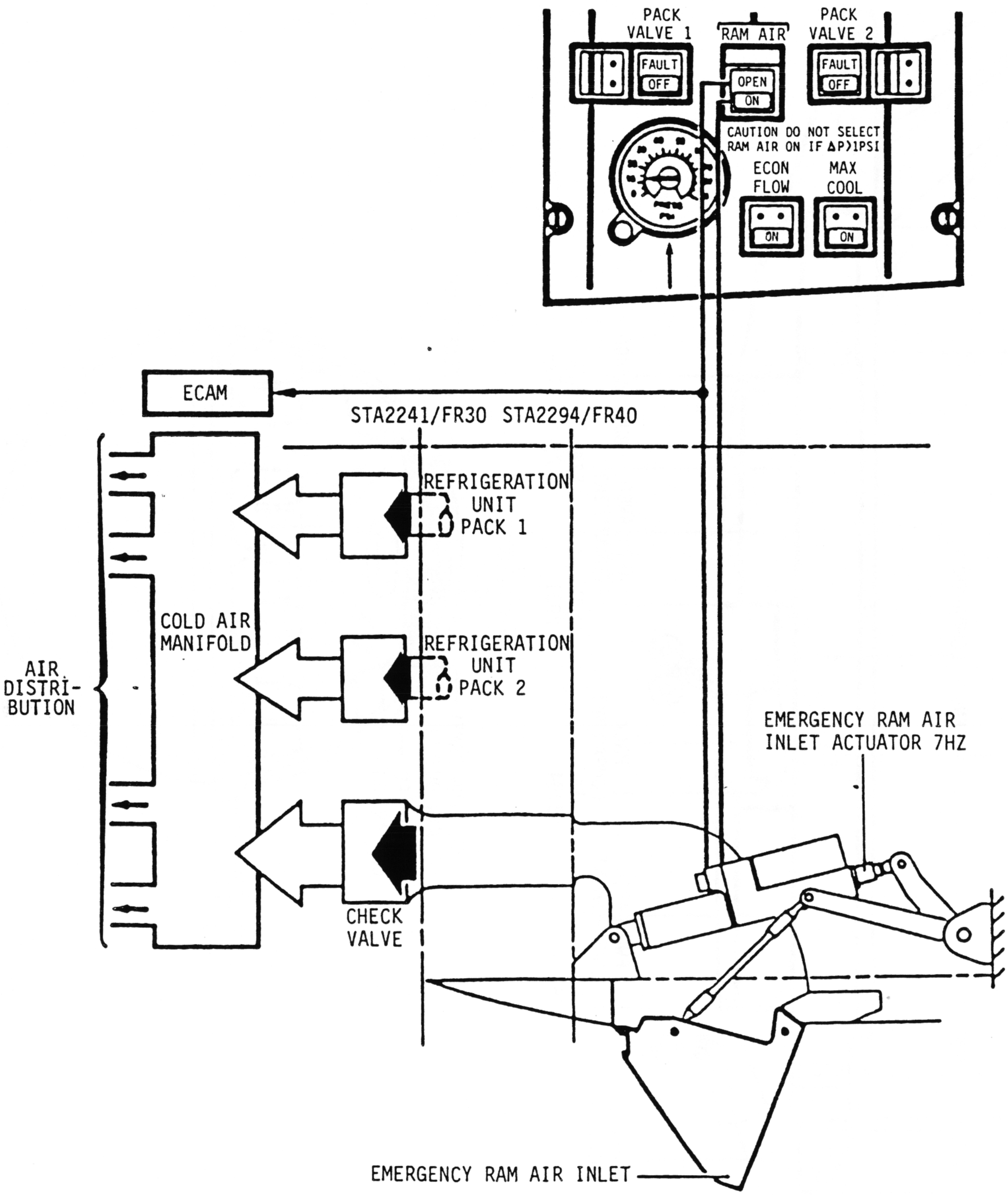


FIGURE 11-6. AIRBUS A-310 RAM AIR EMERGENCY INLET

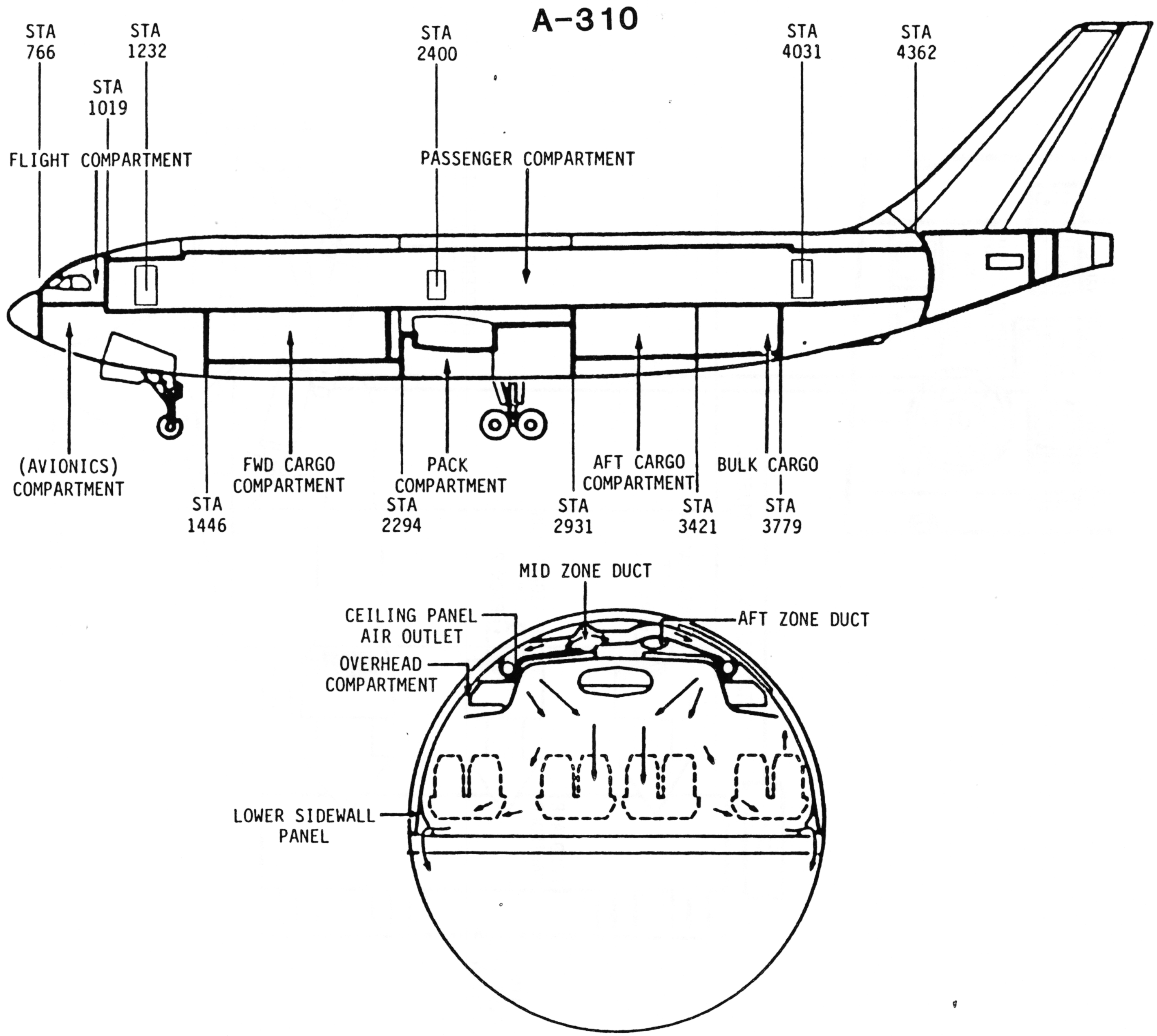


FIGURE 11-7. AIRBUS A-310 PASSENGER CABIN AIR FLOW PATTERNS

A-310

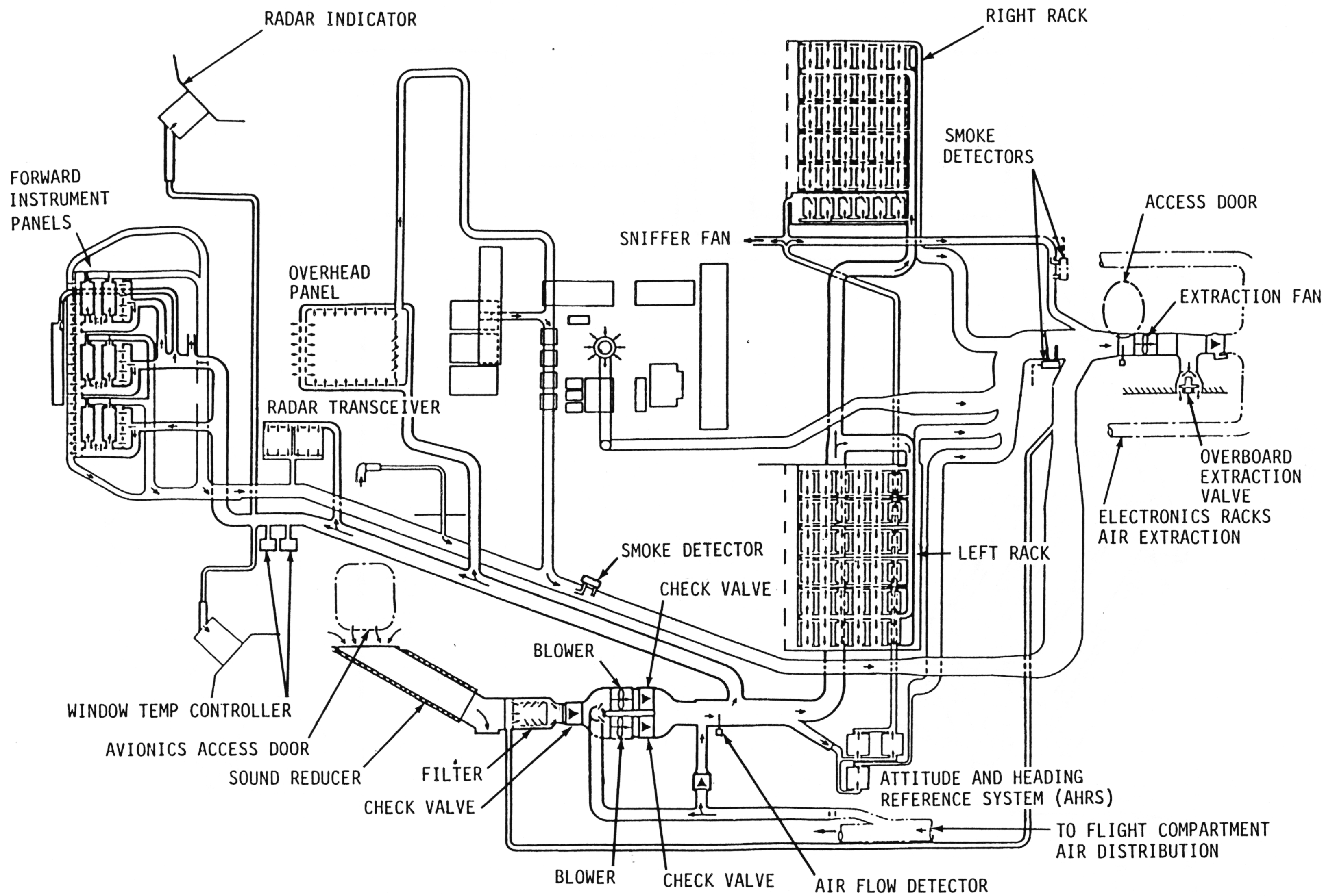


FIGURE 11-8. AIRBUS A-310 EQUIPMENT COOLING SYSTEM

A-310

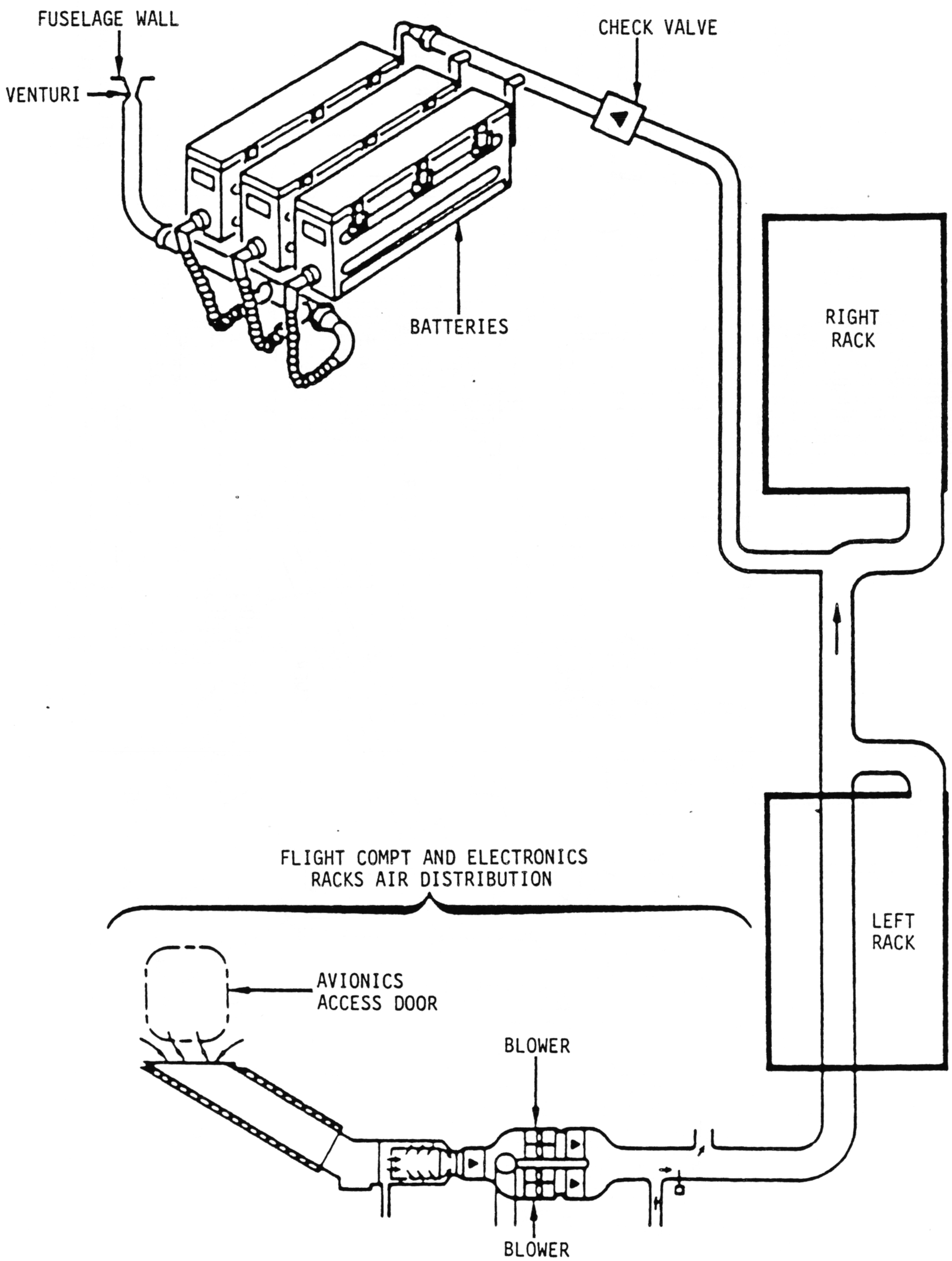


FIGURE 11-9. AIRBUS A-310 BATTERY COOLING

A-310

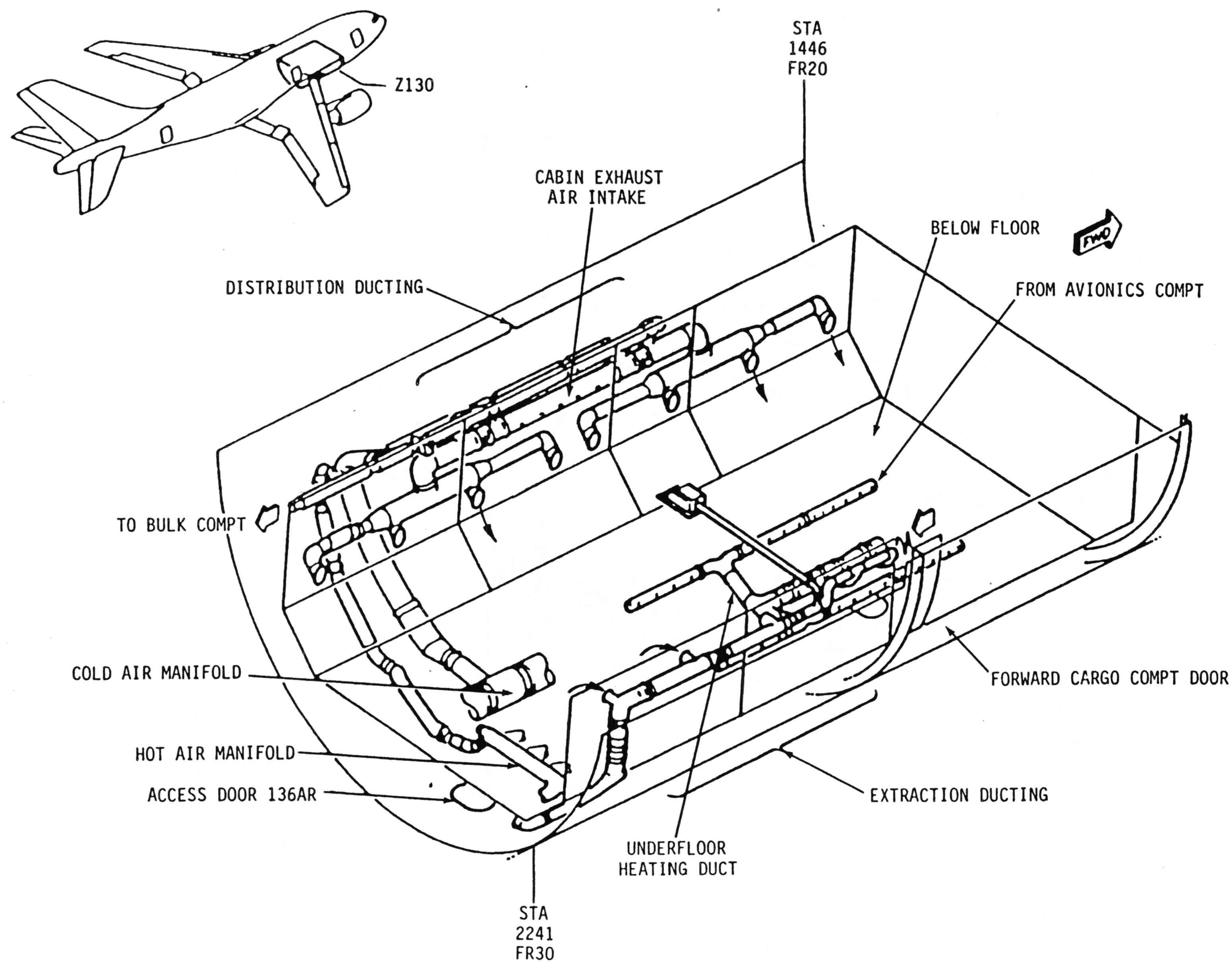


FIGURE 11-10. AIRBUS A-310 FORWARD CARGO COMPARTMENT HEATING SYSTEM

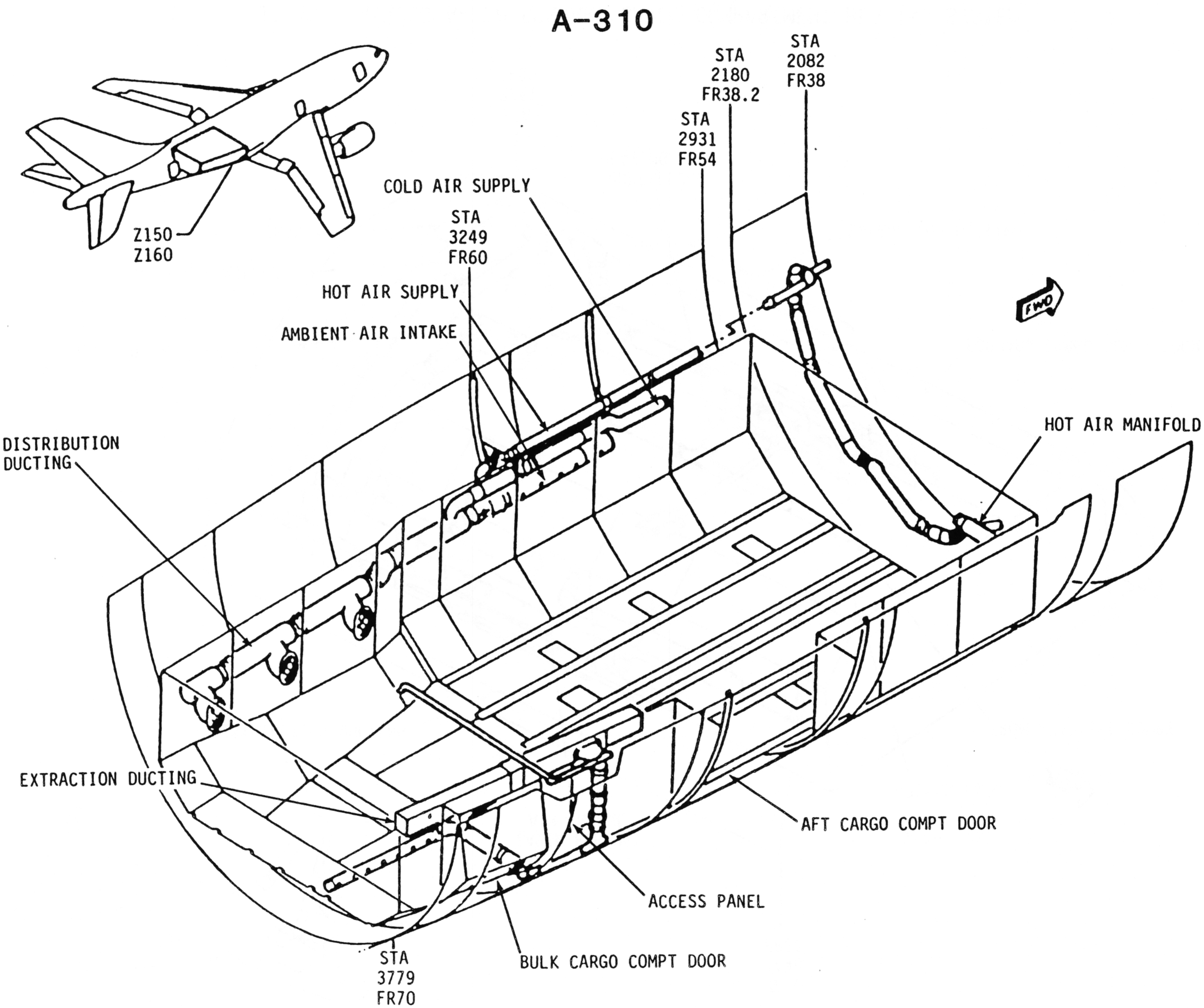


FIGURE 11-11. AIRBUS A-310 BULK CARGO COMPARTMENT HEATING SYSTEM

A-310

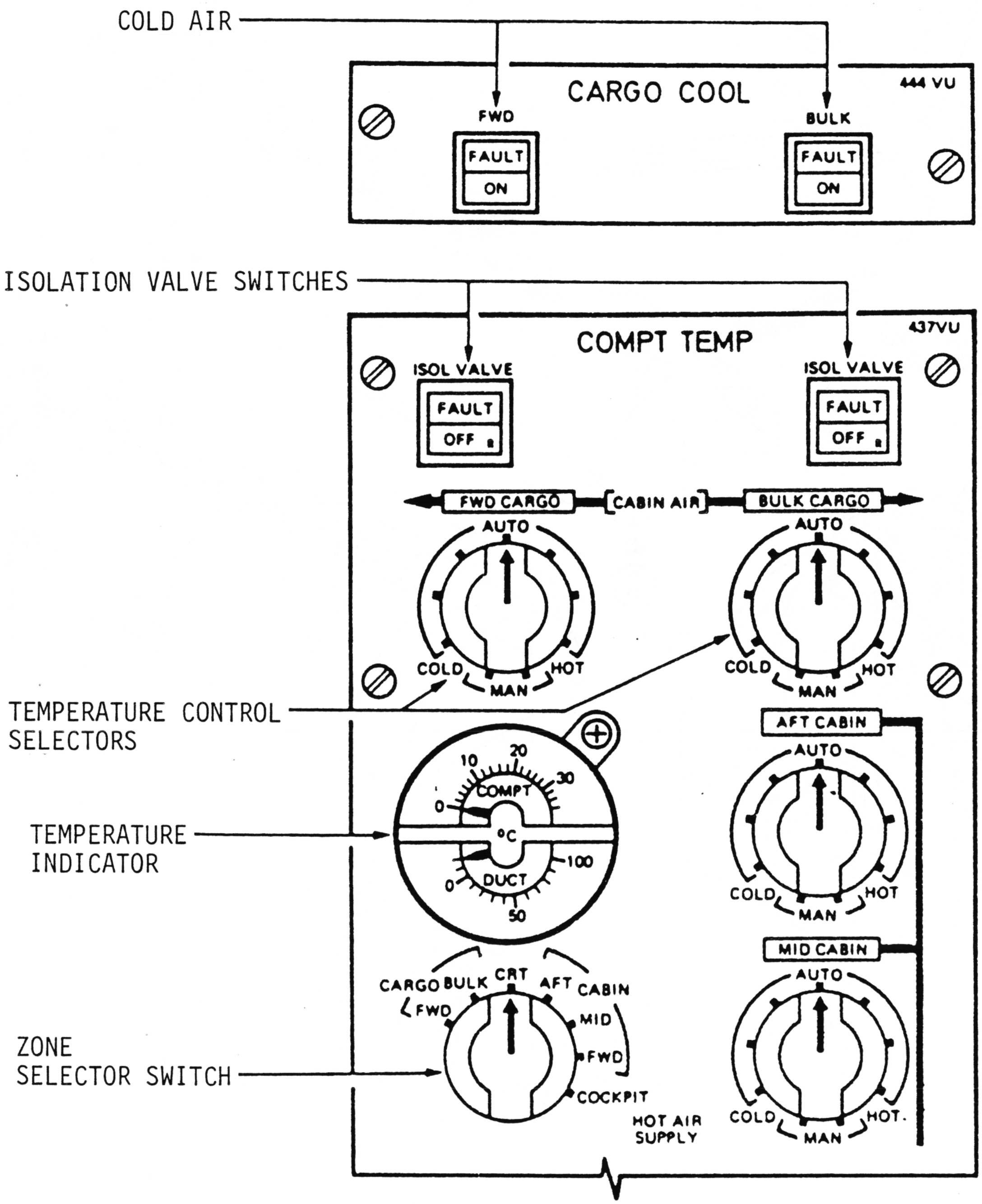


FIGURE 11-12. AIRBUS A-310 CARGO COMPARTMENT TEMPERATURE CONTROLS

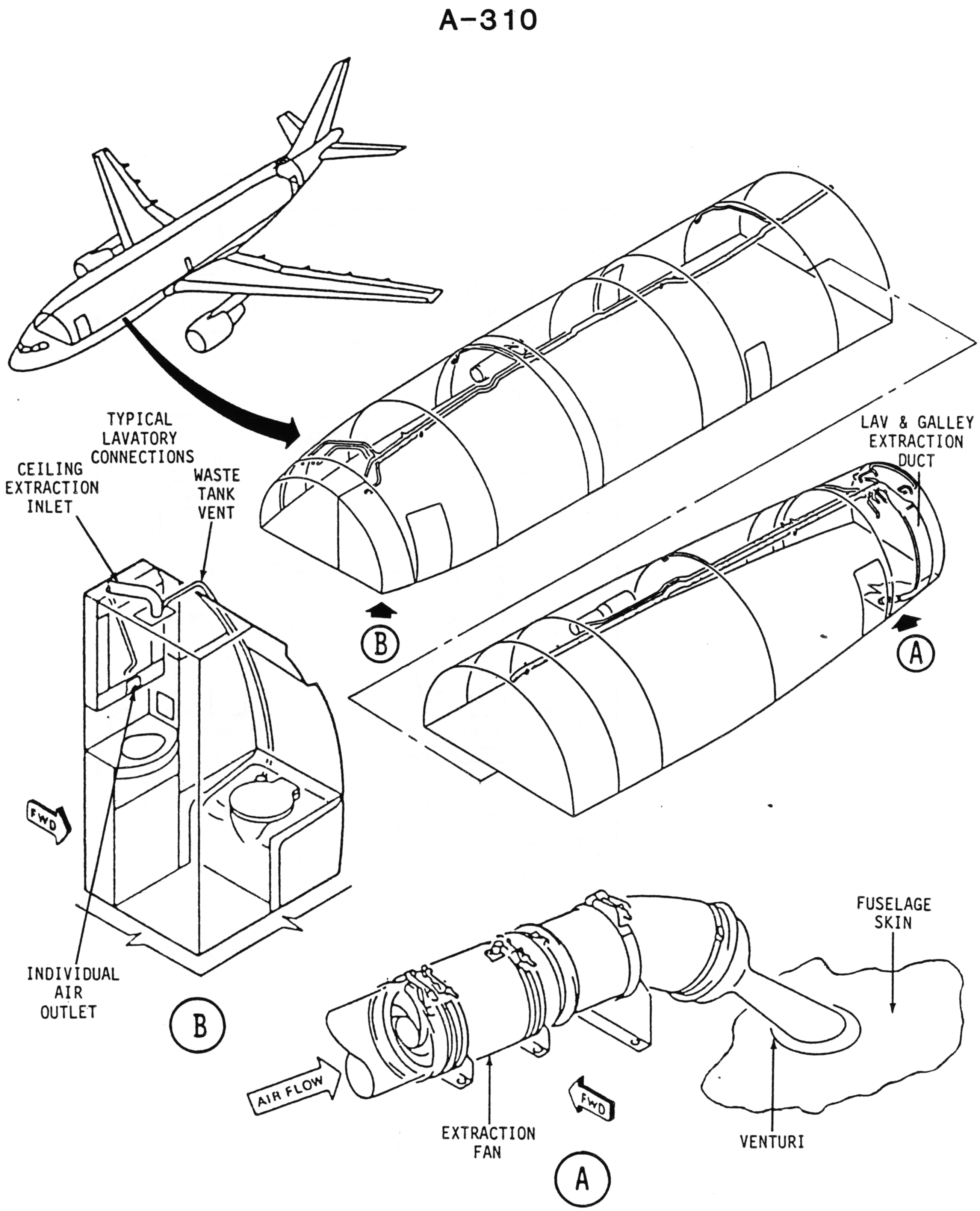


FIGURE 11-13. AIRBUS A-310 LAVATORY AND GALLEY VENTING

A-310

