DOCKET NO. **SA- 516**

EXHIBIT NO. **2A**

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C

OPERATIONAL FACTORS FACTUAL REPORT

FACTUAL REPORT

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
DENVER FIELD OFFICE
4760 OAKLAND STREET, SUITE 500
DENVER, COLORADO 80239

OCTOBER 16, 1997

GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

A. ACCIDENT: DCA-96-MA-070

Location:	East Moriches, New York
Date:	July 17, 1996
Time:	2031 Eastern Daylight Time
Airplane:	Boeing 747-131, N93119

B. OPERATIONAL FACTORS GROUP

The group met at the accident site on July 18, 1996, through September 30, 1996. The following group members participated in the investigation

Chairman:	Norman F. Wiemeyer	NTSB
Members:	Lou Burns	ALPA
	Terry Stacey	TWA
	Gary Graham	IFFA
	Linda Kuntz	TWA
	Bill Bumpus	FAA
	Kevin Longwell	Boeing

C. SUMMARY

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK). The airplane was being operated on an instrument flight rules (IFR) flight plan under the provisions of Title 14 Code of Federal Regulations (CFR) Part 121, on a regularly scheduled flight to Charles De Gaulle International

Airport (CDG), Paris, France, as Trans World Airlines (TWA Flight 800). The airplane was destroyed by explosion, fire, and impact forces with the ocean. All 230 people aboard were killed.

D. DETAILS OF INVESTIGATION

I. FLIGHT INFORMATION

The flight departed from TWA terminal 5, gate 27, coordinates N40 38.8, W073 46/6. Scheduled departure time was 1900 EDT. Actual departure time was 2002. The 1 hour and 2 minute delay in departure was due to a passenger/luggage mismatch and a piece of disabled ground equipment. The scheduled en route time was 6 hours 9 minutes. The flight was normally scheduled to terminate in Paris but was extended to Rome due to cancellation of a company Kennedy/Rome flight earlier in the day. A crew change was planned in Paris.

Total persons aboard the aircraft was two hundred thirty (230). Eighteen (18) were active crew, seventeen (17) were deadheading crew, and one hundred ninety five (195) were passengers.

Takeoff was planned, and occurred, on runway 22R which is 10,500 feet in length and has a slope of 0.00 degrees. Based on a temperature of 71 degrees Fahrenheit (22 degrees Celsius) and a flap setting of 10 degrees, takeoff speeds were calculated as a V1 (takeoff decision speed) of 113 knots, a Vr (takeoff rotation speed) of 146 knots, and a V2 (takeoff safety speed) of 153 knots. Engine pressure ratio (EPR) settings were 1.330 standard and 1.455 maximum.

The dispatch release provided information that for flight 800 the takeoff weight was 590,441 pounds as follows:

Empty operating weight		359,440 lbs.
Crew and passenger weight	(230)	34,650 lbs.
Forward compartment cargo		6,062 lbs.
Rear compartment cargo		12,428 lbs.
Aft compartment cargo		1,261 lbs.
Zero fuel weight	(MZFW 526,500)	413,841 lbs.
Takeoff fuel		176,600 lbs.
Gross takeoff weight	(ATOW 708,300)	590,441 lbs.
Taxi fuel		4,500 lbs.
Taxi weight		594,941 lbs.

Based on the directed location and the program weight of the passengers, fuel, and cargo, the plane's takeoff center of gravity in mean aerodynamic chord (MAC) was calculated to be 18.4

percent, and the horizontal stabilizer takeoff trim setting was 6.1 units nose up.

The dispatch release for the flight contained three open minimum equipment list items:

1. 27-51-2. Number 2 left canoe flap track fairing missing. Notice to dispatch is required due to performance penalty and a placard is required.

2. 78-1-3. Number 3 engine thrust reverser inoperative. This must be noted to the flight crew and the associated systems for stopping the aircraft must be operational. The thrust reverser must be deactivated and the aircraft placarded.

3. 34-23 One of the two weather radar transmitters inoperative. One may be inoperative and the flight crew advised with the aircraft properly placarded.

The Operations Group reviewed TWA procedures, voice recorder information, flight recorder data, radar data, and performance data during the course of the investigation. This review provided no evidence that flight 800 was operated in a manner inconsistent with either Federal Air Regulations or TWA procedures.