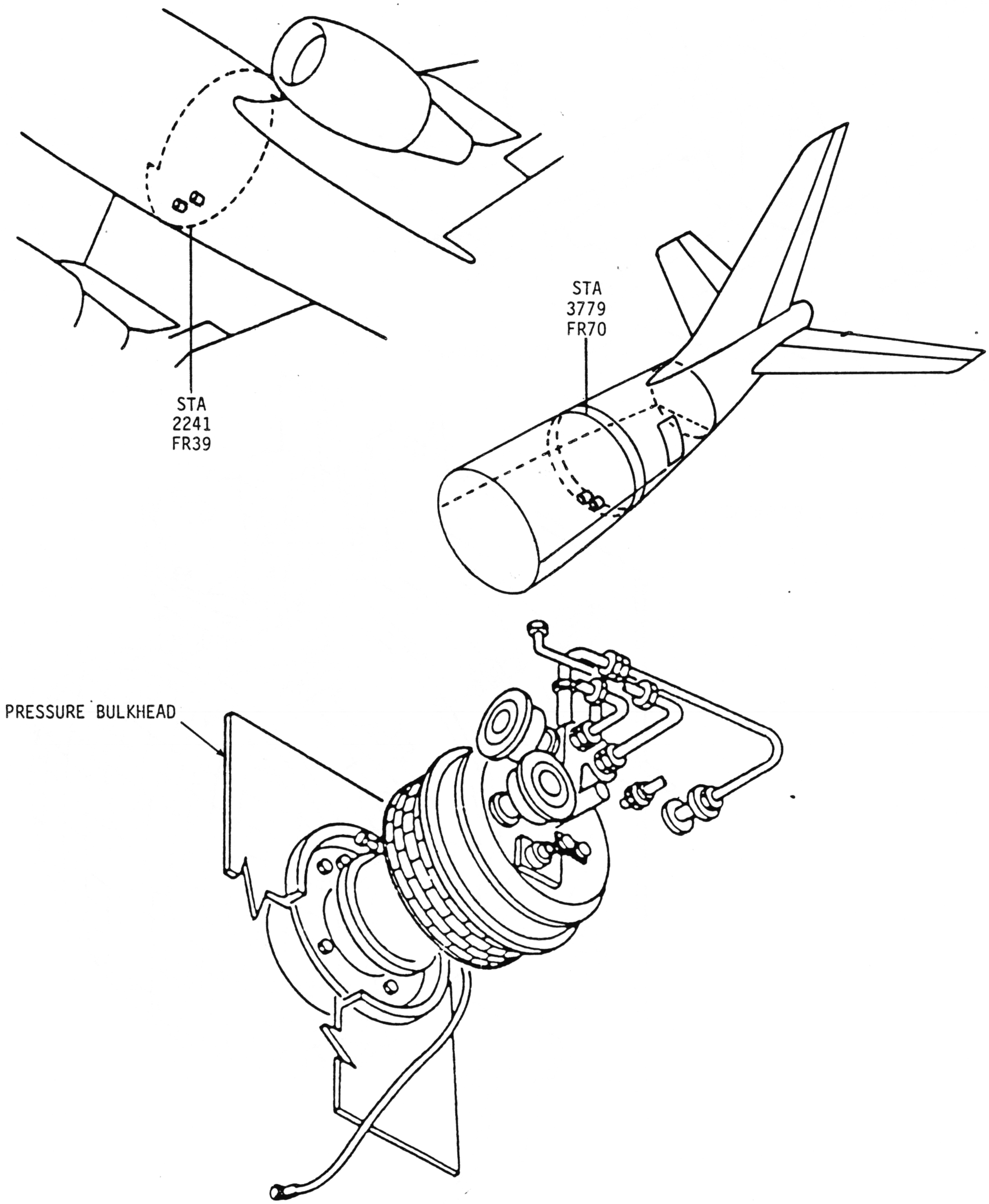


FIGURE 11-14. AIRBUS A-310 PRESSURIZATION OUTFLOW VALVES

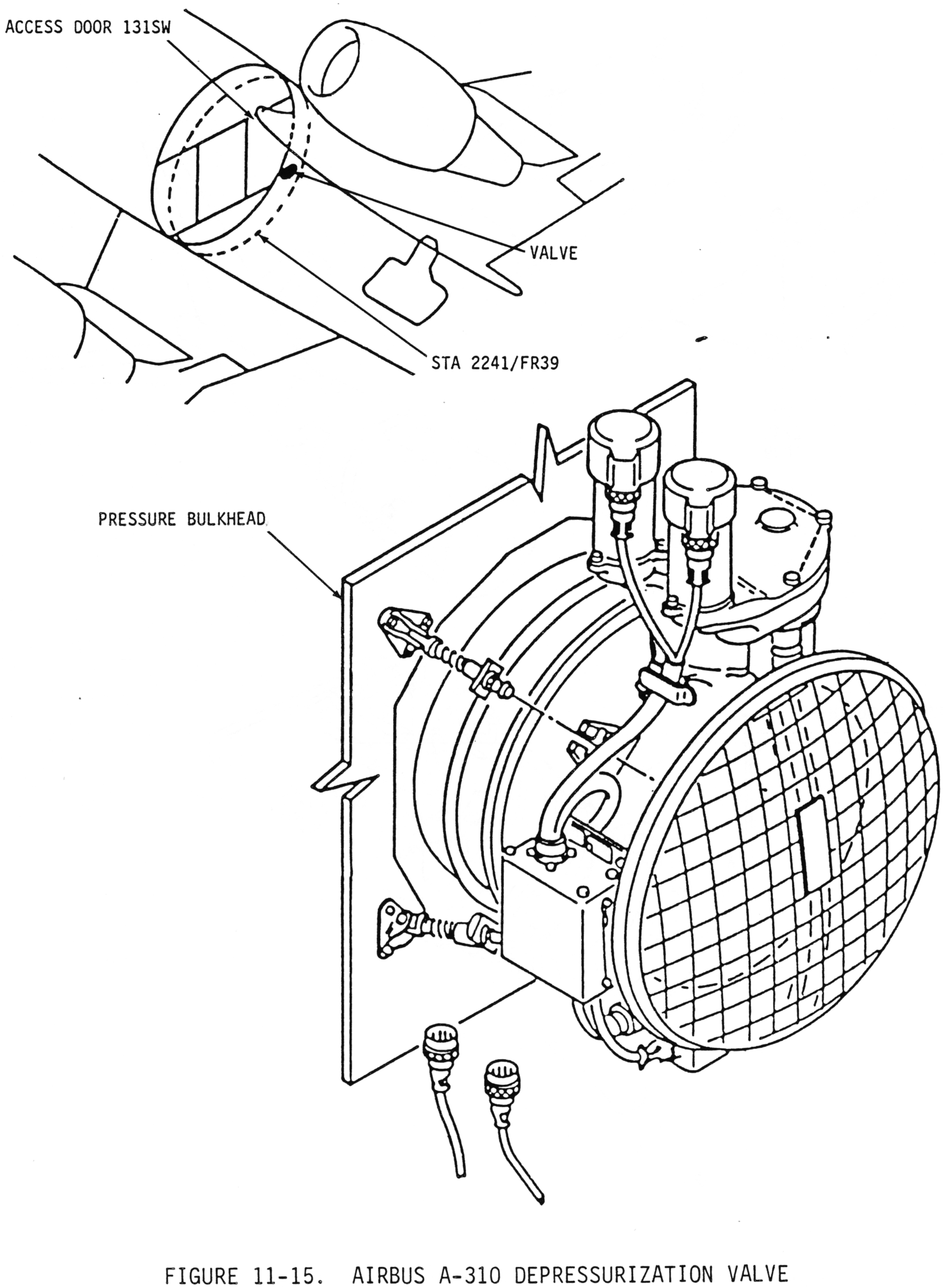


FIGURE 11-15. AIRBUS A-310 DEPRESSURIZATION VALVE

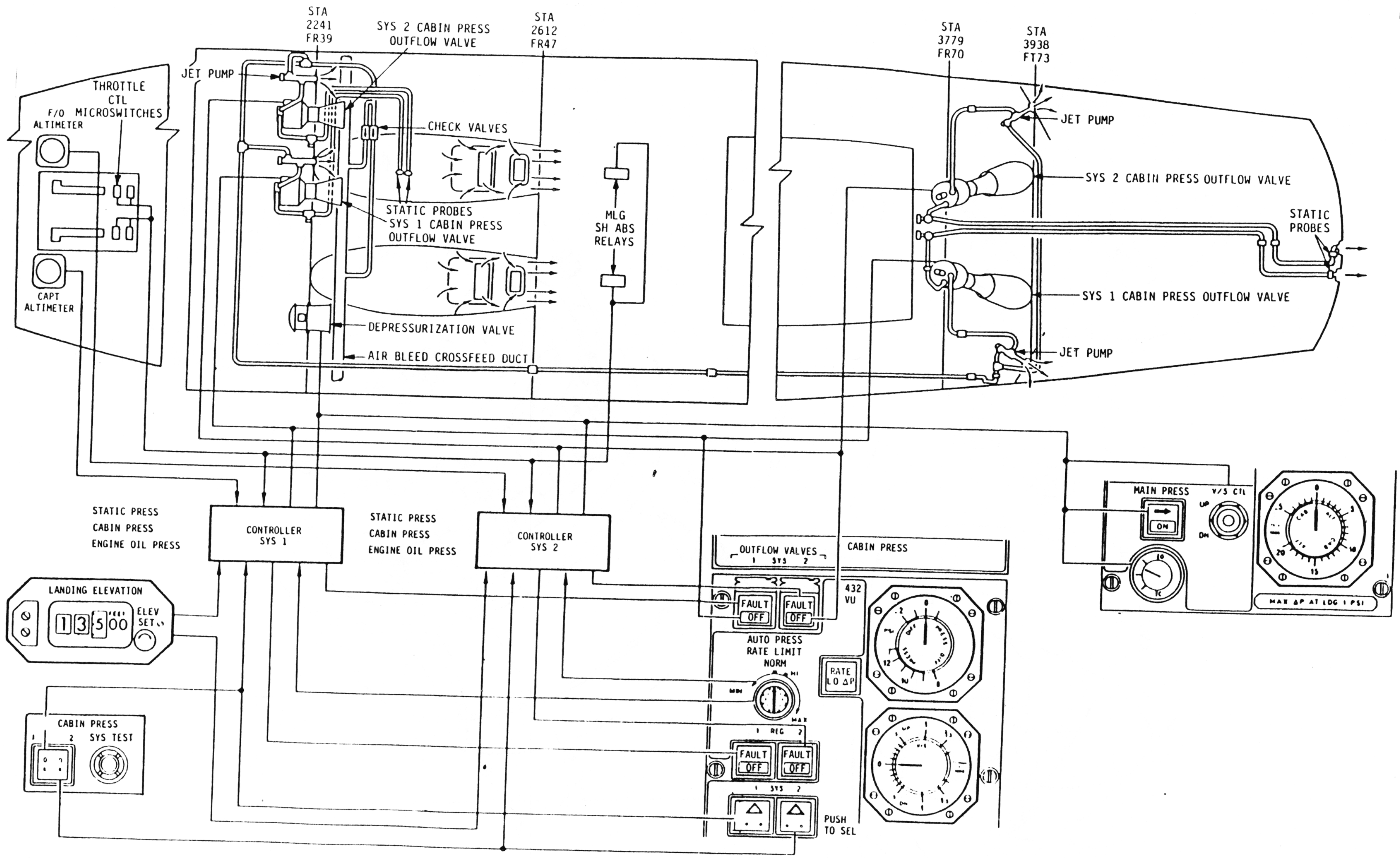


FIGURE 11-16. AIRBUS A-130 PRESSURIZATION CONTROL SCHEMATIC

A-310

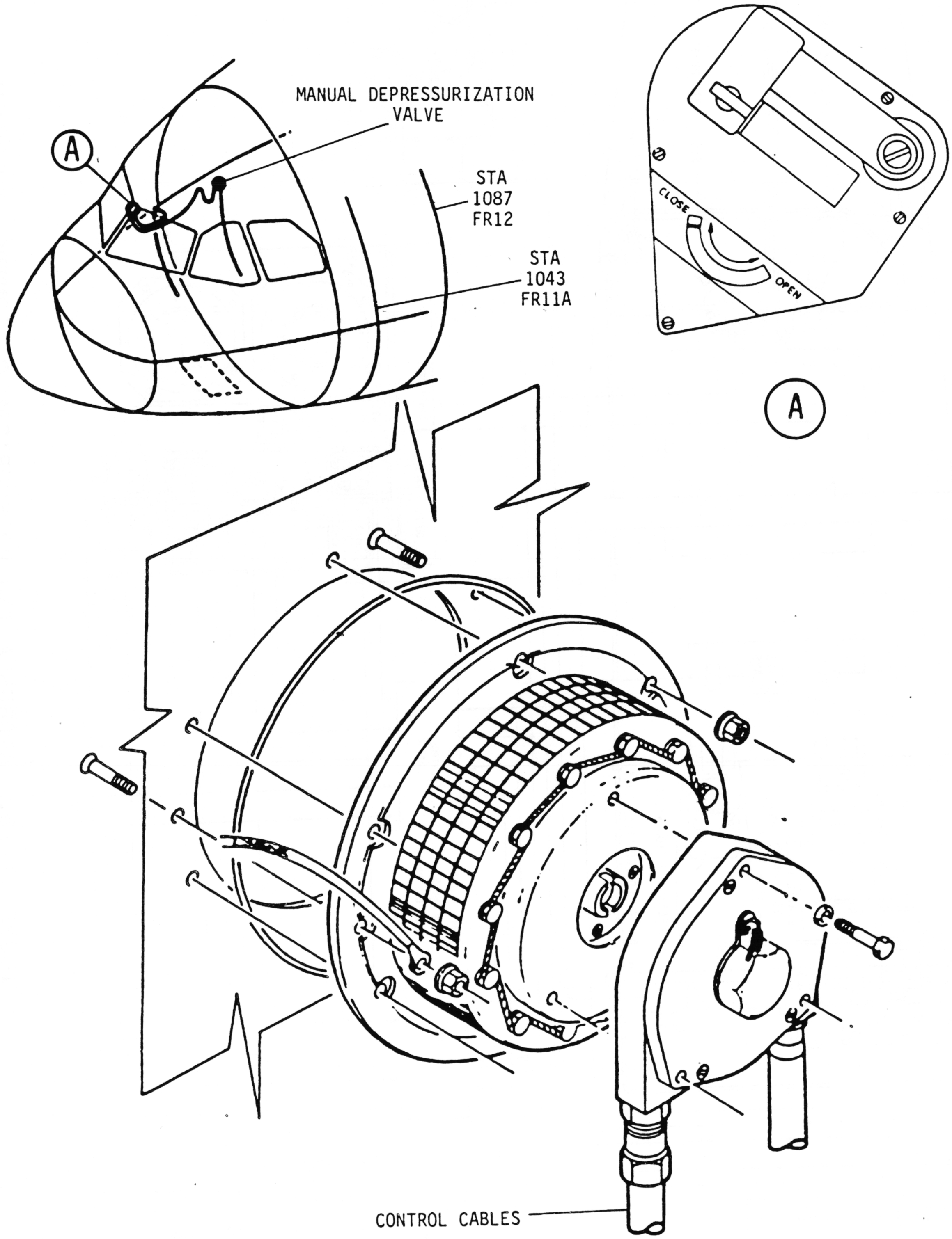


FIGURE 11-17. AIRBUS A-310 MANUAL DEPRESSURIZATION VALVE

A-310

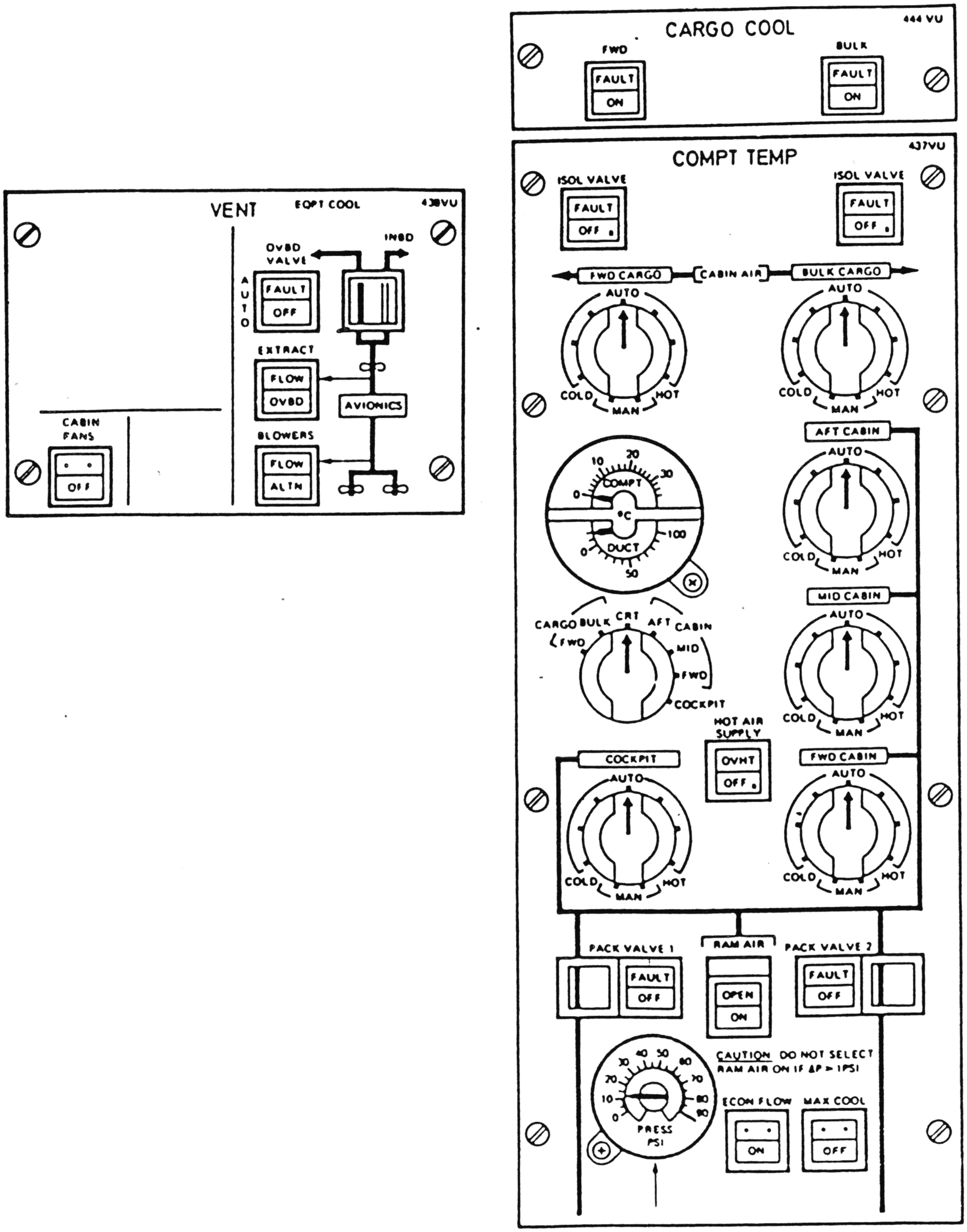


FIGURE 11-18. AIRBUS A-310 ECS CONTROL PANEL

SECTION 11

LOCKHEED L-1011

Model Variation

The Lockheed L-1011 was introduced in the early seventies to capture a segment of the long-range wide-body aircraft market. It was sized to fill a gap between long-range narrow body transports and the much larger 747. The major competitors for this market were the Douglas DC-10 and, on shorter route systems, the Airbus A300.

The L-1011 was produced in four models; the -1, -100, -200 and -500. A summary of first flights, certification dates and number produced is shown in Table 12-1. The -1, -100 and -200 are dimensionally similar, the main differences being increased range and payload as the series progressed. The -200 was also fitted with increased thrust engines. The -500 model is a shortened version with the highest takeoff weight, longest range, and higher-thrust engines. The cargo capacity of the -500 was also increased by elimination of the lower deck galley.

All models have the same packs and pressurization controls, the main differences being in the distribution and ventilation ducting on the -500 models (as a result of the elimination of the lower galley).

L-1011 Environmental Control System (ECS)

The L-1011 ECS is a three pack air cycle system that uses bleed-air as the air source. A schematic of the system is shown in Figure 12-1. The air-conditioning packs are located on both sides of the nose landing gear wheel well in an unpressurized area of the fuselage. The air-conditioning packs utilize engine bleed-air from the compressor stages of all three engines as an air source. During ground operations, a pneumatic ground cart or the APU can be used as a hot air source. A schematic of the pack is shown in Figure 12-2. Pressures and temperatures at points A through E on Figure 12-2 are listed in Table 12-2.

The hot bleed-air pressure and temperature are regulated by the pneumatic system before being supplied to the pack flow-control valve.

The flow-control valve is an electronically controlled pneumatically operated valve that regulates flow through the system to maintain nearly constant volumetric flow in response to variations in bleed-air supply pressure and cabin pressure. After leaving the flow-control valve, the air is routed to the trim air system and primary heat exchanger. The trim air system provides a source of hot air, used to adjust the temperature of the pack discharge air, to vary the temperature of the air supplied to the different cabin zones. Most of the air is routed to the primary heat exchanger, where it is cooled by ram air before being routed to the air cycle machine (ACM) compressor and compressor bypass check valve. The compressor raises the air to higher temperature and pressure, and routes it to the secondary heat exchanger.

The compressor bypass valve allows hot air to bypass the compressor to increase system efficiency when cooling demands are low. Air from the compressor bypass valve is routed to the secondary heat exchanger.

Air is cooled in the secondary heat exchanger, and routed to the ACM turbine and turbine bypass valve. The air routed to the turbine expands in the turbine to drive the ACM compressor and heat exchanger cooling fan. As the air expands, it cools to form cold air. The cold air is routed to the water separator. The turbine bypass valve controls the amount of air passing through the turbine and, therefore, the amount of cold air produced. When the packs are operated in the humidity control mode, the turbine bypass valve is held full closed so that all the air is routed through the turbine. This causes more moisture to condense in the turbine outlet and be removed in the water separator. An automatic control system limits the turbine discharge temperature from going below 35°F. Air bypassing the turbine is mixed with the turbine discharge air and then all the air is routed to the water separator. The water separator removes entrain water droplets from the air stream, and directs the cold dry air to the cold air plenum.

Distribution

Cold air from all three packs enters the cold air plenum where it is divided and routed to the flight deck, lower galley (all except -500 models), and passenger cabin zones. The cold air manifold is located below the floor near the number 1 right-hand passenger door (see Figure 12-3). Cold air leaving the manifold is mixed with hot trim air to adjust the temperature and then routed to the distribution systems.

The passenger cabin distribution system is shown in Figure 12-4. The passenger cabin is divided into three zones; forward, mid, and aft. Each zone is supplied from the cold air manifold by a riser located behind the sidewall forward of the number 1 right-hand door. The main distribution ducting consists of supply ducts located above the ceiling running the length of the cabin zones. Each set of zone supply ducts routes air to the conditioned air outlets and individual air outlets. Conditioned air enters the cabin through cabin aspirators (see Figure 12-5). The function of the cabin aspirators is to increase circulation of cabin air by drawing cabin air into the aspirator, mixing it with cold air from the supply duct, and exhausting the mixture into the cabin. The aspirators use air from the supply ducting, exhausted in a jet pump to draw cabin air into the aspirator. The cabin aspirators are located in the ceiling areas over the seating areas. A cross section of the passenger cabin is shown in Figure 12-6.

The flight deck distribution system is shown in Figure 12-7. The flight deck outlets are supplied from the cold air manifold by a duct running forward on each side of the flight deck. On most airplanes, the supply duct has a manually controllable valve that allows the flight crew to adjust the airflow to the flight deck. The flow varies between 300 and 400 CFM (cubic feet per minute).

The flight deck has outlets located below the two side windows, and in the ceiling at the back of the compartment. The crew is also provided with gasper style outlets located at each crewman's station. These outlets are supplied with conditioned air and are adjustable for flow and direction.

The conditioned air system also supplies air to the lower deck galley (-1, -100, -200 models only). The galley distribution ducting is supplied from the cold air manifold by a duct running aft below the left passenger cabin floor. Air enters the lower galley through outlets in the overhead lighting fixtures. Each outlet has a flapper door that can be closed to reduce the airflow into the galley. A flow-control valve in the supply line limits the airflow to approximately 425 CFM maximum. The galley distribution system is shown in Figure 12-8. On -500 models, the forward galley units are supplied from the forward cabin distribution system through covered ceiling outlets. The mid and aft galleys do not have conditioned air outlets. Airflow rates and air change rates for the various compartments are shown in Tables 12-3, 12-4 and 12-5. Airflow patterns in the passenger cabin are shown in Figure 12-9.

Individual (Gasper) Air

The L-1011 gasper system does not use a separate system of ducting, instead, gasper outlets are supplied from the air conditioning distribution system. The overhead ducting has direct connections for the center seat outlets and supplies the side outlets through the lateral duct and outboard distribution ducts (see Figures 12-4 and 12-10).

The gasper outlets are mounted above each side seat on all airplanes, and above the center seats on airplanes with eight abreast seating. The outlets are electrically operated valves that can be adjusted to closed, half open, and full open.

Equipment Cooling

The L-1011 uses draw-through cooling to cool the instrument panels, flight engineer's console, forward electronics compartment, and mid electronics compartment.

The forward equipment cooling system is shown in Figure 12-11. The system uses a fan to draw air from the forward electronics compartment into the avionics racks and around the rack mounted equipment. The fan operates anytime electrical power is available. During ground operations, the fan exhausts air overboard. Upon liftoff, the exhaust flow-control valve closes and the fan exhausts air under the forward cargo compartment. If the fan fails in flight, the exhaust valve opens, and flow through the system is driven by cabin pressure.

The forward instrument panels and flight engineer's console cooling system is shown in Figures 12-12 and 12-13. A small fan draws air from the flight deck through an outlet below flight engineer's table, and exhausts air onto the forward instrument panel and the flight engineer's panel. On some airplanes the fan draws air from the aft cabin supply riser. If the aft cabin supply temperature exceeds 90 °F, the diverter valve opens, and cooling air is drawn into the ducting from the air-conditioning distribution bay.

The mid-equipment center cooling system is shown in Figure 12-14. The mid-equipment cooling system draws air from the left and right equipment racks, and the space aft of the galley. The fan operates when electric power is available and normally exhausts under the galley floor. Air is then exhausted overboard through the forward outflow valve. During ground operations or if the fan fails in flight, air is exhausted overboard through the exhaust flow-control valve.

On -500 models, the mid-equipment center cooling system draws air from the left and right equipment racks, and the space aft of the forward cargo compartment. The -500 system is shown in Figure 12-15.

The auxiliary batteries are cooled by using a fan to blow air from the galley conditioned or supply duct, into the battery box. If the galley supply air is warmer than 90 °F, the diverter valve opens and air is drawn directly from the galley. The fan operates whenever electric power is available, and the battery charger circuit breaker is closed.

On -500 models, the battery cooling fan draws air from the mid-cabin air-supply duct. If the mid cabin supply air is warmer than 90 °F, the battery cooling diverter valve opens and air is drawn from the right utility tunnel, (See Figure 12-15).

Cargo Heating

The L-1011 has three cargo compartments; forward, center and aft. The forward and center compartments are certified as FAR Part 25 Class C compartments, and have the necessary fire detection and suppression systems. The aft compartment is certified as a FAR Part 25 Class D compartment. Its only limitation is a ventilating airflow of less than 1500 cubic feet per hour (CFH).

All three cargo compartments use a closed loop recirculation system using pneumatic ducts as the heat source. The cargo heat systems are shown in Figures 12-16 through 12-18. The cargo heat systems draw air from the cargo compartment, pass it through a heat exchanger and return the air to the compartment. The forward system receives heat from a heat exchanger mounted on the pack pneumatic supply ducts located below the compartment floor. The mid and aft compartments receive heat from the No. 2 engine pneumatic supply duct. The circulation fans operate on 115 volt 400 Hz electric power, and are automatically controlled to maintain compartment temperature between 55-70 °F. Overheat switches will limit the compartment temperature to 90 °F, if the fan controller fails to stop fan operation. On -500 models, the forward cargo temperature can be set by the ground crew during loading by using a selector knob located inside the compartment.

Approximately 50 of the 250 airplanes produced incorporated an additional ventilating system in the aft cargo compartment. This system provides fresh air to the compartment for carrying live cargo. The system consists of a vent fan that draws air from the passenger cabin exhaust outlets, and exhausts the air into the aft cargo compartment through an outlet in the right aft cargo lining. When the fan is operating, air from the compartment is normally exhausted overboard through a flow-control valve. If the cool air overboard switch is released, closing the overboard exhaust valve, air is exhausted from the compartment through the exhaust bypass valve into the right utility tunnel.

The cargo ventilation modification also includes two smoke detectors that signal the overboard exhaust valve, exhaust bypass valve, and vent fan valve to close, effectively sealing the compartment. The heating ducting remains the same for all models.

Ventilation

Air is vented overboard by four systems; galley exhaust, lavatory venting, equipment cooling system and pressurization outflow valves. On -500 models, air is also vented overboard by the cabin overhead exhaust system.

The galley exhaust system for -1, -100 and -200 models is shown in Figure 12-19. The system uses a fan to draw air from behind the ovens into the exhaust ducting. The fan exhausts air overboard through a flow-control valve. The fan operates anytime AC bus number 2 is energized. The flow-control valve is self-modulating to maintain a nearly constant volumetric flow. Flow overboard is approximately 29-44 pounds per minute at 8.4 psi differential pressure. On the ground, the valve can flow up to 535 CFM with the cabin unpressurized. The valve can be closed by releasing the cool-air-overboard switch light. This also closes the forward and mid-equipment cooling system exhaust valves.

The exhaust system also includes ducting to vent carbon dioxide gas from dry-ice-cooled refrigeration carts, (See Figure 12-20). The ducting draws air and gas from the floor area below the sink and opposite the galley door. The ducting is connected to the mid-equipment cooling system, and operates when electric power is available.

The -500 galley vent system is shown in Figure 12-21. The -500 models have upper deck galleys located in the forward, mid, and aft cabin areas. The exhaust ducting is located above the ceiling, and draws air through filtered outlets in the galley ceiling panels. Air is exhausted overboard through the galley exhaust flow-control valve. Flow through the system is driven by cabin differential pressure. The flow-control valve closes when the cool air overboard switch is released.

The galley exhaust system also provides cooling for overhead mounted transformers and circuit panels. A fan draws cabin air through the panels and exhausts into the galley exhaust ducting. If the overboard valve is closed, the fan motor is automatically de-energized.

The -500 models are also equipped with an overhead exhaust system that vents air from above the ceiling area (See Figure 12-22). Because the galley refrigerators exhaust air above the ceiling, the temperature of this area can become overly hot during summer operations. If the air temperature above the ceiling reaches 100 °F, the exhaust flow-control valve will open and the exhaust fan will dump air overboard.

If the fan fails, differential pressure will continue to drive air overboard. The exhaust flow-control valve will close automatically when the temperature falls below 95 °F, or if the cool-air-overboard switch is released.

The forward and aft lavatory ventilation systems are shown in Figures 12-23 and 12-24. The systems are identical in operation, differing only in the airflow and ducting configuration.

The ventilation systems use cabin pressure during flight or a jet pump during ground operations, to draw air from the lavatory waste tanks. This causes air from the lavatory to be drawn into the toilet bowl, and then into the waste tank. Flow through the system is controlled by an exhaust flow-control valve. The valve is self-modulating to maintain a constant flow of approximately 62 to 64 CFM for the forward lavatory system and between 170 and 174 CFM for the aft system. The aft system, also provides a 10 CFM ventilation airflow from the animal compartment of the aft cargo compartment.

During ground operations, pneumatic air exhausted into the venturi of the jet pump draws air from the waste tank.

For equipment cooling ventilation details, see the equipment cooling system.

The pressurization outflow valves are the primary means of venting air overboard. The L-1011 has two outflow valves; forward and aft, located on the lower left fuselage approximately below number 2 and 4 passenger doors. The outflow valve is shown in Figure 12-25. The outflow valves respond to signals generated in the pressure controller to vary the amount of air passing overboard to maintain cabin pressure as required. If airflow from the packs is reduced, the valves will close until the forward valve is exhausting approximately 2000 CFM. If pressure continues to fall, the aft valve will close further. If the aft valve reaches full closed and the pressure is still falling, the forward valve will then continue closing until cabin pressure is maintained.

Pressurization Controls (PCS)

The pressurization control system controls the amount of air passing overboard through the outflow valves to maintain the lowest cabin altitude for the selected flight altitude, minimize the cabin altitude rate of change, and ensure that the cabin is unpressurized at landing. The pressurization control system has three operating models; normal, standby, and manual. The panel is shown in Figure 12-26. Pressurization control system capabilities and limitations are shown in Table 12-6.

The normal mode requires the crew to input the desired cabin altitude, barometric correction for landing altitude, and the desired cabin altitude rate of change. The pressure controller then modulates the outflow valve to maintain cabin pressure as requested. If the selected cabin altitude is too low for the flight altitude, the controller automatically increases the cabin altitude to the minimum amount necessary. Normal differential pressure is limited to 8.44 psi, maximum pressure is limited to 8.59 psi by the controller. The safety relief valves provide pressure relief at 8.8 psi.

The standby mode is used when the auto mode fails. To operate in this mode, the flight engineer selects standby, and then controls the cabin altitude with the standby rate knob. Turning the knob to ascent will increase the cabin altitude, descent will decrease the cabin altitude, and hold maintains the cabin altitude. During standby, the differential pressure gauge, cabin altitude, and rate of change must be monitored to avoid discomfort to the passengers.

Manual mode allows direct control of the outflow valves. A separate switch and indicator are provided to control and monitor the position of each valve. To put an outflow valve in the manual mode, the manual switch light corresponding to each valve must be depressed. A toggle switch then allows the crew to vary the opening directly. The gauges must be monitored to avoid excessive cabin altitude change rate, cabin altitude, and differential pressure.

ECS Controls

The ECS control panel is shown in Figure 12-27. The ECS controls include; controls to operate the packs, set compartment temperature, control turbine bypass valve and ram-air louvers, cargo heating systems and ventilation exhaust valves. Gauges are provided to indicate compartment temperature and temperature through the pack.

The pack controls consist of on-off switches and an auto-manual control switch. The on-off switch starts the pack (1 for each pack). There is no provision for adjusting the flow through the system.

During auto control, the pack discharge temperature is controlled by the pack controller. The controller accepts inputs from the zone temperature controller, and then modulates the ram-air louvers and turbine bypass valve to adjust discharge temperature. If the packs are switched to manual control, the crew manually controls the turbine bypass valve and ram-air louvers. The pack discharge temperature gauge must be monitored to prevent subfreezing discharge temperatures. Auto control limits pack discharge temperatures to 38 °F.

The L-1011 is divided into five temperature control zones (four on the -500). Each zone has a separate temperature controller that modulates the amount of hot air passing through the trim air valve to maintain cabin temperature. The zone temperature selector allows the crew to set the compartment temperature between 65-85 °F.

The cargo heat systems are set to either cold or hot. The hot setting activates the heating fan and thermostatic controls. See cargo heating description for details. The cold position changes the control to maintain the temperature at 40 °F minimum.

The ECS monitor panel is shown in Figure 12-28. The pack temperature gauge allows the crew to monitor the pack inlet, compressor discharge, turbine inlet, turbine discharge and hot air manifold temperature. The temperature displayed is controlled by the selector knob. The pack select switch controls which pack's temperatures are displayed. The cabin temperature gauge displays the temperature of the selected cabin zone.

Electrical energy requirements of ECS components and control systems are shown in Tables 12-7 through 12-10. The loads presented are the load per unit. To find the total load, multiply the load by the number of units. Also note that not all equipment operates continuously throughout the flight, and that some equipment operates only during certain system configurations or emergency conditions.

TABLE 12-1. LOCKHEED L-1011 PRODUCTION DATA

MODEL	FIRST FLIGHT (REF 1)	CERTIFICATION (REF 31)	NO. PRODUCED (REF 3)
-1	11-16-70	4-14-72	162
-100		6-6-75	14
-200	4-10-76	7-25-75	24
-500	10-78	4-16-79	47

TABLE 12-2. LOCKHEED L-1011-1,-100,-200,-500 SYSTEM TEMPERATURES AND PRESSURES (REF 12)

(^{o}F DRY BULB AND PSIA)

FLIGHT REGIME	FLOW CONTROL VALVE INLET A		FLOW CONTROL VALVE OUTLET B		WATER SEPARATOR OUTLET C		FLIGHT DECK SUPPLY D		PASS. CABIN SUPPLY E		CABIN		AMBIENT	
	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP	PRESS	TEMP
SEA LEVEL TAKEOFF	52.5	500	51.4	500	15.2	43.1	14.8	43.1	14.8	43.1	14.8	75	14.7	103
SEA LEVEL	93	532	39	532	15.4	40.7	14.8	40.7	14.8	40.7	14.8	75	14.7	103
10,000 FT CLIMB	70	510.5	36.9	510.5	10	54.2	9.5	54.2	9.5	54.2	9.5	75	11.3	75
25,000 FT CRUISE	DATA NOT AVAILABLE													
33,000 FT CRUISE	28.6	410	27.8	410	12.8	35.4	12.3	35.4	12.3	35.4	12.3	75	3.8	-21
35,000 FT CRUISE	23.3	377	22.4	377	12.5	35.9	12.1	35.9	12.1	35.9	12.1	75	3.5	-28
42,000 FT CRUISE	18.8	394	18	394	11.3	34.1	10.92	34.1	10.92	34.1	10.92	75	2.5	-44
20,000 FT DESCENT	30.9	448	30.1	448	15.0	45.4	14.6	45.4	14.6	45.4	14.6	75	6.8	28
15,000 FT DESCENT	30.8	420	30.2	420	15.0	53.2	14.6	53.2	14.6	53.2	14.6	75	8.3	47

MAXIMUM SUPPLY TEMP 190^{o}

MINIMUM SUPPLY TEMP 32^{o}

TABLE 12-3. LOCKHEED L-1011-1,-100,-200,-500 VOLUME FLOW (REF 12)

FLIGHT REGIME	FLOW CONTROL VALVE (LB/MIN)	PASSENGER CABIN		FLIGHT DECK	
		TOTAL (CFM)	% RECIRC	TOTAL (CFM)	% RECIRC
SEA LEVEL TAKEOFF	191.8	7,075	NOT APPLICABLE	486	NOT APPLICABLE
SEA LEVEL	151	5,606		385	
7,000 FT CLIMB	161	9,397		645	
25,000 FT CRUISE	DATA NOT AVAILABLE				
33,000 FT CRUISE	124.3	5,627		387	
35,000 FT CRUISE	116.9	5,381		369	
42,000 FT CRUISE	98.7	5,033		346	
20,000 FT DESCENT	123.9	4,725		325	
15,000 FT DESCENT	115.6	4,109		303	

TABLE 12-4. LOCKHEED L-1011-1,-100,-200 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	22.4	58.3
SEA LEVEL	17.8	46.2
7,000 FT CLIMB	29.7	77.4
25,000 FT CRUISE	N/A*	N/A*
33,000 FT CRUISE	17.8	46.4
35,000 FT CRUISE	17.0	44.2
42,000 FT CRUISE	15.9	41.5
20,000 FT DESCENT	15.0	39.0
15,000 FT DESCENT	14.0	36.3

*NOT AVAILABLE

TABLE 12-5. LOCKHEED L-1011-500 AIR CHANGE RATES (CHANGES PER HOUR)

FLIGHT REGIME	PASS. CABIN	FLIGHT DECK
SEA LEVEL TAKEOFF	24.3	58.3
SEA LEVEL	19.3	46.2
7,000 FT CLIMB	32.3	77.4
25,000 FT CRUISE	N/A*	N/A*
33,000 FT CRUISE	19.3	46.4
35,000 FT CRUISE	18.5	44.2
42,000 FT CRUISE	17.3	41.5
20,000 FT DESCENT	16.3	39.0
15,000 FT DESCENT	15.2	36.3