CARGO

This flight was designated a "LIFE GUARD" flight because it was carrying human eyes. These were carried in a special container on the flight deck.

A review of the cargo manifest and shipping documents was conducted by the operations group during the investigation. No evidence was found that TWA or regulatory requirements for packaging, labeling or loading were not complied with. For details regarding cargo refer to exhibit 2N.

II. WEATHER INFORMATION

Recorded weather at John F. Kennedy International Airport (JFK)at 1950 EDT was clear skies with 25 miles visibility, temperature 71 degrees Fahrenheit, dew point 68 degrees Fahrenheit, wind from 220 degrees magnetic heading at 4 knots and an altimeter setting of 30.09 inches of mercury. There were no remarks.

The 1950 EDT recorded weather at Islip, New York (ISP), which is the nearest reporting station to the accident site, was scattered clouds at 2,500 feet, 8 miles visibility, temperature

69 degrees Fahrenheit, dew point 68 degrees Fahrenheit, wind from 190 degrees magnetic at 3 knots, and an altimeter setting of 30.09 inches of mercury. Remarks were - haze.

A radiosonde balloon launched from Upton, New York, on July 17, 1996, reached an altitude of 13,451 feet above sea level at 1934 EDT. The readings at that altitude were wind from 297 degrees magnetic at 18 knots. At 1938 EDT, the readings at 14,326 feet above sea level were winds from 300 degrees magnetic at 20 knots.

A weather package was a part of the dispatch release and is contained in exhibit 2C.

III. CREW INFORMATION

There were four flight deck crew members on duty.

Captain Steven Snyder, ATP 1475512. DOB 11/21/38. Captain Snyder was serving as a check airman and was the pilot in command. He was occupying the right seat and was filling the role of first officer on this flight. According to TWA, he had approximately 4,700 hours in this make and model aircraft and approximately 17,000 total flight hours. He held a first class medical certificate with no limitations and his last physical was conducted on April 15, 1996. His last proficiency check in the aircraft was completed on January 17, 1996.

Captain Snyder joined TWA as a pilot on April 13, 1964. He flew as a pilot in the Convair 880, Lockheed 1011, Boeing 727 and 707. He first qualified as a Captain in July of 1968 and flew as captain on the Lockheed 1011 and Boeing 707. He received a type rating on the Boeing 747 on December 30, 1974, and qualified as a check airman on that aircraft on May 3, 1993.

Captain Ralph Kevorkian, ATP 1453736. DOB 10/18/37. Captain Kevorkian was occupying the left seat and was receiving his second "initial operating experience" training flight as part of his qualification as a captain on the Boeing 747 type aircraft. He was filling the role of captain on this flight. According to TWA, he had approximately 5,490 hours in type and 18,800 total flight hours. He held a first class medical certificate with the limitation that he possess glasses for near vision. His last physical was conducted on March 22, 1996. His last proficiency check was completed on June 19, 1996.

Captain Kevorkin applied for employment with TWA on May 20, 1965, as a pilot. Following his acceptance and training, he served as a first officer on the Convair 880, Boeing 707, Lockheed 1011 and Boeing 747. He also served as a captain on the Boeing 707 and

Lockheed 1011. He received a type rating on the Boeing 747 on February 19, 1990 and started captain training on the Boeing 747 on May 21, 1996.

Richard Campbell, ATP 1409009, flight engineer-turbo jet 1694661. DOB 7/2/33. Based on company procedures and CVR voice recognition, Mr. Campbell was occupying the jump seat across from the engineer panel. He was a check engineer conducting training of a "new hire" flight engineer. According to TWA, his flight engineer experience on the Boeing 747 was approximately 2,397 hours and total flight engineer experience was approximately 3,047 flight hours. He held a first class medical certificate with the limitation that he wear glasses for near and distant vision and his last physical was conducted on July 17, 1996. His last proficiency check was completed on June 14, 1996.