*NOT AVAILABLE

TABLE 12-6. LOCKHEED L-1011 VENTILATION PARAMETERS

VOLUMES (CU FT)		L-1011-1,-100,-200		-500
TOTAL PRESSURIZED		33,640		29,580
PASSENGER CABIN		18,950		17,435
FLIGHT DECK		500		500
FORWARD CARGO		1,600		2,400
CENTER CARGO		1,600		1,400
AFT CARGO		700		500
LOWER DECK GALLEY				—
PRESSURIZATION				
MAX ΔP (PSI)				
CONTROLLER LIMITED			8.44 - 8.59	
SAFETY VALVE LIMITED			8.80	
CABIN ALTITUDE CHANGE RATES		ASCENT		DESCENT
AUTO CONTROLLER	MAX	1,500		900
	MIN	200		100
STANDBY CONTROLLER	MAX		1,000	
	MIN		0	

TABLE 12-7. LOCKHEED L-1011-1,-100,-200 AC ELECTRICAL REQUIREMENTS (REF 29)

EQUIPMENT	POWER REQD	LOAD WATTS	LOAD VARS	SOURCE
Mid Electric Service Center Fan	115V 400 Hz 3Ø	1,170	877	AC Bus 1
Fwd Electric Service Center Fan	115V 400 Hz 3Ø	2,000	1,500	AC Bus 1
Zone Temp Controller	115V 400 Hz 1Ø	50	44	AC Bus 1 ØA
Pack Controller	115V 400 Hz 1Ø	345	304	AC Bus 1 ØB
Cabin Temp Meter	115V 400 Hz 1Ø	25	15	AC Bus 1 ØC
Turbine Bypass Valve	115V 400 Hz 1Ø	115	101	AC Bus 1 ØB
Ram Air Lower Actuator	115V 400 Hz 1Ø	115	101	AC Bus 1 ØB
Galley Fan	115V 400 Hz 3Ø	810	607	AC Bus 2
Cargo Fan	115V 400 Hz 3Ø	1,100	970	AC Bus 2
Zone Temp Controller	115V 400 Hz 1Ø	50	44	AC Bus 2 ØC
Pack Controller	115V 400 Hz 1Ø	345	304	AC Bus 2 ØA
Turbine Bypass Valve	115V 400 Hz 1Ø	115	101	AC Bus 2 ØA
Ram Air Louvers	115V 400 Hz 1Ø	115	101	AC Bus 2 ØA
Pressure Controller	115V 400 Hz 1Ø	245	152	AC Bus 3 ØA
Outflow Valve	115V 400 Hz 1Ø	40	25	AC Bus 3 ØB
Outflow Valve	115V 400 Hz 1Ø	40	25	AC Bus 3 ØC
Floor Heat	115V 400 Hz 1Ø	1,400	-	AC Bus 3 ØA
Floor Heat Control Assy	115V 400 Hz 1Ø	1,100	-	AC Bus 3 ØB
Floor Heat Control Assy	115V 400 Hz 1Ø	1,100	-	AC Bus 3 ØC
Cargo Fan	115V 400 Hz 3Ø	1,100	970	AC Bus 3
Zone Temp Controller	115V 400 Hz 1Ø	50	44	AC Bus 3 ØA
Zone Temp Controller	115V 400 Hz 1Ø	50	44	AC Bus 3 ØB
Zone Temp Controller	115V 400 Hz 1Ø	50	44	AC Bus 3 ØC
Turbine Bypass Valve	115V 400 Hz 1Ø	115	101	AC Bus 3 ØA
Ram Air Louvers	115V 400 Hz 1Ø	115	101	AC Bus 3 ØA
Pack Controller	115V 400 Hz 1Ø	345	304	AC Bus 3 ØA

TABLE 12-8. LOCKHEED L-1011-1,-100,-200 DC ELECTRICAL REQUIREMENTS (REF 29)

EQUIPMENT	REQD POWER	LOAD (AMPS)	NO. OF UNITS	SOURCE
Zone Temp Controller	28 VDC	.20	1	DC Bus 1
Hot Manifold Control Valve	28 VDC	.60	2	DC Bus 1
Hot Manifold Flow Indicator	28 VDC	.04	4	DC Bus 1
Hot Manifold Duct Overheat	28 VDC	.04	2	DC Bus 1
Hot Manifold Valve Lockout Relay	28 VDC	.11	2	DC Bus 1
Hot Manifold Indicator Relay	28 VDC	.11	2	DC Bus 1
Zone Trim Auto Control Relay	28 VDC	.12	1	DC Bus 1
Zone Trim Limit Relay	28 VDC	.12	1	DC Bus 1
Zone Trim Closed Indicator	28 VDC	.04	2	DC Bus 1
Hot Manifold Isolation Valve	28 VDC	.60	1	DC Bus 1
Hot Manifold Isolation Lockout	28 VDC	.11	1	DC Bus 1
Hot Manifold Isolation Valve Flow Indicator	28 VDC	.04	4	DC BUS 1
Manual Cool, Warm Relays	28 VDC	.11	2	DC Bus 1
TBV, RAA* Manual Relays	28 VDC	.12	2	DC Bus 1
Signal Conditioner	28 VDC	.02	1	DC Bus 1
Avionic Air Ovbd Indicator	28 VDC	.04	4	DC Bus 1
Avionic Low Flow Indicator	28 VDC	.04	4	DC Bus 1
Flow Sensor	28 VDC	.10	2	DC Bus 1
TBV, RAA* Position Indication	28 VDC	.10	2	DC Bus 1
Aft Lav Floor Heat Valve	28 VDC	2.0	1	DC Bus 1
Aft Lav Floor Heat Relay	28 VDC	.11	1	DC Bus 1
Zone Temp Controller	28 VDC	.20	2	DC Bus 2
Hot Manifold Isol Valve	28 VDC	.60	1	DC Bus 2
Hot Manifold Isol Ovht Ind	28 VDC	.04	4	DC Bus 2
Zone Trim Auto Control Relay	28 VDC	.12	2	DC Bus 2
Zone Trim Limit Relay	28 VDC	.12	2	DC Bus 2
Zone Trim Closed Ind	28 VDC	.04	4	DC Bus 2
Cargo Fan Cold Relay	28 VDC	.12	3	DC Bus 2
Cargo Fan Ovht Relay	28 VDC	.12	3	DC Bus 2
Cargo Heat Cold Indicator	28 VDC	.04	4	DC Bus 2
Cargo Heat Hot Indicator	28 VDC	.04	6	DC Bus 2
Press Relief Open Indicator	28 VDC	.04	2	DC Bus 2
Zone Trim Manual Relay	28 VDC	.12	5	DC Bus 2
Manual Cool/Warm Relays	28 VDC	.11	2	DC Bus 2
TBV RAA* Manual Relays	28 VDC	.12	2	DC Bus 2
Ram Auto Light	28 VDC	.04	2	DC Bus 2
Ground Warmup Relay	28 VDC	.18	1	DC Bus 2
Floor Heat Control	28 VDC	.50	1	DC Bus 2
TBV, RAA* Position Indication	28 VDC	.10	2	DC Bus 2
Hot Manifold Isolation Lockout	28 VDC	.11	1	DC Bus 2
Zone Temp Controller	28 VDC	.20	2	DC Bus 3
Zone Trim Auto Control Relay	28 VDC	.12	2	DC Bus 3
Zone Trim Limit Relay	28 VDC	.12	2	DC Bus 3
Zone Trim Closed Ind	28 VDC	.04	4	DC Bus 3
Cool Air Valve	28 VDC	.40	5	DC Bus 3
Cool Air Valve	28 VDC	.40	5	DC Bus 3
Manual Cool/Warm Relay	28 VDC	.11	2	DC Bus 3
TBV, RAA* Manual Relays	28 VDC	.12	2	DC Bus 3
Ins** Relay	28 VDC	.20	1	DC Bus 3
ATM*** Priority Relay	28 VDC	.11	1	DC Bus 3
Signal Conditioner	28 VDC	.03	1	DC Bus 3
Pressure Selector Panel	28 VDC	1.00	1	DC Bus 3
ATM on Relay	28 VDC	.11	1	DC Bus 3
TBV, RAA* Position Indicator	28 VDC	.10	2	DC Bus 3
Flow Control Valve (FCV)	28 VDC	1.00	3	DC Essential
FCV Flow Indication	28 VDC	.04	6	DC Essential
FCV Overheat Indication	28 VDC	.04	6	DC Essential
Relay FCV Overheat	28 VDC	.12	3	DC Essential
Flow Control Relay	28 VDC	.18	3	DC Essential
Pack Controller	28 VDC	.10	3	DC Essential
Mass Flow Controller	28 VDC	.80	3	DC Essential
Cool Air Ovbd Indicator	28 VDC	.04	2	DC Essential
Outflow Valves	28 VDC	2.00	2	DC Essential
Pack Fail Relay	28 VDC	.11	1	DC Essential

* Turbine Bypass Valve, Ram Air Actuator
** Inertial Navigation System Fan
*** Air Turbine Motor

TABLE 12-9. LOCKHEED L-1011-500 AC ELECTRICAL REQUIREMENTS (REF 30)

EQUIPMENT	POWER REQD	LOAD WATTS	LOAD VARS	NO. OF UNITS	SOURCE
Cabin Ovhd Exhaust	115V 400 Hz 3Ø	810	607	1	AC Bus 1
Mid Cabin Elec Panel Fan	115V 400 Hz 3Ø	165	98	1	AC Bus 1
Galley Exhaust Duct Heater	115V 400 Hz 1Ø	195	0	1	AC Bus 1 ØA
Mid Elec Service Ctr Fan	115V 400 Hz 3Ø	1,170	877	1	AC Bus 1
Fwd Elec Service Ctr Fan	115V 400 Hz 3Ø	2,000	1,500	1	AC Bus 1
Inst Clg Diverter Valve	115V 400 Hz 1Ø	80	82	1	AC Bus 1 ØA
Zone Temp Controller	115V 400 Hz 1Ø	50	44	1	AC Bus 1 ØA
Pack Controller	115V 400 Hz 1Ø	345	304	1	AC Bus 1 ØB
Cabin Temp Meter	115V 400 Hz 1Ø	25	15	1	AC Bus 1 ØC
Turbine Bypass Valve	115V 400 Hz 1Ø	115	101	1	AC Bus 1 ØB
Ram Air Actuator	115V 400 Hz 1Ø	115	101	1	AC Bus 1 ØB
Cargo Fan	115V 400 Hz 3Ø	1,100	970	2	AC Bus 2
Individual Air Outlet Valve - 32 total	115V 400 Hz 1Ø	15	7	2	AC Bus 2 ØA
Individual Air Outlet Valve - 35 total	115V 400 Hz 1Ø	15	7	2	AC Bus 2 ØB
Individual Air Outlet Valve - 30 total	115V 400 Hz 1Ø	15	7	2	AC Bus 2 ØC
Zone Temp Controller	115V 400 Hz 1Ø	50	44	1	AC Bus 2 ØC
Pack Controller	115V 400 Hz 1Ø	345	304	1	AC Bus 2 ØA
Turbine Bypass Valve	115V 400 Hz 1Ø	115	101	1	AC Bus 2 ØA
Ram Air Actuator	115V 400 Hz 1Ø	115	101	1	AC Bus 2 ØA
Lavatory Jet Pump Heater	115V 400 Hz 1Ø	40	0	2	AC Bus 3 ØC
Pressure Controller	115V 400 Hz 1Ø	125	77	1	AC Bus 3 ØA
Outflow Valve	115V 400 Hz 1Ø	40	25	2	AC Bus 3 ØB
Outflow Valve	115V 400 Hz 1Ø	40	25	2	AC Bus 3 ØC
Cargo Fan	115V 400 Hz 3Ø	1,100	970	1	AC Bus 3 ØC
Instrument Cooling Fan	115V 400 Hz 3Ø	825	772	1	AC Bus 3
Individual Air Outlet Valve - 68 total	115V 400 Hz 1Ø	15	7	2	AC Bus 3 ØA
Individual Air Outlet Valve - 62 total	115V 400 Hz 1Ø	15	7	2	AC Bus 3 ØB
Individual Air Outlet Valve - 22 total	115V 400 Hz 1Ø	15	7	2	AC Bus 3 ØC
Zone Temp Controller	115V 400 Hz 1Ø	50	44	1	AC Bus 3 ØA
Zone Temp Controller	115V 400 Hz 1Ø	50	44	1	AC Bus 3 ØB
Turbine Bypass Valve	115V 400 Hz 1Ø	115	101	1	AC Bus 3 ØA
Ram Air Actuator	115V 400 Hz 1Ø	115	101	1	AC Bus 3 ØA
Pack Controller	115V 400 Hz 1Ø	345	304	1	AC Bus 3 ØA
Inertial Navigation System Fan	115V 400 Hz 3Ø	120	74	1	AC Essential

TABLE 12-10. LOCKHEED L-1011-500 DC ELECTRICAL ENERGY REQUIREMENTS (REF 30)

EQUIPMENT	POWER REQD	LOAD (AMPS)	NO. OF UNITS	SOURCE
Hot Manifold Control Valve	28 VDC	.60	2	DC Bus 1
Hot Manifold Control Valve Flow Indicator	28 VDC	.04	4	DC Bus 1
Hot Manifold Control Valve Duct Overheat Indicator	28 VDC	.04	2	DC Bus 1
Hot Manifold Control Valve Valve Lockout Relay	28 VDC	.11	2	DC Bus 1
Hot Manifold Control Valve Indicator Relay	28 VDC	.11	2	DC Bus 1
Zone Temp Trim Control Relay	28 VDC	.12	1	DC Bus 1
Zone Trim Closed Relay	28 VDC	.04	2	DC Bus 1
Hot Manifold Isolation Valve	28 VDC	.60	1	DC Bus 1
Hot Manifold Isolation Valve Lockout Relay	28 VDC	.11	1	DC Bus 1
Hot Manifold Isolation Valve Flow Indicator	28 VDC	.04	4	DC Bus 1
Manual Cool, Warm Relays	28 VDC	.11	2	DC Bus 1
TBV, RAA* Manual Relays	28 VDC	.12	2	DC Bus 1
Signal Conditioner	28 VDC	.10	1	DC Bus 1
Avionic Air Overboard Indicator	28 VDC	.04	4	DC Bus 1
Avionic Air Low Flow Indicator	28 VDC	.04	4	DC Bus 1
Flow Sensor	28 VDC	.10	2	DC Bus 1
TBV, RAA* Position Indicator	28 VDC	.10	2	DC Bus 1
Aft Lav Floor Heat Valve	28 VDC	2.00	1	DC Bus 1
Aft Lav Floor Heat Relay	28 VDC	.11	1	DC Bus 1
Humidity Control Relay	28 VDC	.12	1	DC Bus 1
Instrument Cooling Fan Indicator	28 VDC	.04	2	DC Bus 1
Zone Temp Control Relay	28 VDC	.11	1	DC Bus 1
Zone Temp Controller	28 VDC	.20	2	DC Bus 2
Hot Manifold Isolation Valve	28 VDC	.60	1	DC Bus 2
Hot Manifold Isolation Valve Overheat	28 VDC	.04	4	DC Bus 2
Zone Temp Trim Control Relay	28 VDC	.12	2	DC Bus 2
Zone Trim Closed Relay	28 VDC	.04	4	DC Bus 2
Cargo Fan Cold Relay	28 VDC	.12	3	DC Bus 2
Cargo Fan Overheat Relay	28 VDC	.12	3	DC Bus 2
Cargo Heat Hot Indicator	28 VDC	.04	6	DC Bus 2
Cargo Heat Cold Indicator	28 VDC	.04	4	DC Bus 2
Pressure Relief Open Indicator	28 VDC	.04	4	DC Bus 2
Manual Cool, Warm Relays	28 VDC	.11	2	DC Bus 2
TBV, RAA* Manual Relays	28 VDC	.12	2	DC Bus 2
Ram Auto Light	28 VDC	.04	2	DC Bus 2
Ground Warmup Relay	28 VDC	.18	1	DC Bus 2
TBV, RAA* Position Indicator	28 VDC	.10	2	DC Bus 2
Hot Manifold Isolation Lockout Relay	28 VDC	.11	1	DC Bus 2
Zone Temp Control Relay	28 VDC	.11	2	DC Bus 2
Cabin Overhead Exhaust Fan Indicator	28 VDC	.04	2	DC Bus 2
Lavatory Jet Pump Valve	28 VDC	1.50	2	DC Bus 2
Zone Temp Controller	28 VDC	.20	1	DC Bus 3
Zone Trim Control Relay	28 VDC	.12	1	DC Bus 3
Zone Trim Closed Relay	28 VDC	.04	2	DC Bus 3
Manual, Cool, Warm Relay	28 VDC	.11	2	DC Bus 3
TBV, RAA* Manual Relays	28 VDC	.12	2	DC Bus 3
ATM** Priority Relay	28 VDC	.11	1	DC Bus 3
Signal Conditioner	28 VDC	.03	1	DC Bus 3
Pressure Selector Relay	28 VDC	1.00	1	DC Bus 3
ATM on Relay	28 VDC	.11	1	DC Bus 3
TBV, RAA* Position Indicator	28 VDC	.10	2	DC Bus 3
Zone Temp Control Relay	28 VDC	.11	1	DC Bus 3
Flow Control Valve Bus	28 VDC	1.00	3	DC Essential Bus
Flow Control Valve Flow Indication	28 VDC	.04	6	DC Essential Bus
Flow Control Overheat Indication	28 VDC	.04	6	DC Essential Bus
Flow Control Overheat Relay	28 VDC	.12	3	DC Essential Bus
Flow Control Relay	28 VDC	.18	3	DC Essential Bus
Pack Controller	28 VDC	.10	3	DC Essential Bus
Mass Flow Control Valve	28 VDC	.80	1	DC Essential Bus
Cool Air Overboard Indicator	28 VDC	.04	2	DC Essential Bus
Mass Flow Control Valve	28 VDC	.88	1	DC Essential Bus
Mass Flow Control Valve	28 VDC	.80	2	DC Essential Bus
Outflow Valves	28 VDC	2.00	2	DC Essential Bus
Pack Fail Relay	28 VDC	.11	1	DC Essential Bus
Ins Cooling Relay	28 VDC	.12	1	DC Essential Bus
Flow Sensor	28 VDC	.10	1	DC Essential Bus
Ins Cooling Indicator Light	28 VDC	.04	2	DC Essential Bus
Ins Cooling Latch Relay	28 VDC	.11	1	DC Essential Bus
Cabin Ovhd Exh Fan Control Relay	28 VDC	.12	1	DC Essential Bus
Cabin Ovhd Ex Fan Fail Relay	28 VDC	.15	1	DC Essential Bus
Galley Fan Control Relay	28 VDC	.12	1	DC Essential Bus

* Turbine Bypass Valve, Ram Air Actuator
** Air Turbine Motor

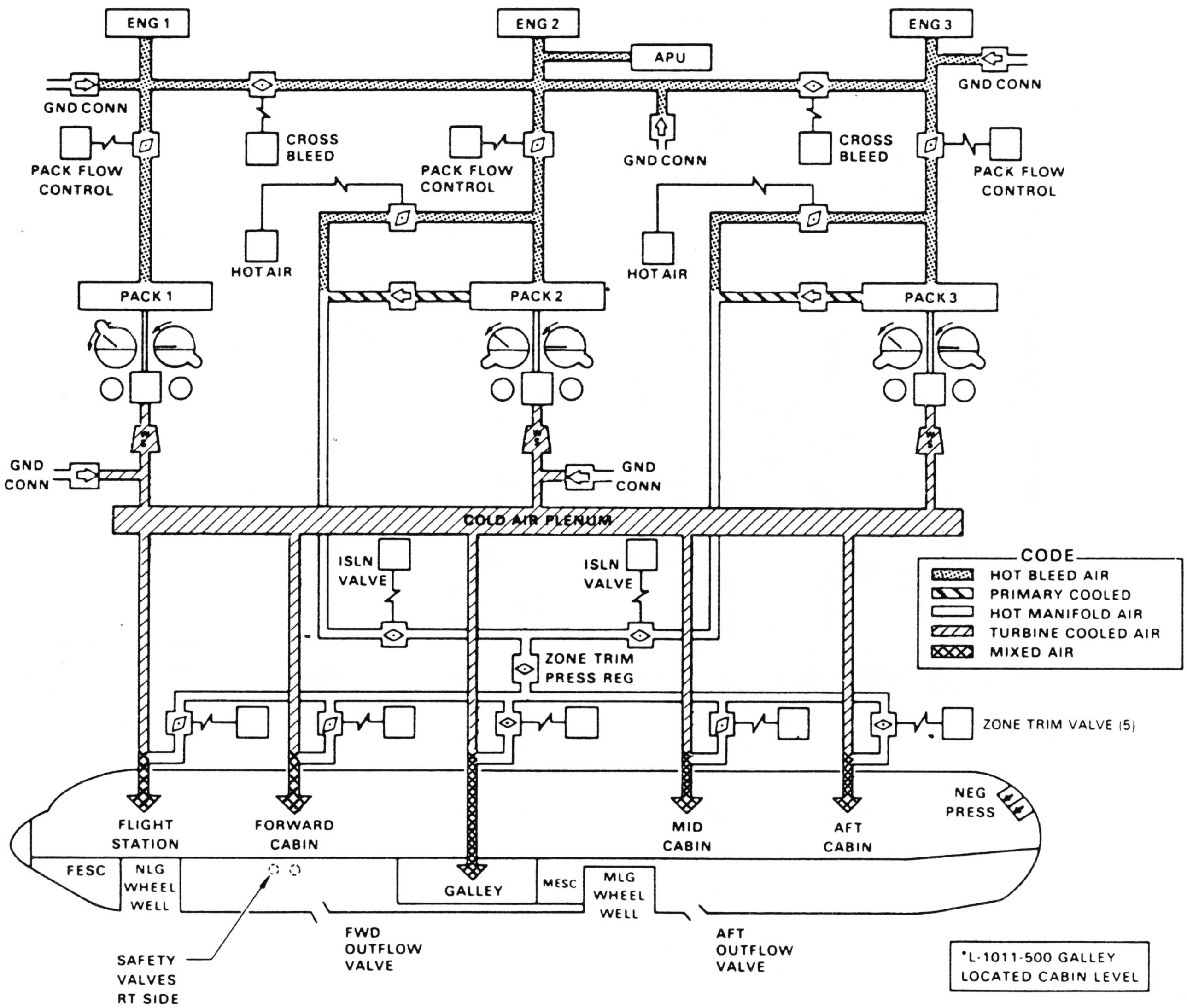


FIGURE 12-1. LOCKHEED L-1011 AIR CONDITIONING AND PRESSURIZATION CONTROL SCHEMATIC

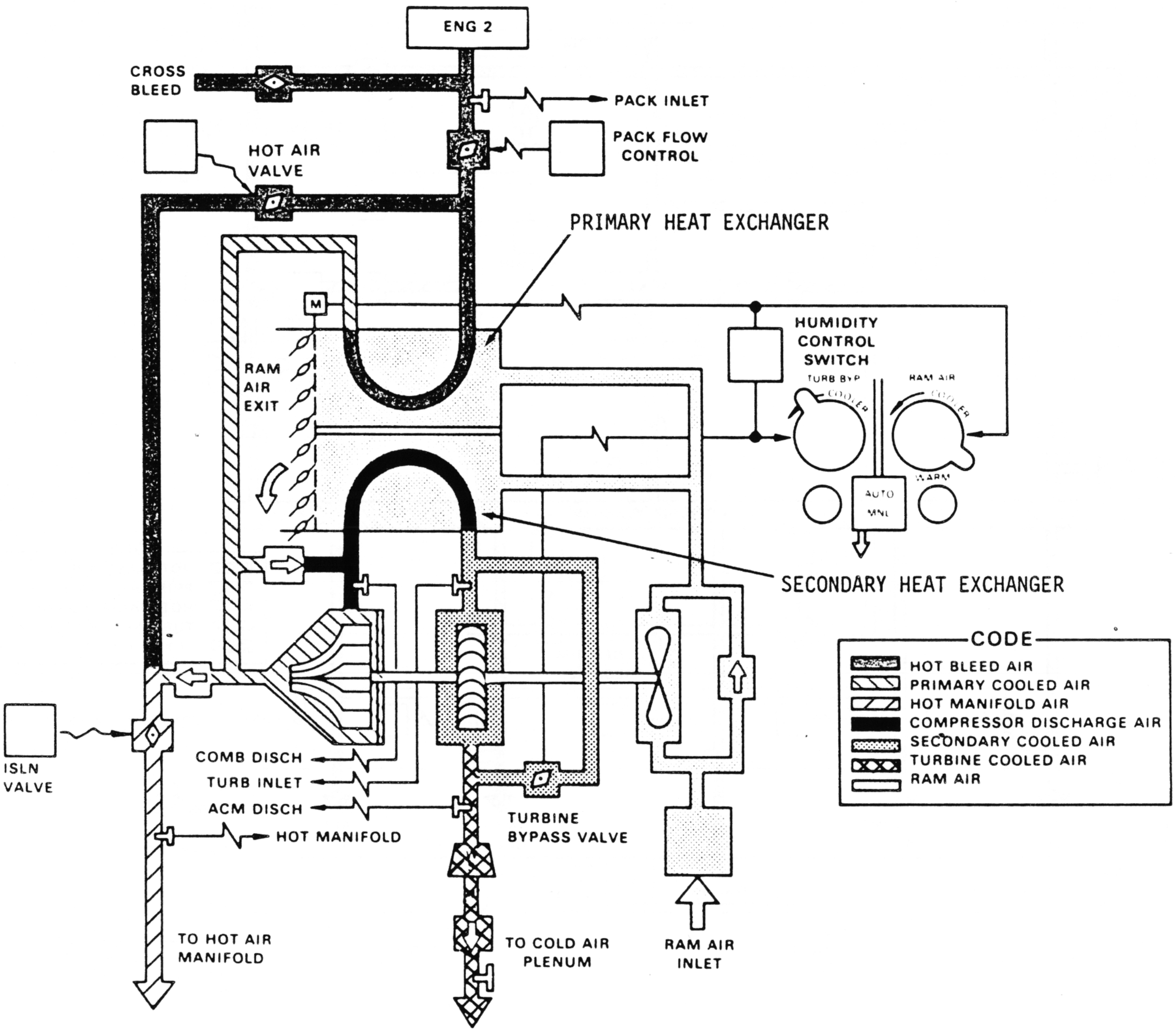


FIGURE 12-2. LOCKHEED L-1011 AIR CONDITIONING PACK SCHEMATIC

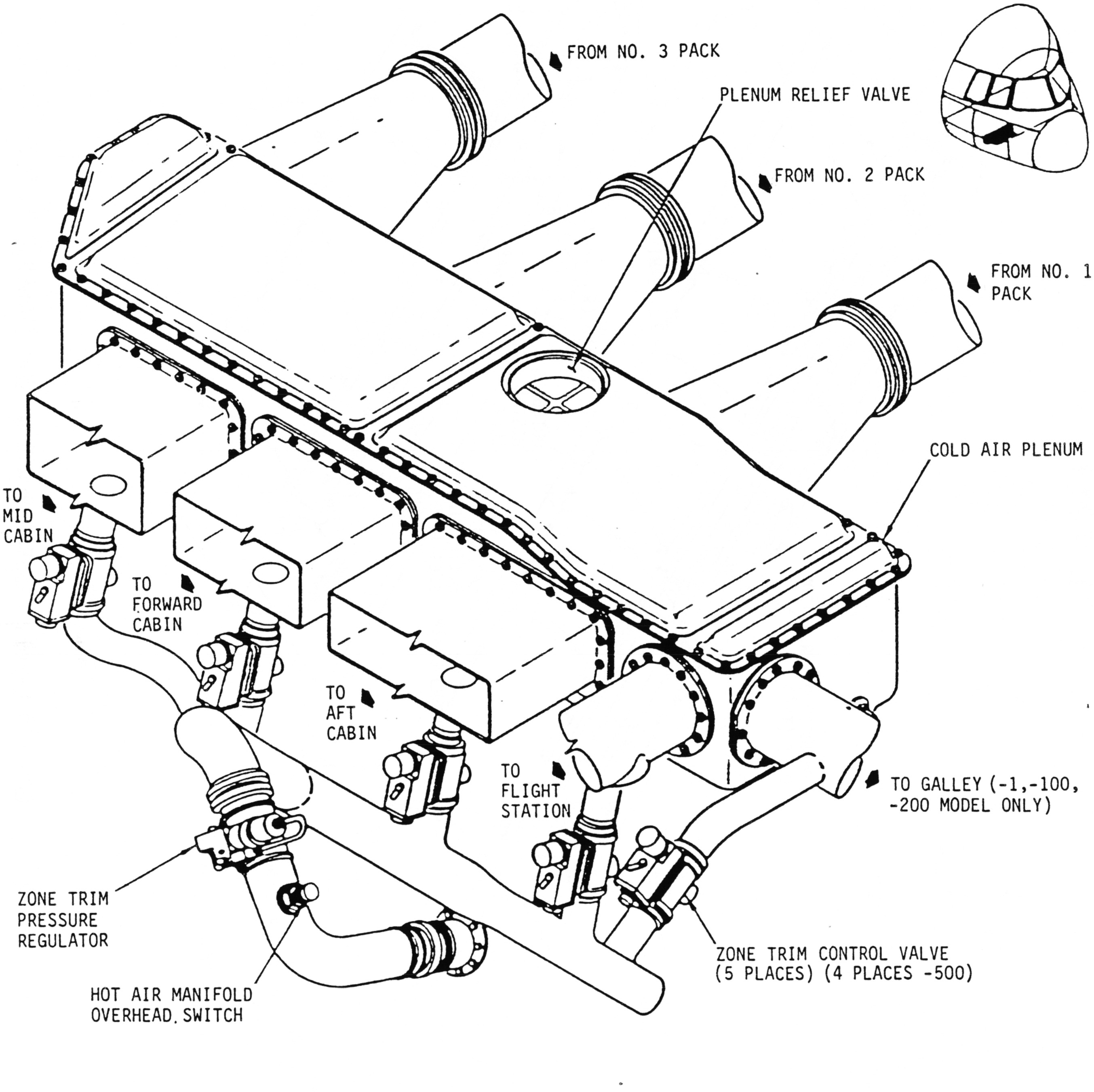


FIGURE 12-3. LOCKHEED L-1011 COLD AIR MANIFOLD

L-1011

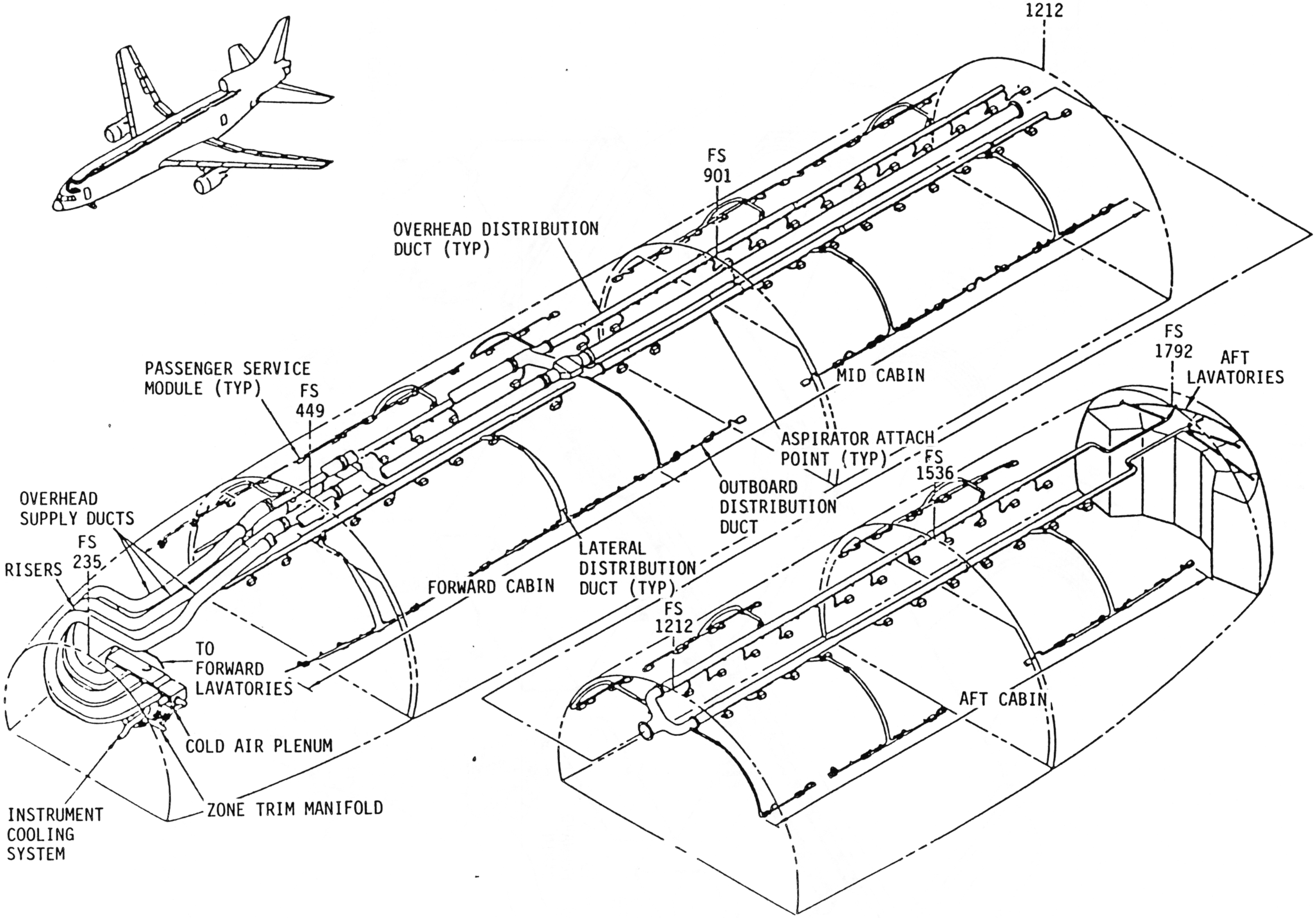


FIGURE 12-4. LOCKHEED L-1011 PASSENGER CABIN CONDITIONED AIR DISTRIBUTION

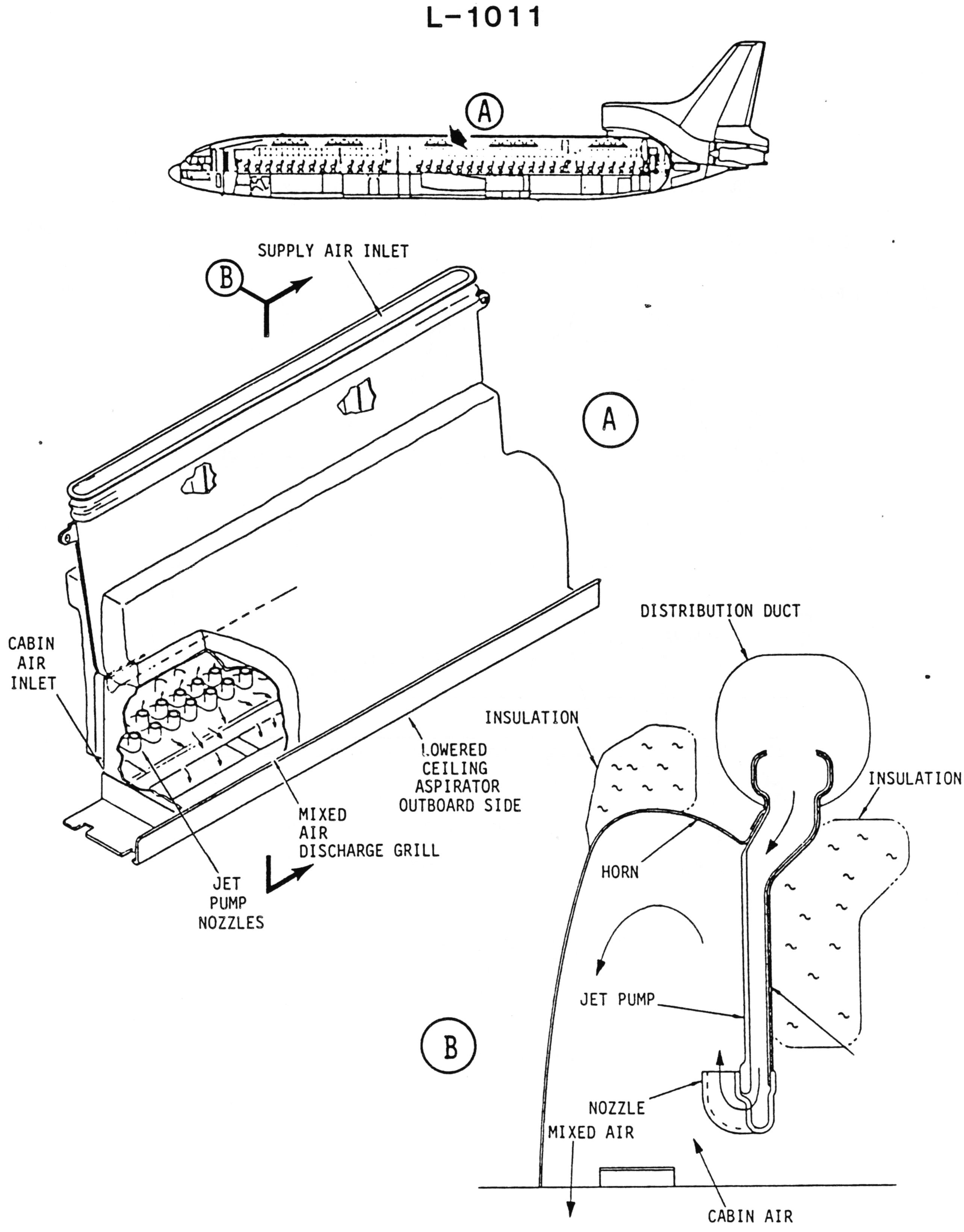


FIGURE 12-5. LOCKHEED L-1011 PASSENGER CABIN ASPIRATOR

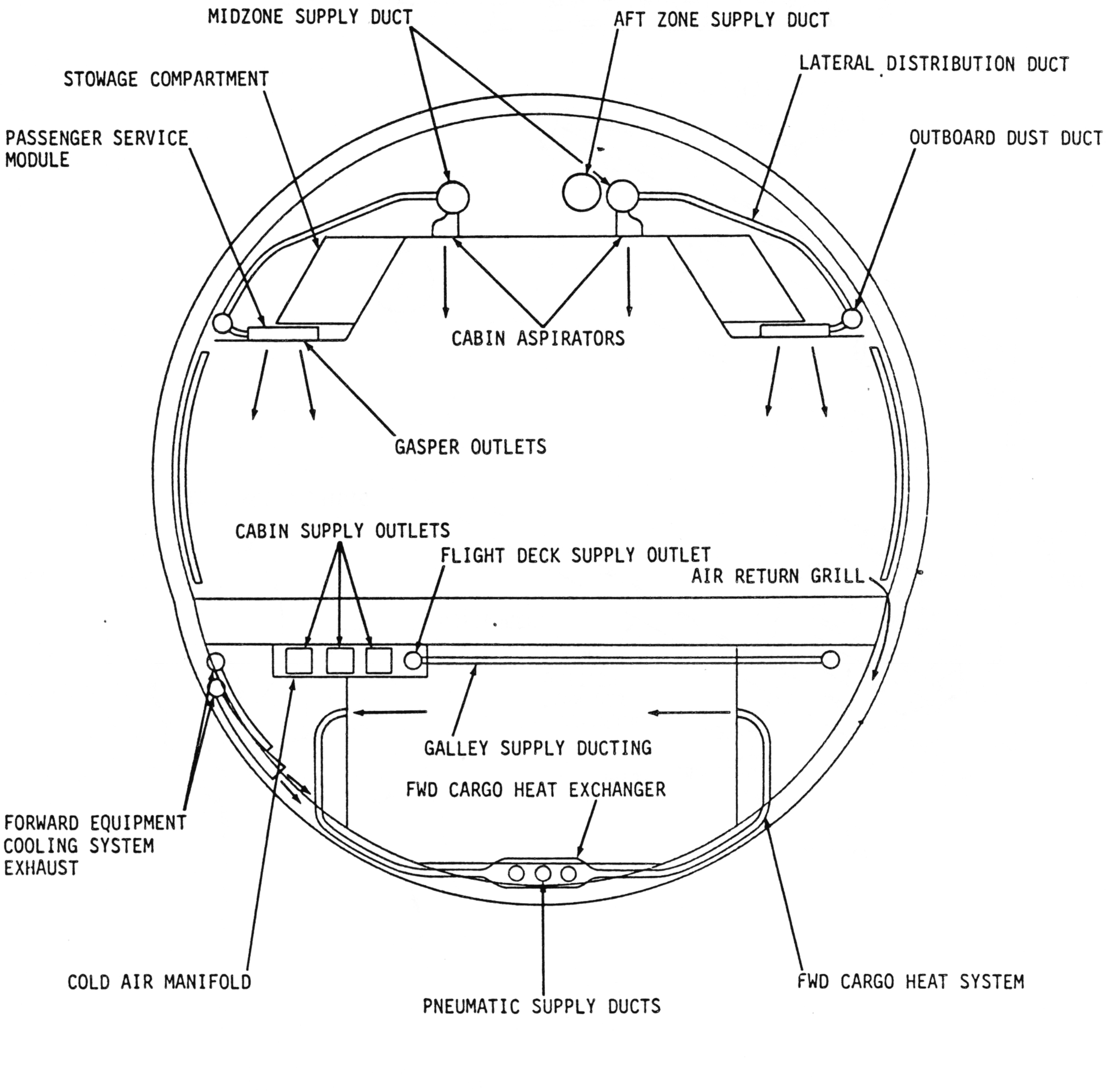


FIGURE 12-6. LOCKHEED L-1011 PASSENGER CABIN CROSS SECTION

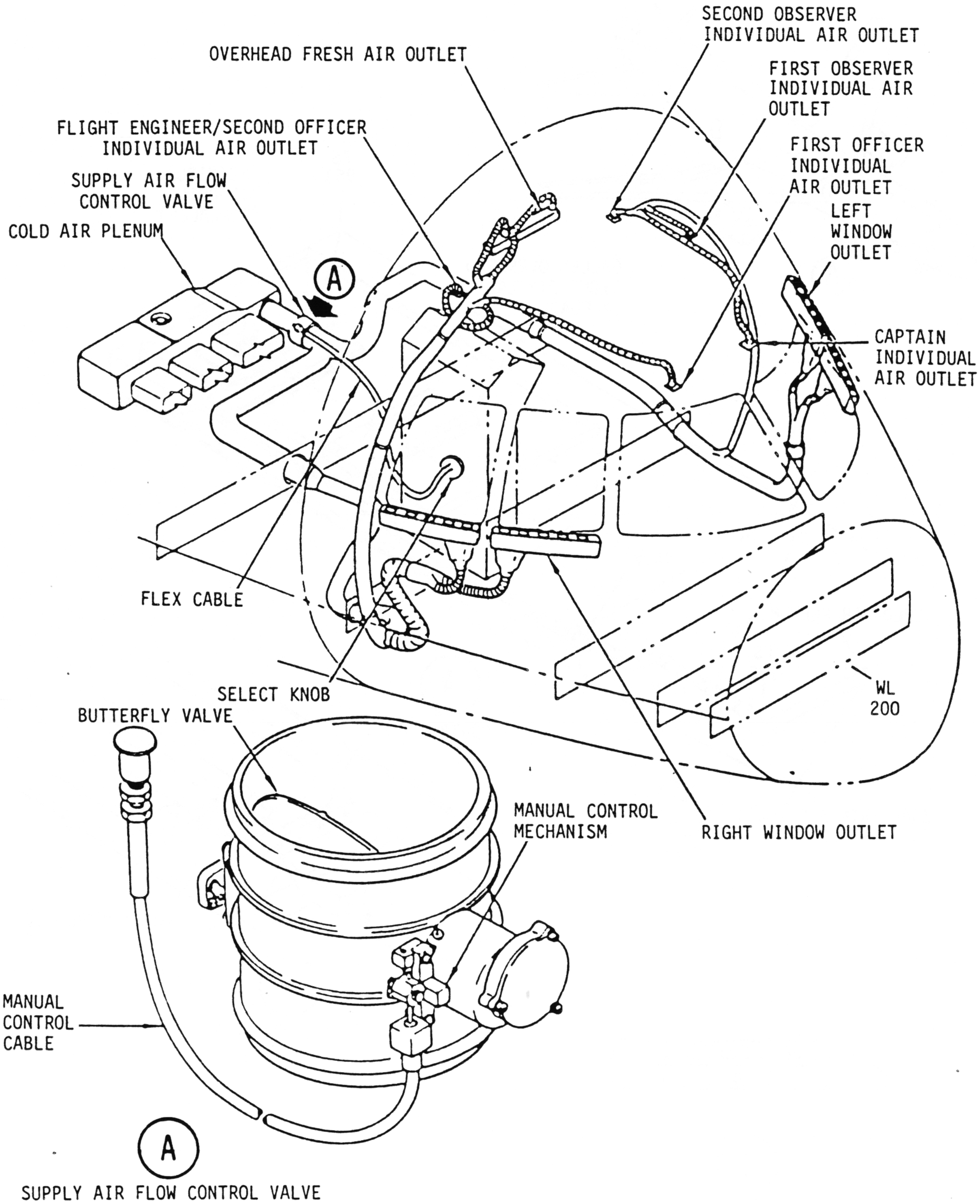


FIGURE 12-7. LOCKHEED L-1011 FLIGHT DECK CONDITIONED AIR DISTRIBUTION