Mr. Campbell received his commercial pilot certificate on April 16, 1958, with a single engine land rating and instrument certificate. He had previously served in the United States Air Force. He completed his pre-employment physical with TWA and was assigned to duty with TWA on February 26, 1966. He was assigned as a flight engineer on the Lockheed Constellation 749, 749A and 1049G on September 30, 1966. He became a reserve co-pilot on that aircraft February 28, 1967. The equipment flown from that time until he was qualified as a captain on the Lockheed or Boeing 747 is unknown. On November 19, 1986, he received a type rating on the Boeing 747 and flew that aircraft as a captain until he retired due to reaching age 60 on July 2, 1993. From that date until the accident occurred, he served as a flight engineer and check engineer on the Boeing 747.

Oliver Krick, ATP and flight engineer-turbo jet powered certificate number 306804492. DOB 7/10/71. Mr. Crick was a "new hire" with TWA and had no previous experience as a flight engineer. He was on his sixth leg of initial operating experience as a flight engineer on the Boeing 747 and had no previous flight engineer experience. According to company procedures, he should have been occupying the flight engineer station and according to TWA records, he had approximately 2,520 total flight hours and approximately 30 hours flight engineer experience, all of which was in the Boeing 747. He held a first class medical certificate with no limitations, dated December 12, 1995, and earned his flight engineer certificate on June 22, 1996.

A review of flight time limits, duty period limits, and rest requirements was conducted by the operations group during the investigation. The review provided no evidence that any flight deck crewmember was violating any of the limits established by regulation and/or the pilots' working agreement.

The flight attendants on duty for the flight were:

Melinda Torche
Marit Rhoads
Maureen Lockhart
D. C. Diluccio
Janet Christopher
Grace Melodtin
Mike Schuldt
Snadra Meade
Ray Lang
Dan Callas
Jill Ziemkiewicz
Arlene Johnson
Jacque Charbonnier
Constance Charbonnier

IV. AIRCRAFT INFORMATION

a. General

The accident aircraft was a Boeing 747-131, with a United States Registration of N93119, a serial number of 20083, and listed by TWA as ship number 17119. It was manufactured in 1971. According to the flight operations manual, the maximum certified gross weight of this aircraft was 734,000 pounds.

b. Flight 800 Data

According to a cargo service employee, who was working the flight, he was asked by a crewmember about the heat in the aft cargo compartment. He stated that the compartment was "hot." The crewmember then said something about "okay that's the reason for the light."

There is an aft cargo overheat sensing system associated with the aft cargo heat system. According to the TWA aircraft operating manual, when the temperature reaches approximately 110 degrees Fahrenheit, heat to the compartment is automatically eliminated. When the temperature drops below approximately 80 degrees Fahrenheit, the automatic control is reactivated. According to a TWA check engineer interviewed during the investigation, during warm days, it is not uncommon for this light to come on during the time the aircraft is parked at the gate, and once the cargo doors are closed the light extinguishes. The aft cargo overheat light must be extinguished prior to taxi.

During the time the aircraft was on the ground at JFK, between the Athens flight and the Paris flight, TWA maintenance personnel worked on the number three engine thrust reverser. In an interview with the mechanic who worked on the reverser, he said he was unable to correct the problem due to limited ground time and he mechanically locked the thrust reverser in the forward thrust position in accordance with maintenance directives and reported his activities appropriately. Investigation confirmed reporting of this maintenance activity.

During the time the aircraft was being fueled at JFK, the automatic (volumetric) shutoff to the fueling system activated. According to the person who was fueling the aircraft and TWA maintenance personnel, this is a common occurrence. The fueler stated during an interview that he reported the shutdown and a TWA mechanic came out and "pulled a circuit breaker and fuse" and he finished fueling the aircraft manually. According to the fueler, when he finished with fueling the aircraft, the mechanic reset the fuse and circuit breaker. This activity was confirmed during interviews with the TWA mechanics who were involved.

c. Fueling

According to the fueling record, fuel loading on the aircraft was as follows:

TANK	BEFORE FUELING	PLANNED POUNDS	AFTER FUELING	
1R	0	3,350	3,400	LBS.
1M	5,400	24,596	24,600	LBS.
2M	5,300	62,605	62,900	LBS.
CENTER	300	0	300	LBS.
3M	6,900	62,605	62,700	LBS.
4M	6,300	24,596	24,600	LBS.
4R	0	3,350	3,300	LBS.
TOTAL	24,200	181,102	181,800	LBS.