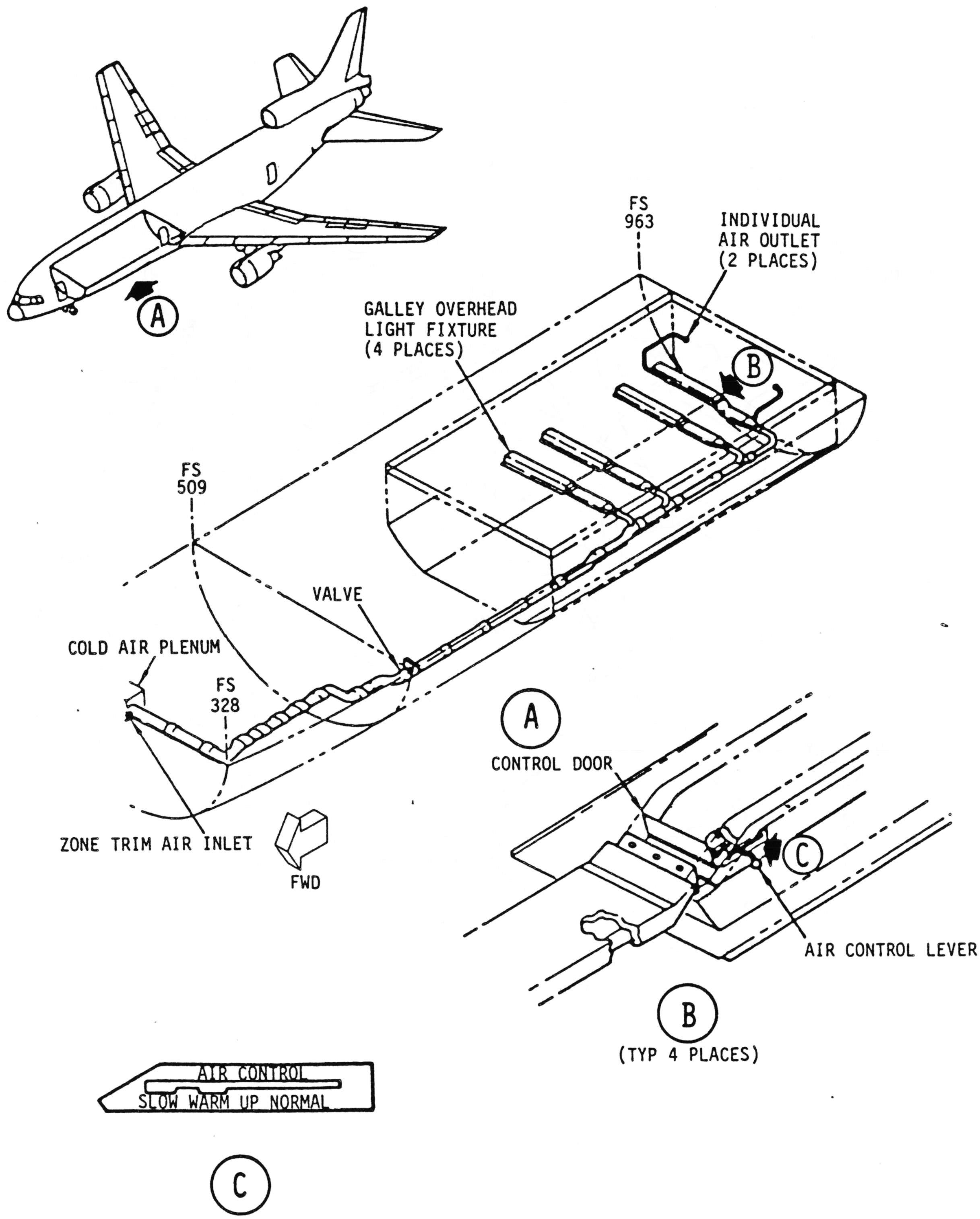


FIGURE 12-8. LOCKHEED L-1011 LOWER GALLEY AIR DISTRIBUTION

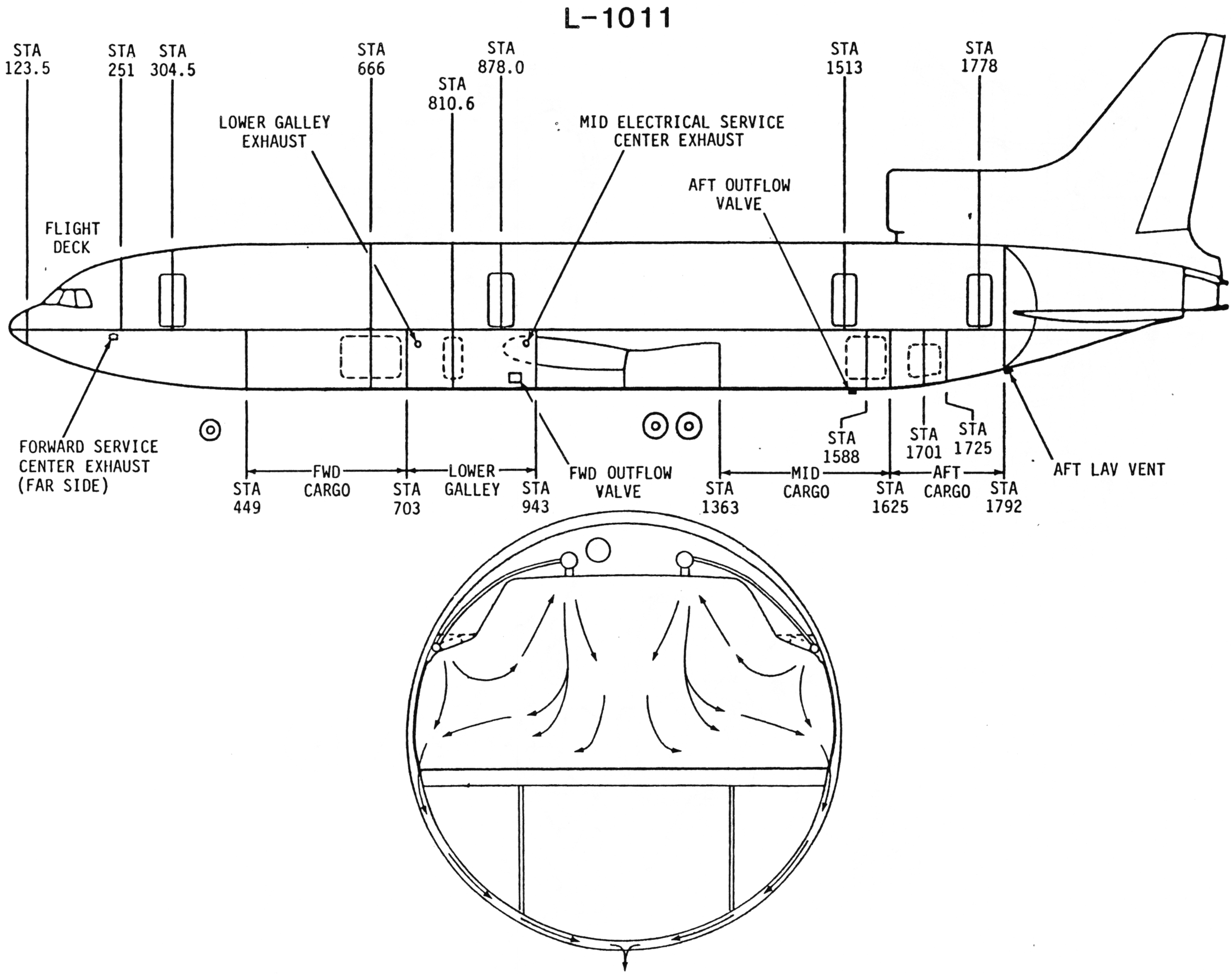


FIGURE 12-9. LOCKHEED L-1011 PASSENGER CABIN AIR FLOW PATTERNS

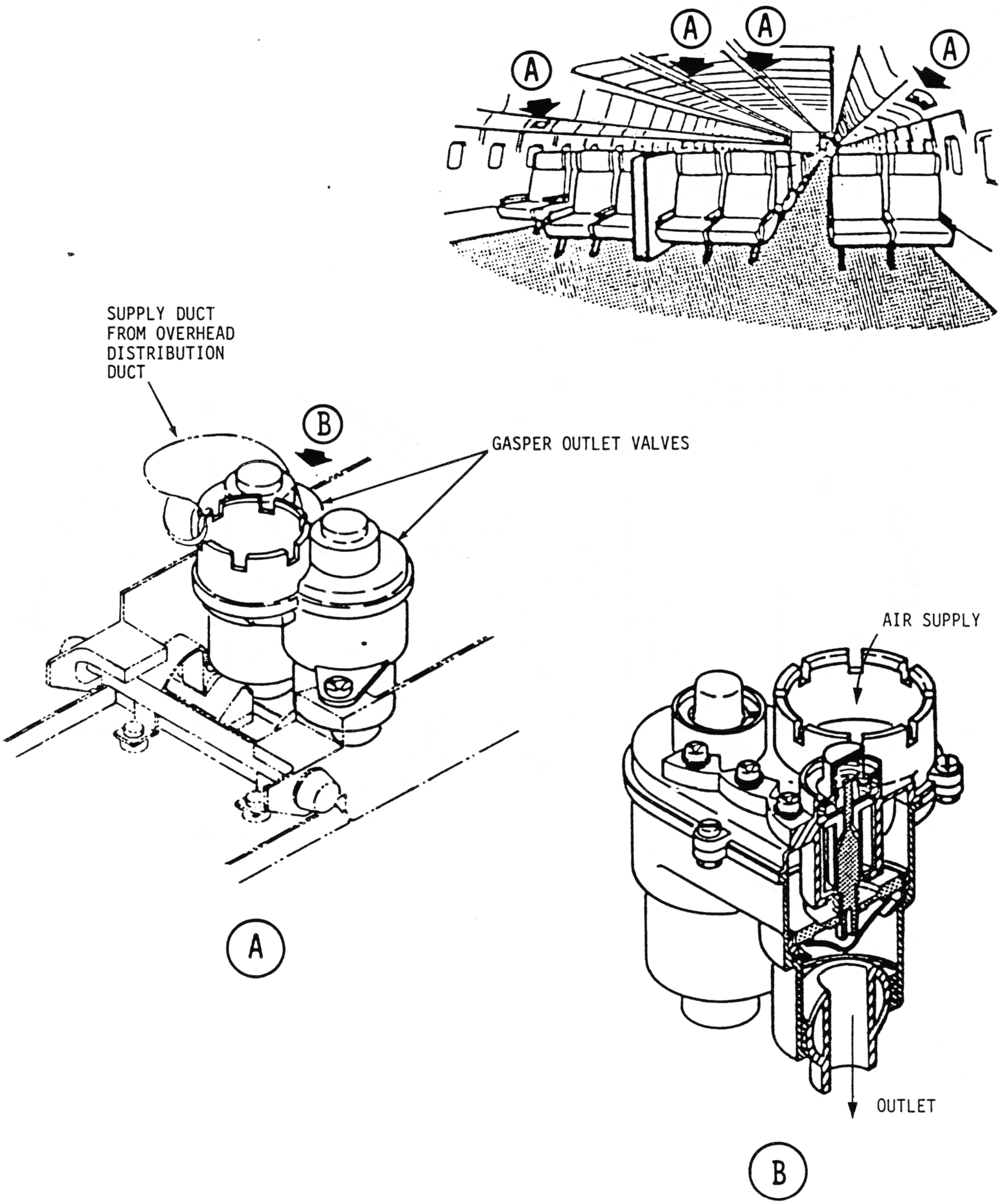


FIGURE 12-10. LOCKHEED L-1011 PASSENGER CABIN INDIVIDUAL AIR OUTLETS

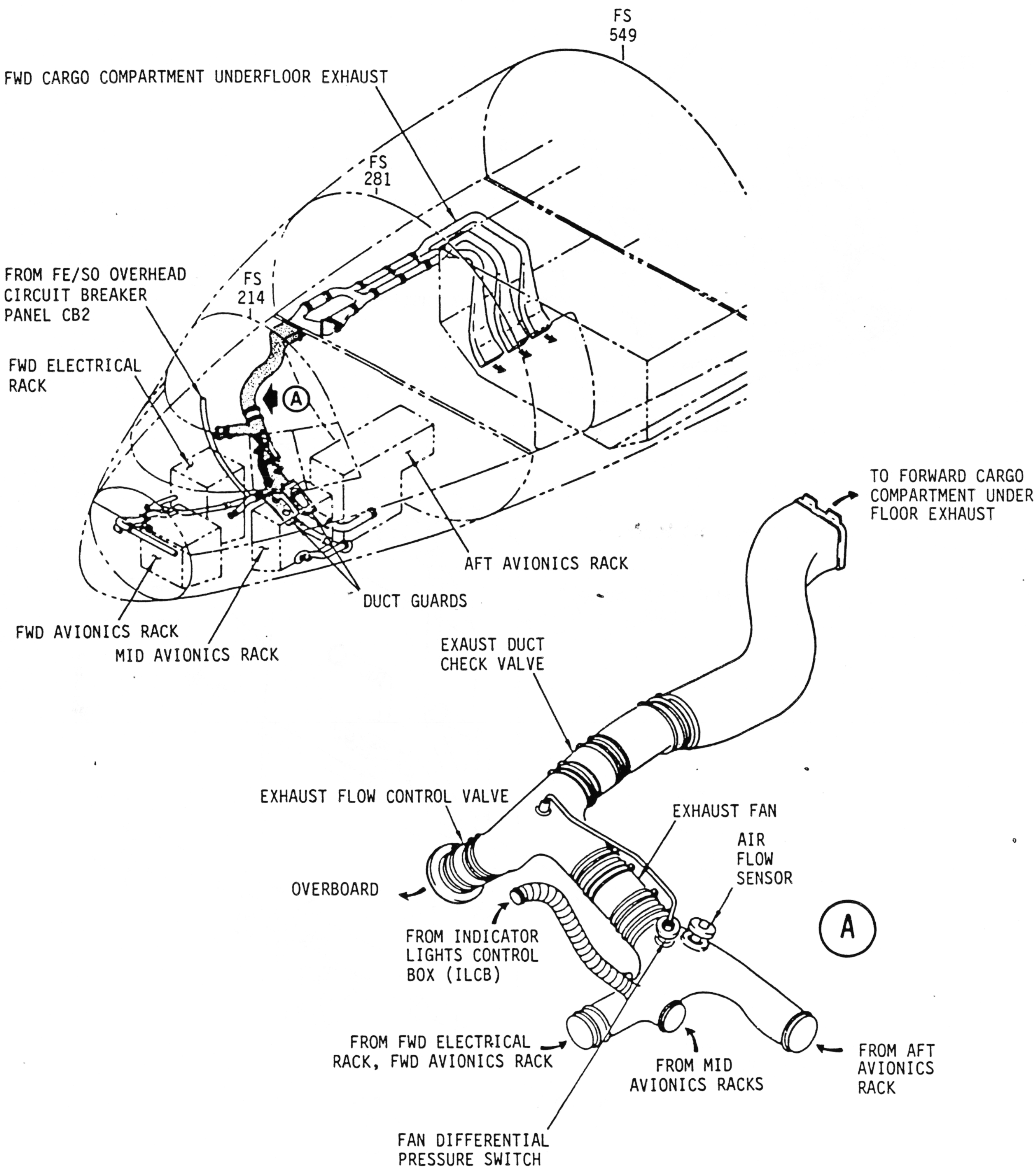


FIGURE 12-11. LOCKHEED L-1011 FORWARD EQUIPMENT COOLING SYSTEM

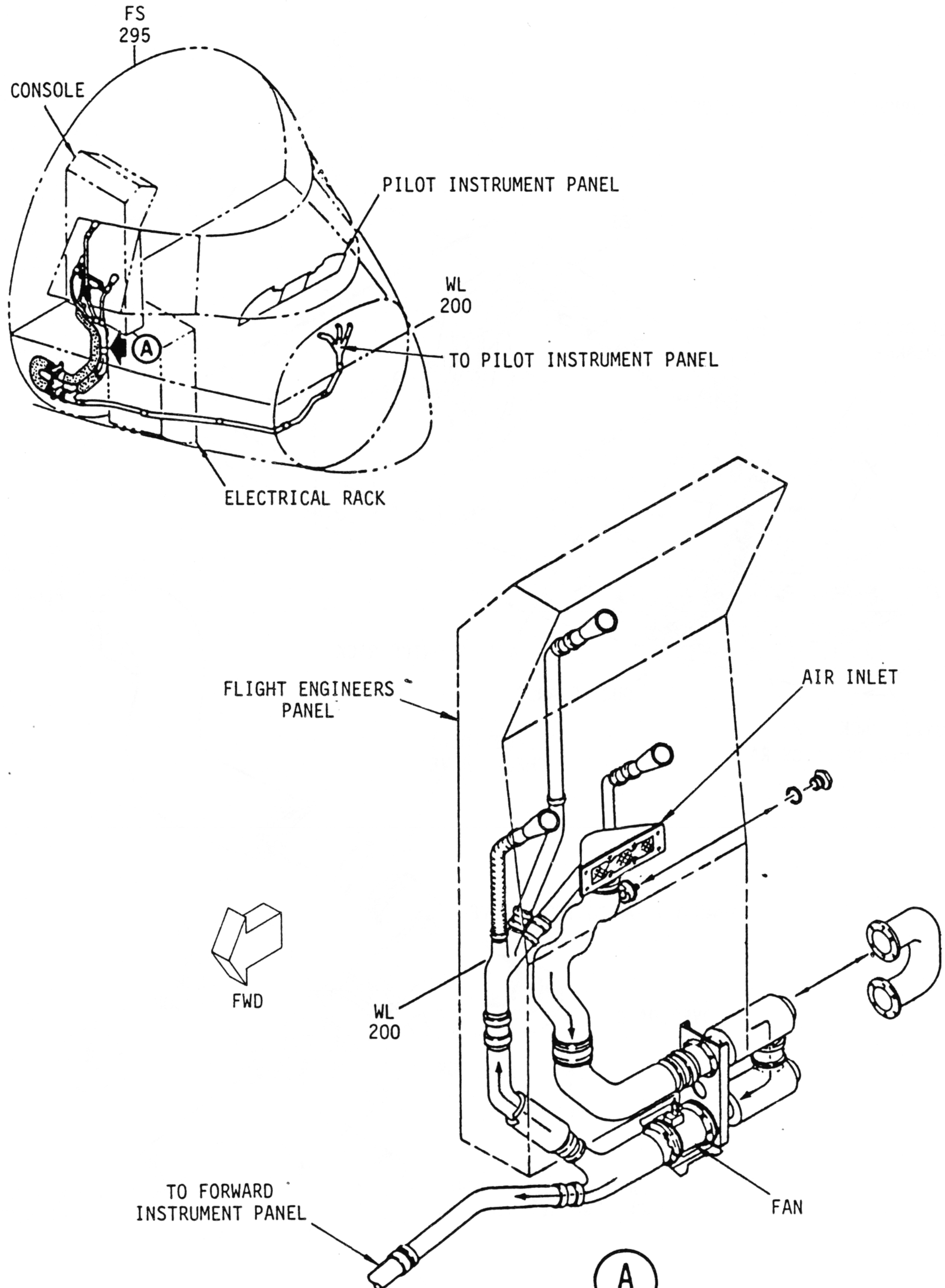


FIGURE 12-12. LOCKHEED L-1011 INSTRUMENT PANEL COOLING SYSTEM

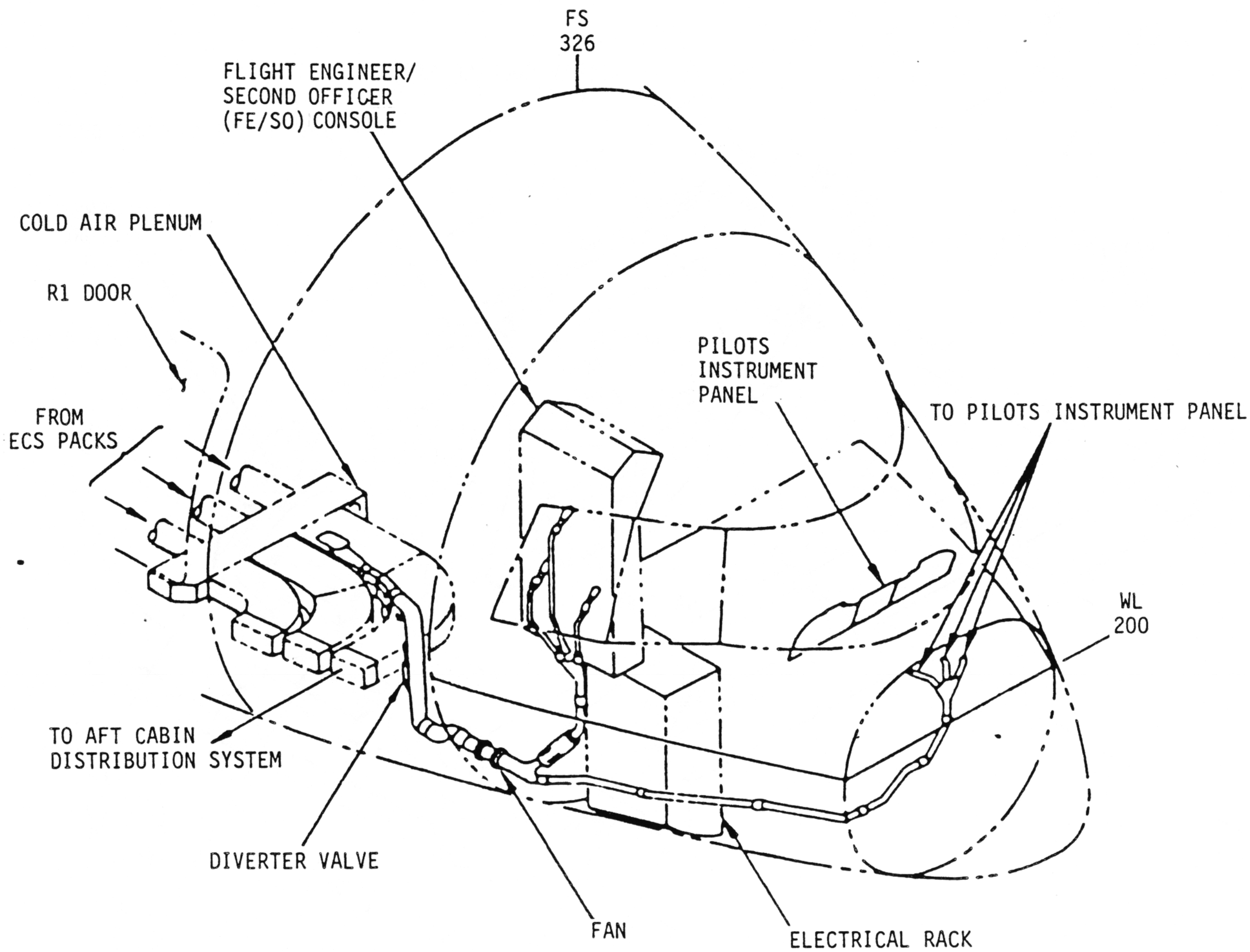


FIGURE 12-13. LOCKHEED L-1011 INSTRUMENT PANEL COOLING SYSTEM

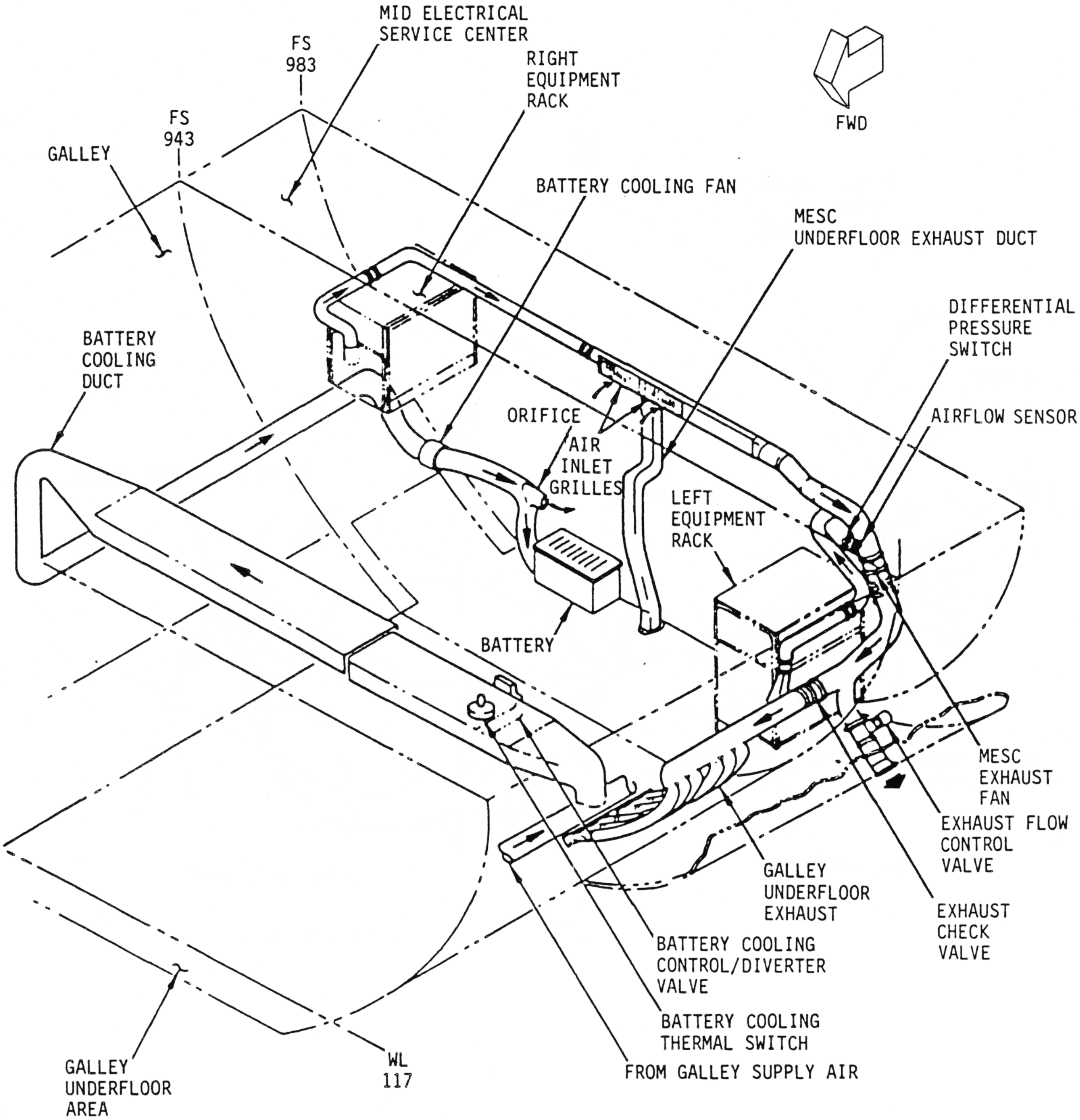


FIGURE 12-14. LOCKHEED L-1011 MID EQUIPMENT COOLING SYSTEM

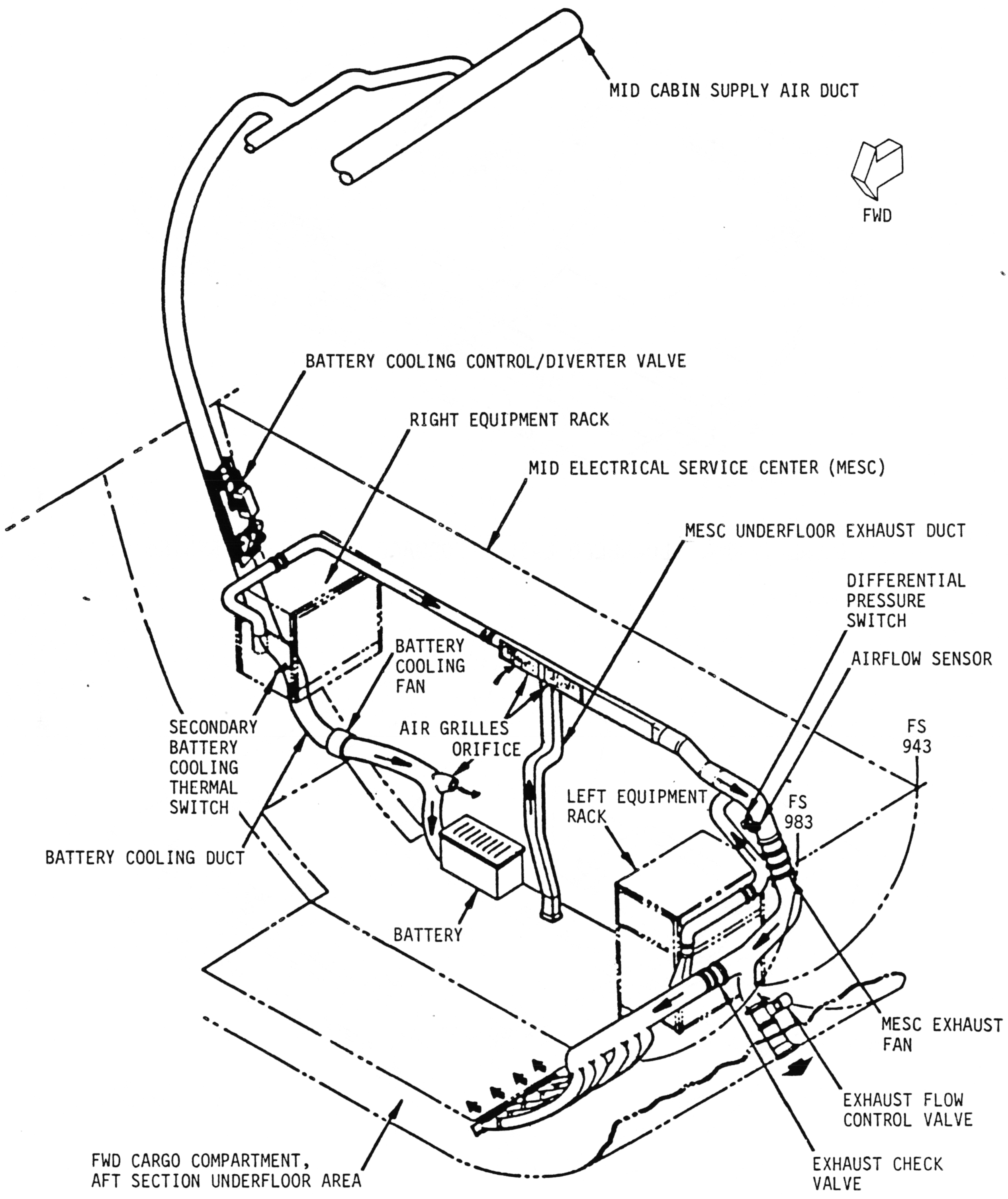


FIGURE 12-15. LOCKHEED L-1011-500 MID EQUIPMENT COOLING SYSTEM

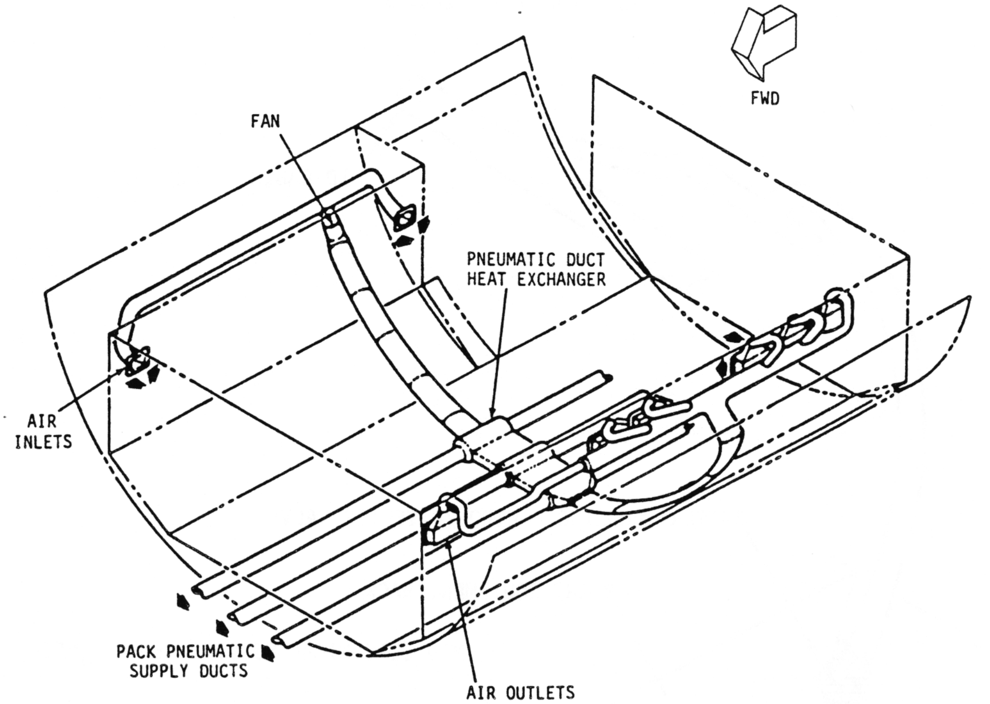


FIGURE 12-16. LOCKHEED L-1011 FORWARD CARGO HEAT SYSTEM

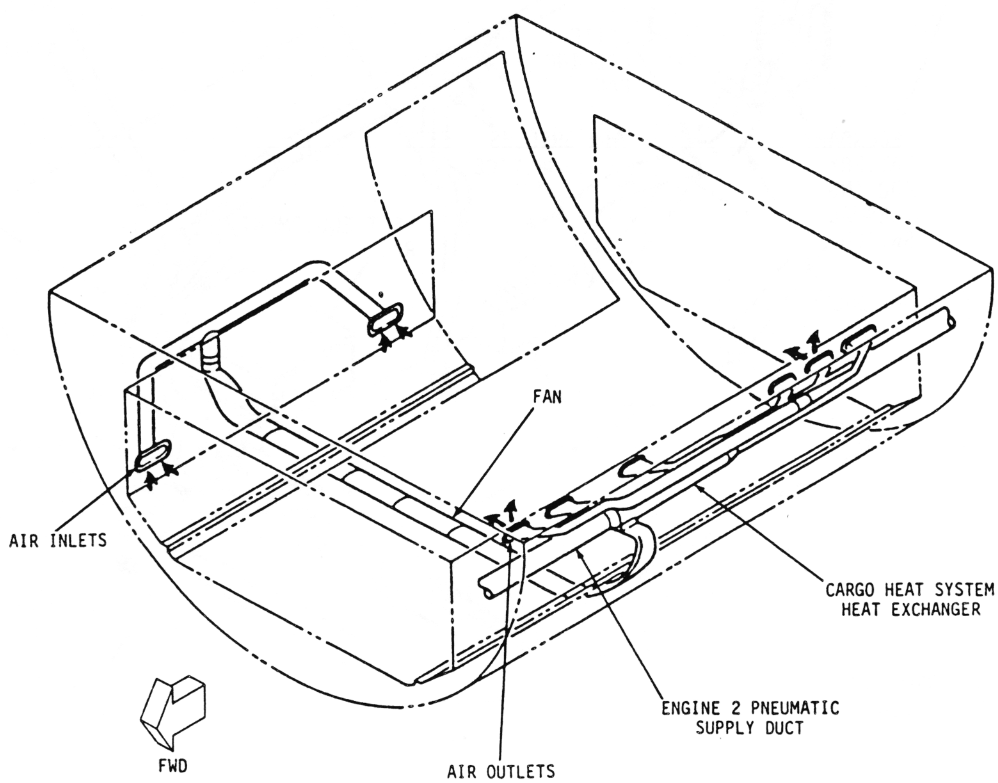


FIGURE 12-17. LOCKHEED L-1011 MID CARGO HEAT SYSTEM

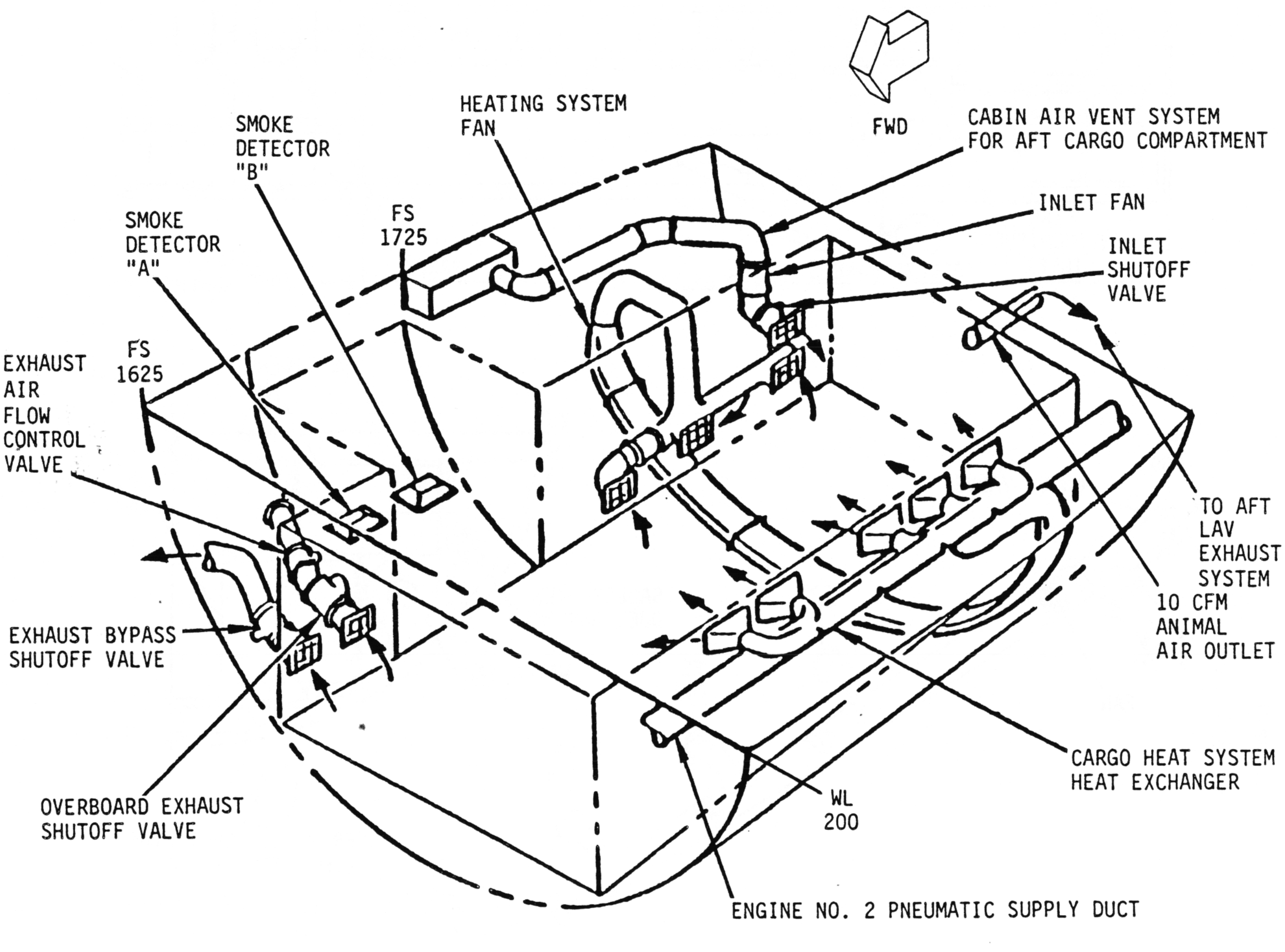


FIGURE 12-18. LOCKHEED L-1011 AFT CARGO HEAT SYSTEM

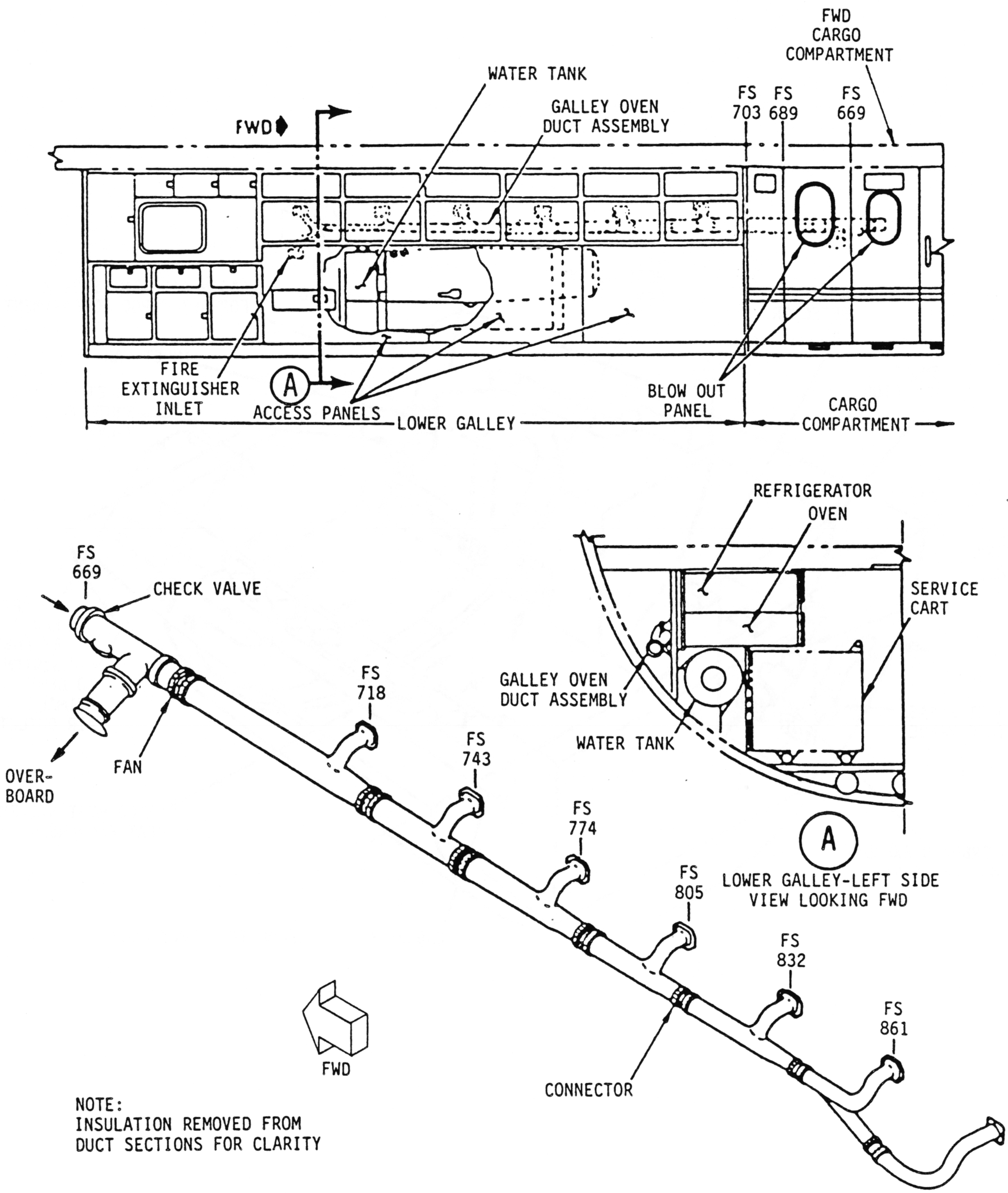


FIGURE 12-19. LOCKHEED L-1011 GALLEY OVEN EXAUST SYSTEM

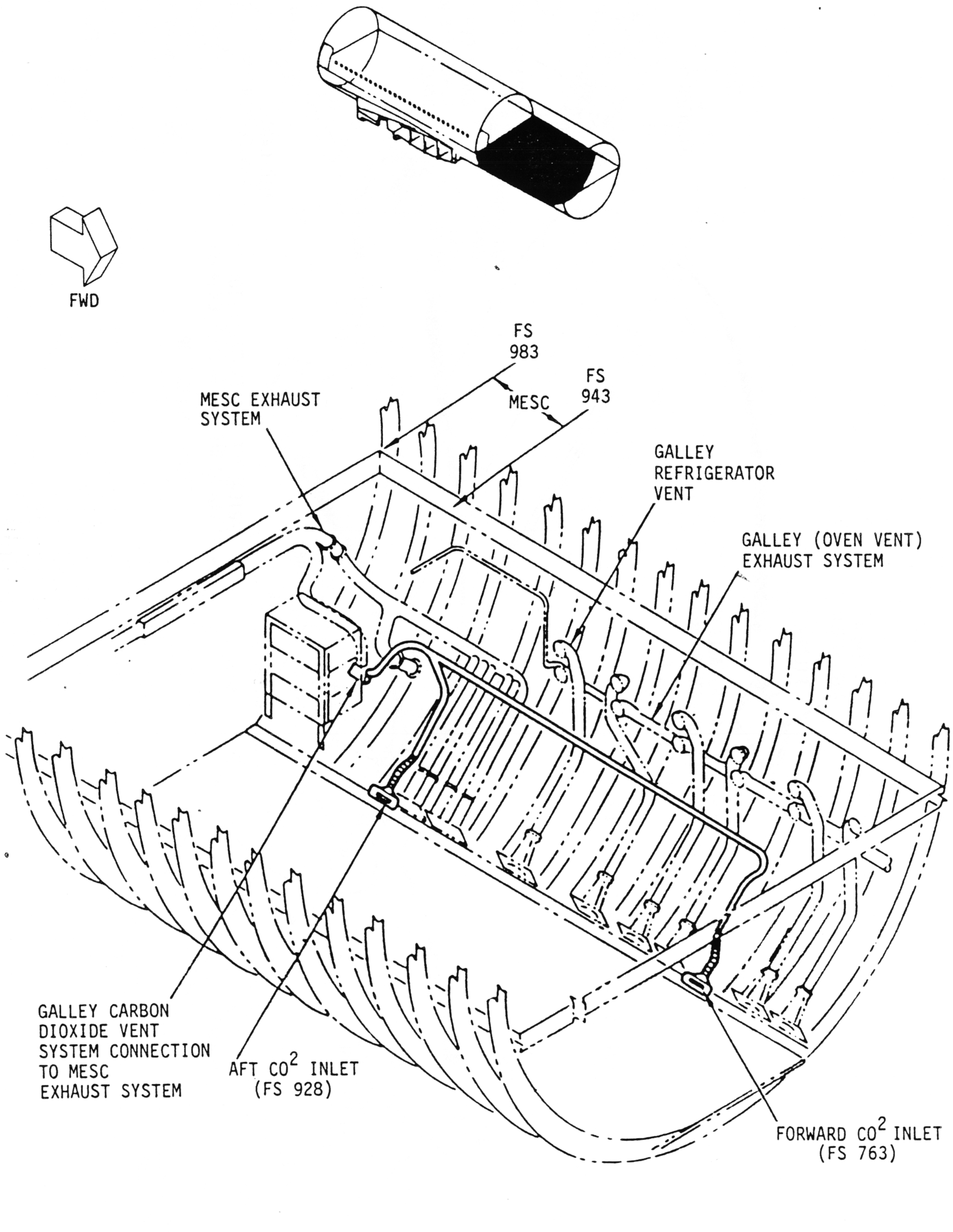


FIGURE 12-20. LOCKHEED L-1011 GALLEY CARBON DIOXIDE VENT

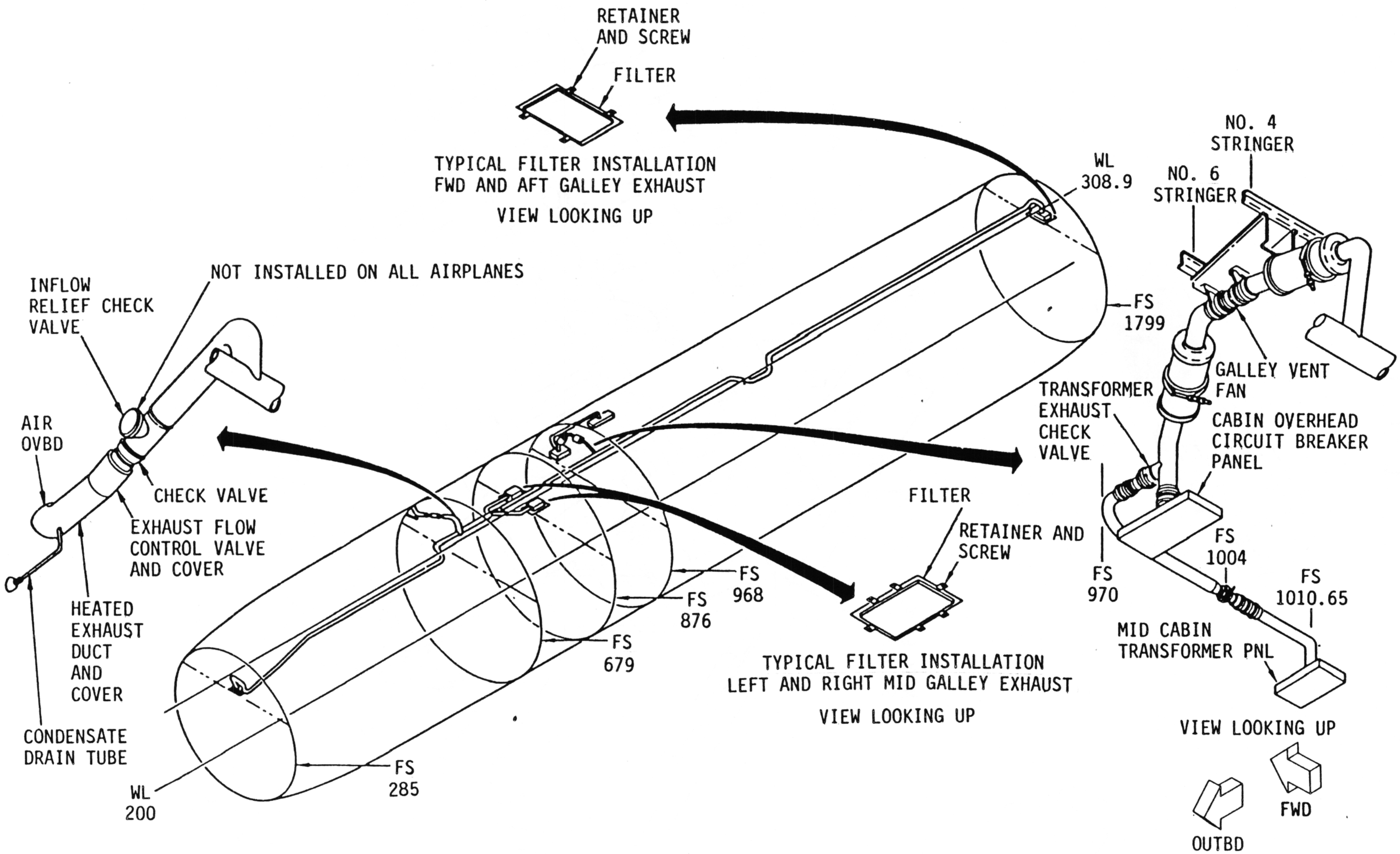


FIGURE 12-21. LOCKHEED L-1011-500 GALLEY VENTING SYSTEM

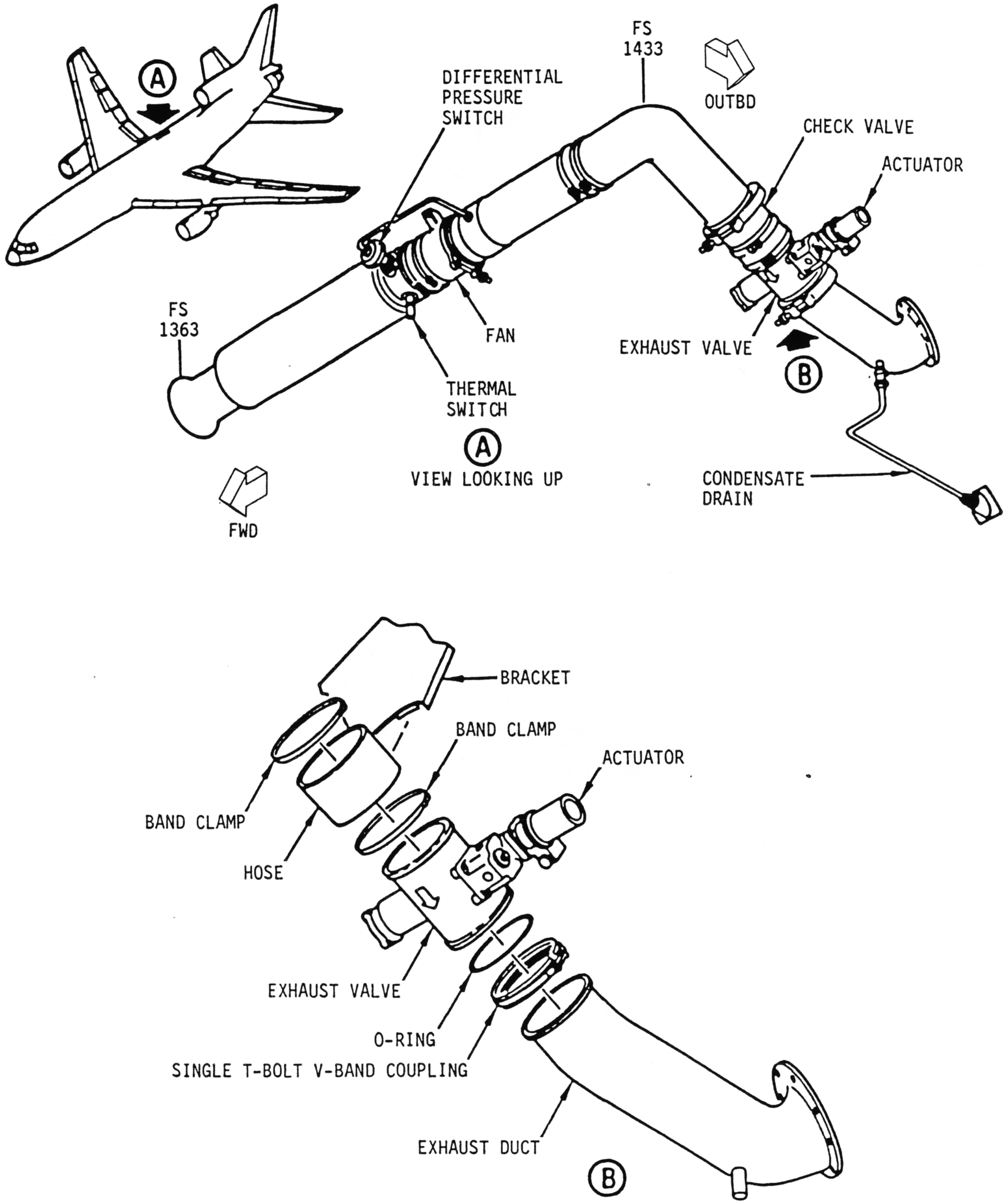


FIGURE 12-22. LOCKHEED L-1011-500 OVERHEAD EXAUST SYSTEM

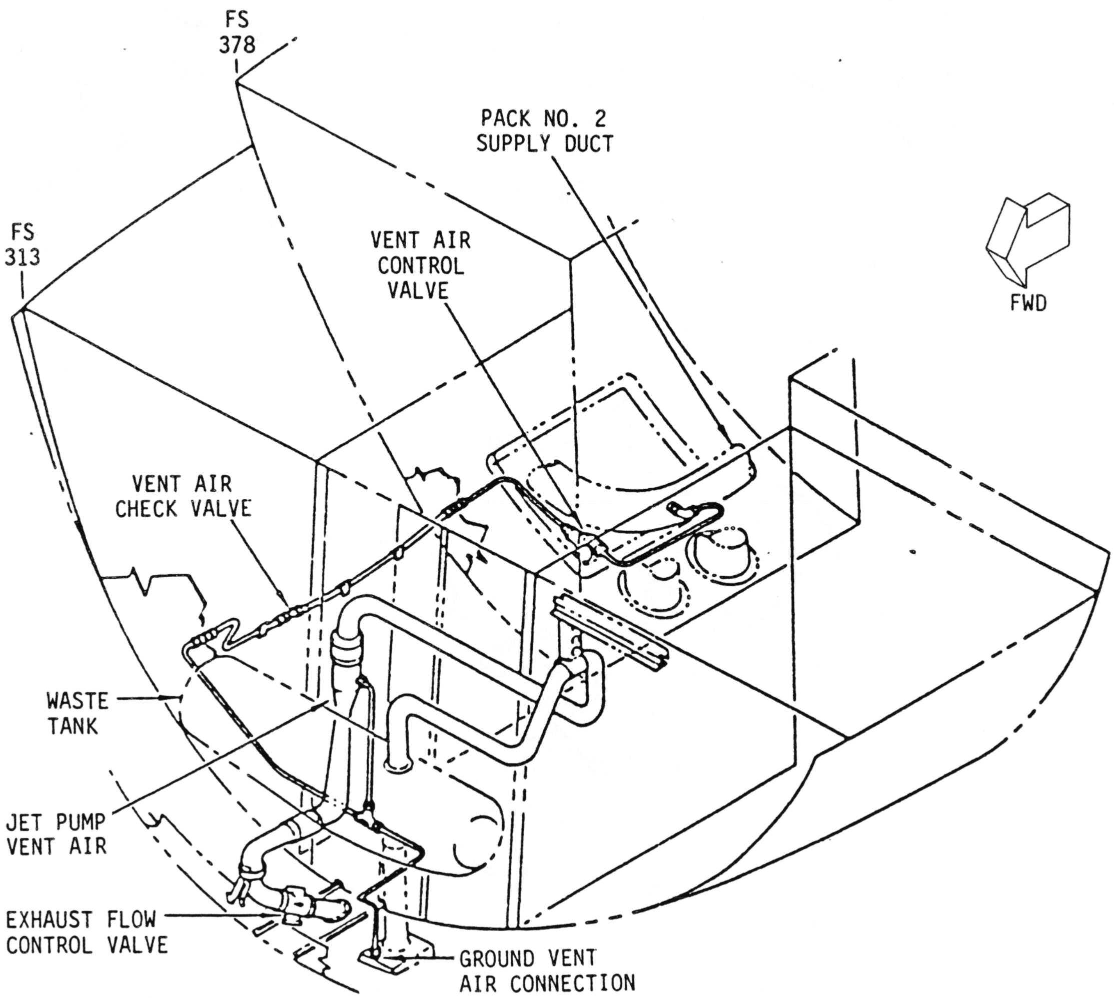


FIGURE 12-23. LOCKHEED L-1011 FORWARD LAVATORY VENT

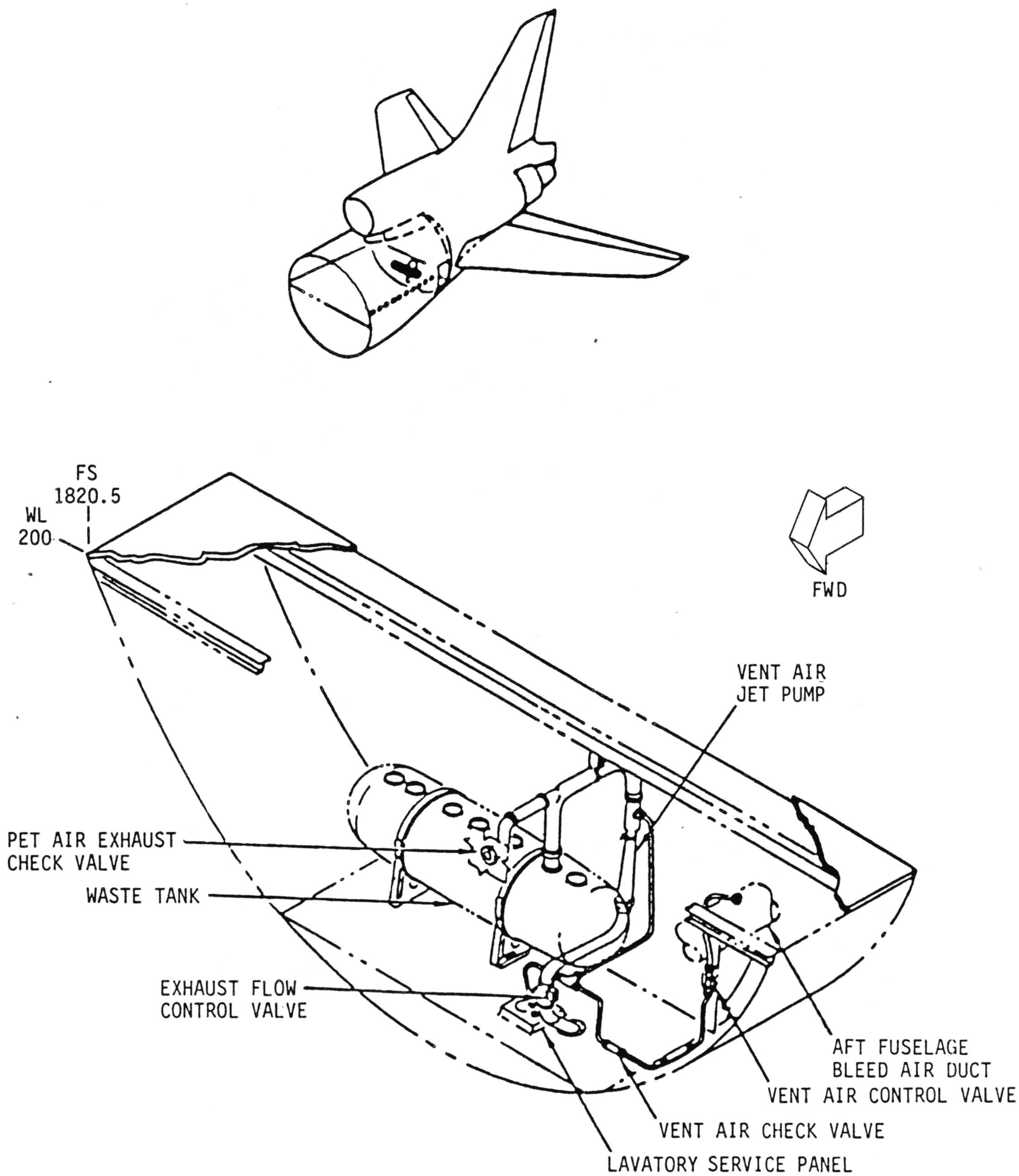