Fuel tank capacities are:

1 and 4 RESERVE	3,350	LBS. EACH
1 AND 4 MAIN	29,614	LBS. EACH
2 AND 3 MAIN	82,008	LBS. EACH
CENTER	86,363	LBS.

(This is an approximate volume of 1,625 cubic feet in the center tank).

According to performance data, the calculated fuel on board the aircraft at the time of the accident was 165,000 lbs.

d. Fuel System Information

FUEL SYSTEM DESCRIPTION

Appropriate portions of fuel system description are reproduced below.

GENERAL

The fuel system consists of seven tanks, a crossfeed manifold, crossfeed valves to provide for fuel management, two fueling stations, a fuel jettison system, and a surge tank in each wing tip.

All tanks are formed by sealing the internal wing structure. They consist of two reserves, four main and one center wing tank. Sump drains are provided for draining the low point of each tank. A drybay area exists outboard of each reserve tank and in the forward bay of the center wing section on the 100 series aircraft.

The aircraft fuel system contains the following valves controlled at the engineer's panel: Engine fuel shut-off valves, crossfeed valves, reserve tank valves, main tank 1 and 4 jettison valves, center wing jettison valves and an APU fuel valve.

When any of these valves are actuated, an associated in-transit light comes on and remains on until the valve actuator motor completes its cycle. The light operates in conjunction with the valve motor and not the valve position.

FUELING

Fueling is normally accomplished using the underwing pressure fueling method. Fuel is delivered under pressure from external fueling stations (one under each wing) through the fueling manifold and then through fueling valves into each tank.

A fueling control panel is located in the lower leading edge of the left wing, outboard of the fueling station. All controls required for operation of the fueling system are located in the fuel control panel. When a full tank is sensed, a volumetric shutoff automatically closes the tank fueling valve.

Fuel quantity indicators are located at the left wing fueling station. Servicing personnel will normally monitor the indicators and close the refueling valve when the desired quantity of fuel is loaded. Overwing fill ports are provided for the four main tanks only.

Fuel quantity is indicated in pounds by the use of a capacitance type indicating system. Each fuel tank contains several units which measure the fuel density. This measurement is displayed on the engineer's panel volume and quantity gauges, each tank and total, calibrated in pounds X 1000.

FUEL BOOST PUMPS

The electrically driven fuel boost pumps, 2 in each main tank, receive power from the normal AC busses. DC power is used for pump control. Boost pump switches are on the engineer's panel. Pump output pressure is rated at 10 psig at 20,000 feet pressure altitude. Each pump incorporates an amber low pressure warning light that comes on whenever the pump discharge pressure drops below limits. The pump pressure lights are powered through the engineer's warning light circuits.

CENTER TANK SCAVENGE

The center tank is provided with a scavenge pump to remove residual fuel that cannot be pumped from the tank by override/jettison pumps.

The scavenge pump is powered from AC bus 1 through a control switch on the engineer's panel. A low pressure light comes on whenever pump discharge pressure drops below limits. The scavenge pump transfers fuel into the number 2 main tank. During ground operation, the pump is deactivated through the ground safety relay. The pump is rated at 1,500 to 1,700 pounds per hour fuel flow.

FUEL JETTISON SYSTEM

The fuel jettison manifold is continuous within the wing, terminating at two fixed jettison nozzles on the trailing edge near each wing tip. Fuel can only be jettisoned directly from main tanks 2 and 3 and the center tank. Fuel flow from the manifold is controlled by jettison nozzle valves which are opened or closed by control switches at the fuel jettison panel on the flight engineer's panel. The jettison manifold is also used for fuel servicing of all the tanks.

MAIN TANK JETTISON PUMPS

The main tank jettison pumps (2 in each tank) are located in tanks 2 and 3 and are rated at 37 psi. The pumps are powered by AC busses 2 and 4 through control switches on the fuel jettison panel. The low pressure warning light is armed when the switch is on, and will come on when the output pressure drops below limits. Jettisoning is automatically terminated by a standpipe at the inlet to the pumps.

CENTER TANK OVERRIDE/JETTISON PUMPS

The center tank override/jettison pumps are rated at 37 psi. The pumps are powered by AC busses 1 and 3 through control switches on the fuel panel. A low pressure light comes on when the output pressure drops below limits. There are no standpipes at the inlet to the pumps in the center tank.

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CENTER WING JETTISON VALVES

The center wing jettison valves are powered by DC busses 2 and 3 through the left and right center wing jettison valve switches at the fuel jettison panel. These valves enable the center tank fuel to enter the jettison manifold. When the valves are open, the jettison and crossfeed manifold are connected together; however, check valves do not allow crossfeed manifold fuel to enter the jettison manifold.

NUMBER 1 AND 4 MAIN TRANSFER VALVES

The number 1 and 4 main tank transfer valves are powered from DC bus 2 and the essential DC bus. The transfer valves provide gravity feed of fuel from the outboard main tanks into the respective inboard main tanks for jettisoning. The valves are controlled by switches on the fuel jettison panel. When the main transfer valves are opened, fuel flows into the inboard tanks and is jettisoned by the inboard main jettison pumps. Fuel transfer is terminated by standpipes at the inlets of the transfer valves.

CROSSFEED MANIFOLD

The crossfeed manifold provides a means of distributing the fuel from the center wing or any main tank to any engine.

Rotary switches on the engineer's panel control crossfeed valve position.

RESERVE TANKS 1 AND 4

The reserve tanks 1 and 4 fuel is gravity fed into the adjacent outboard main tank through the reserve tank valve. The reserve valve is opened by aligning the reserve tank valve switch flow line with the flow lines on the fuel panel. It takes approximately 20 minutes to transfer a full reserve tank into its adjacent main.

FUEL FLOW INDICATOR

A fuel flow indicator is incorporated for each engine. According to the TWA operations manual, the gauge is both pointer and digital and indicates metered fuel to respective engines. (Boeing wire schematics show vertical scale indicators, which do not have pointers or digital readouts. It is calibrated in pounds per hour X 1,000. With electrical power loss or instrument failure, a warning flag drops in front of the digital readout window. Electrical power is supplied from AC BUS 1,2,3, and 4.

According to the minimum equipment list (MEL), the aircraft may be dispatched with one fuel flow indicator inoperative provided the associated N1 and N2 gauges function and the associated main fuel tank quantity indicating system functions normally.

FUEL MANAGEMENT

GENERAL

Boost pump pressure is required during flight to preclude the possibility of engine surge and/or flameout.

EXTENDED TAXI

When expecting an extended taxi that will burn more than 3,000 pounds of fuel, use the following appropriate procedure.

With center tank fuel:

> Use center tank fuel to feed all engines during taxi.

With no center tank fuel:

> Use main tanks 2 and 3 to feed all engines until quantity in main tanks 2 and 3 equals quantity in main tanks 1 and 4 plus their adjacent reserves, then return to tank to engine feed.

RESERVE TANK FUEL

If takeoff is planned with the reserve tanks empty and additional fuel is required, it may be added to the four main tanks provided the following limitations are observed:

Center wing tank must be empty.

In the 100 series aircraft - Fuel in any main tank must not exceed 23,000 pounds and takeoff weight must not exceed 600,000 pounds.

There are no limitations on fuel remaining in any tank for landing. Therefore, if the next takeoff requires fuel in the reserve tanks, landing is permissible with reserve tanks full.

START, TAXI, AND TAKEOFF

Prior to engine start, turn on all main tank boost pumps, open crossfeed valves 1 and 4 and close crossfeed valves 2 and 3.

Start engines, taxi, and takeoff using main tank to engine fuel feed.

If more than 3,000 pounds of fuel is expected to be used during taxi, use the Extended Taxi procedure.

CROSSFEED

Prior to initiating and terminating crossfeed procedure advise the captain and enter the fuel quantity and time on the fuel log.

When the quantity in main tanks 1 and 4 is between 23,000 and 20,000 pounds each, begin crossfeed using one of the following procedures:

With center tank fuel:

Turn on all center tank override/jettison pumps, open all crossfeed valves, turn off boost pumps in main tanks 1 and 4 and feed all engines from the center tank. When override/jettison pump low pressure lights come on steady or inboard tank quantity begins to decrease, turn off the override/jettison pumps.

Turn on the scavenge pump. When its low pressure light comes on steady, turn it off. Continue flight using main tanks 2 and 3 to feed all engines.