FIGURE 12-24. LOCKHEED L-1011 AFT LAVATORY VENT

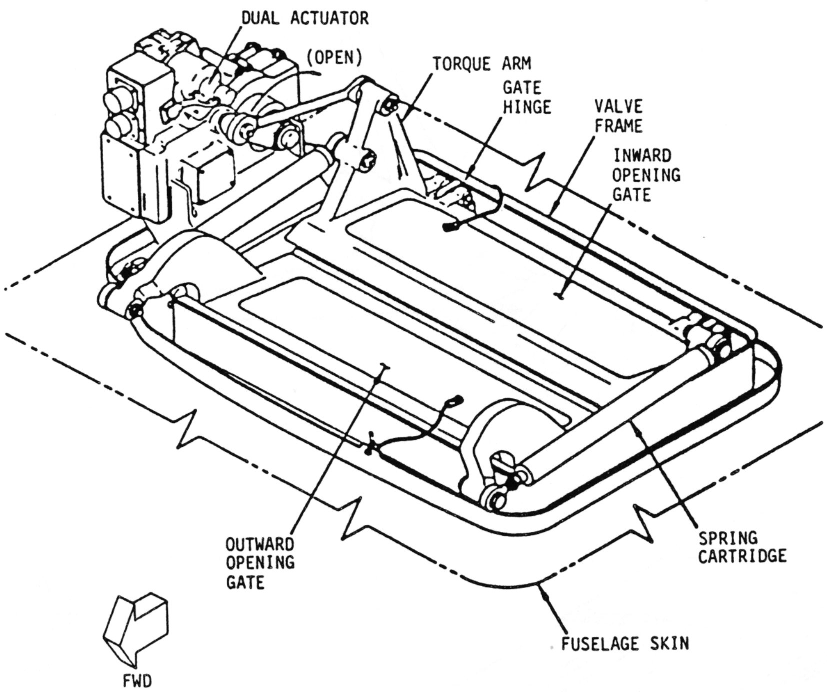


FIGURE 12-25. LOCKHEED L-1011 OUTFLOW VALVE

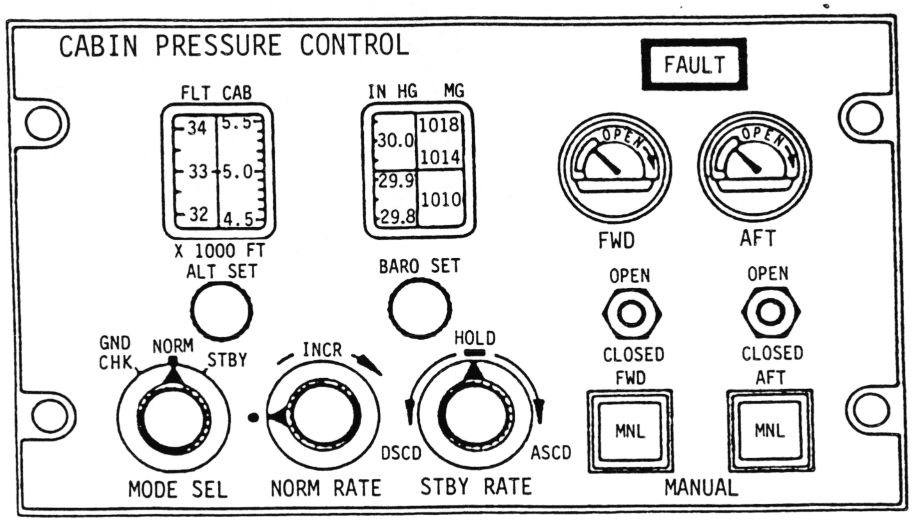
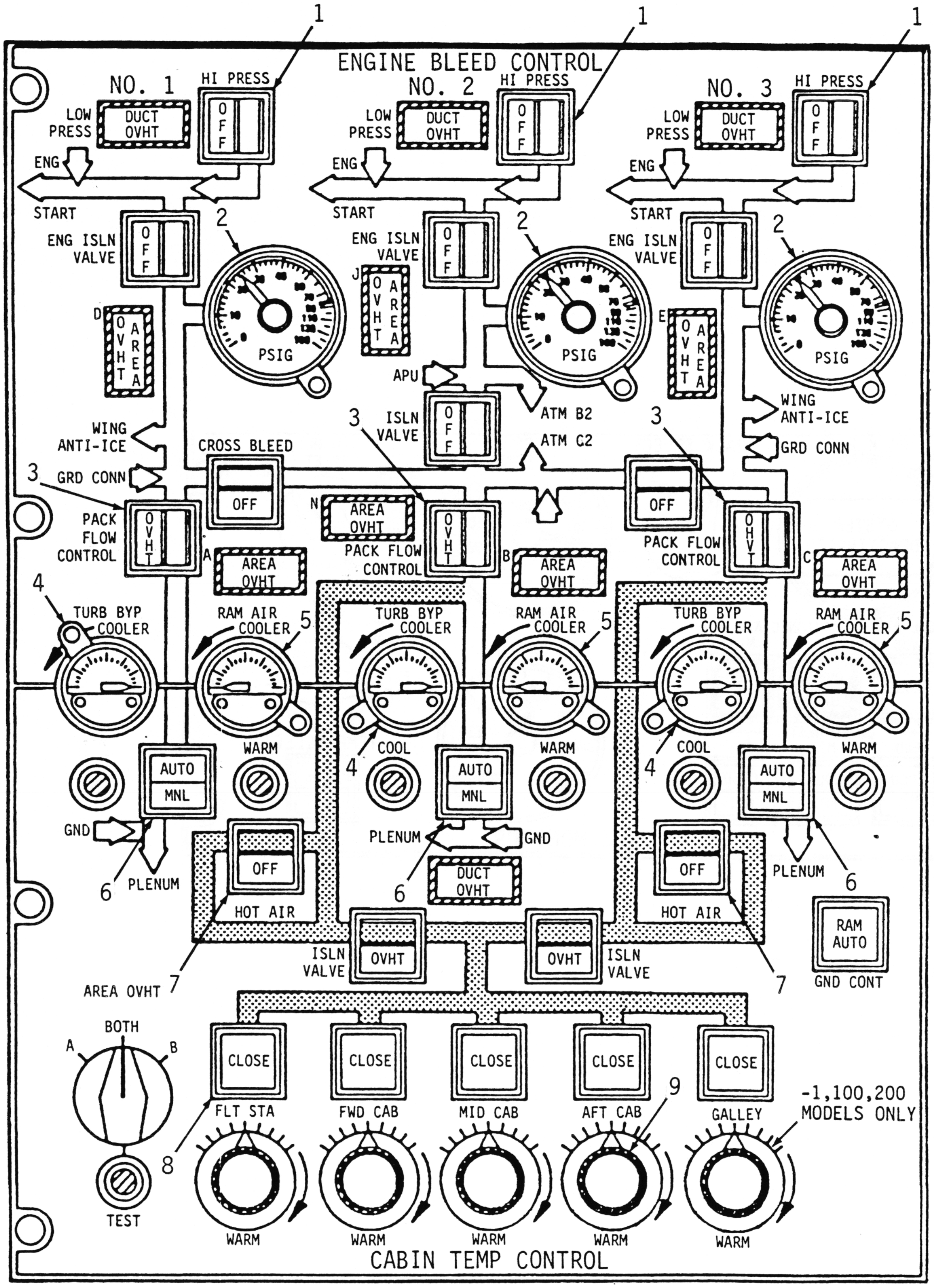


FIGURE 12-26. LOCKHEED L-1011 PRESSURIZATION CONTROL PANEL



(1) ENGINE BLEED AIR SWITCHES

(2) BLEED AIR PRESSURE GAUGES

(3) PACK ON-OFF SWITCHES

(4) TURBINE BYPASS VALVE MANUAL CONTROL & POSITION INDICATOR

(5) RAM AIR LOUVERS MANUAL CONTROL AND POSITION INDICATOR

(6) PACK AUTO-MANUAL CONTROL SELECTOR

(7) HOT AIR FLOW ON-OFF SWITCHES

(8) TRIM AIR FLOW ON-OFF SWITCHES

(9) TEMPERATURE CONTROLS

FIGURE 12-27. LOCKHEED L-1011 INTEGRATED PNUEMATIC SYSTEM CONTROL PANELS

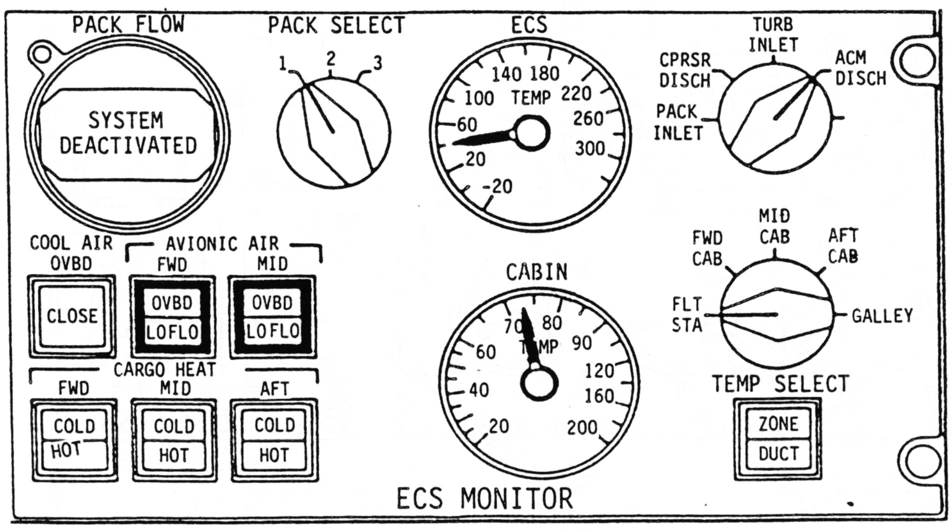


FIGURE 12-28. LOCKHEED L-1011 ECS CONTROL PANEL

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