With no center tank fuel:

Open all crossfeed valves, turn off boost pumps in main tanks 1 and 4 and feed all engines from main tanks 2 and 3.

RESERVE TANK 1 AND 4 FUEL TRANSFER

Transfer reserve tank fuel when the quantity in main tank 1 or 4 is 5,000 pounds or at the start of descent whichever occurs first. Leave reserve tank valves open for the remainder of the flight. Wing life will be improved by keeping reserve tanks full as long as possible. However, if conditions require, limitations allow reserve tank fuel to be transferred when the aircraft weight is 600,000 pounds or less and quantity in main tanks 1 and 4 is less than 19,500 pounds each.

(Based on fuel burn calculations, it is possible that, based on the above procedure, the flight 800 engineer was entering the regime to transfer reserve tank fuel when the accident occurred. However, it is not TWA's normal procedure to do so.)

During the investigation, the crew who brought the aircraft to JFK from Athens was interviewed. They said they experienced no operational abnormalities during the flight from Athens and in answer to a specific question concerning the center fuel tank, the flight engineer said he had no fuel migration back into the tank after he had used all the useable fuel in the tank and the scavenge pump worked normally. He said there was about 300 pounds residual fuel in the tank.

AUXILLARY POWER

GENERAL

SYSTEM DESCRIPTION

The auxiliary power unit (APU) is a self-contained constant speed engine that provides electrical power and bleed air during ground operation. The APU consists of a single spool jet engine, an AC generator, a bleed air supply valve, and an electronic turbine control unit.

The APU is located in the tail section of the aircraft. An air inlet provides air to the compressor through a door located on the right side of the aircraft tail cone. The door must be open when the APU is operating.

The APU fuel system consists of a fuel valve, a DC pump and a pressure switch. Number 2 main tank fuel is automatically supplied to the APU when the APU master switch is on. When the AC busses are not powered, the DC pump supplies the fuel pressure. When the AC busses are powered, the number 2 tank aft boost pump automatically operates. This activates a pressure switch to turn off the DC pump.

Start and ignition is provided by the APU battery. Automatic controls activate and deactivate the starter motor and ignition circuits during the starting cycle.

APU bleed air provides APU inlet anti-icing and bleed air for airplane pneumatic systems. A fan driven by the APU accessory drive supplies cooling air to the generator and oil cooler. APU bleed air also supplies air for air conditioning, engine starting, and air-driven hydraulic pumps.

OPERATION

The APU can only be started at the engineer's panel. Shutdown can be accomplished at the engineer's panel or from a remote control panel in the right body gear wheel well.

When the APU master control switch is positioned to on, the APU fuel control valve opens, the air inlet door opens, and the DC fuel pump operates from the main battery if AC power is not available. A green DC pump light will be on when the DC pump is operating. If AC power is available, number 2 main tank aft boost pump will operate. The APU DOOR blue light will be on when the door is in-transit and the fuel valve blue light will be on when the valve is in-transit.

When the APU master control switch is momentarily positioned to start, the start motor begins to crank the engine. At starter engagement, the APU battery voltage drops to approximately 10 volts and the amperage indicates a plus 60 to 80 amps. Ignition occurs as engine rpm increases above 7 percent. At 50 percent the starter is deactivated and voltage and amperage return to normal. At 95 percent rpm, the ignition circuit is deenergized and the APU can provide electrical and pneumatic power.

Air for accessory cooling is drawn through the cooling air shutoff valve from the air inlet duct by a cooling fan. The valve is closed during APU starting and opens when the rpm is above 95 percent. If the valve fails to open, automatic shutdown of the APU will occur.

The APU is normally shutdown by positioning the master control switch to stop. This simulates an engine overspeed and an amber APU FAULT light illuminates. The overspeed signal de-energizes the fuel valve solenoid which shuts off fuel flow at the APU. The fuel shutoff valve closes and its in-transit light will be on until the fuel valve is fully closed. At 50 percent rpm, the air inlet door is signaled to close and the door light comes on and stays on until the door is closed. If the master control switch fails to stop the APU, the fire control handle can be used as an alternate shutdown.

AUTOMATIC SHUTDOWN

Automatic shutdown occurs in the event of low oil pressure, high oil temperature, engine overspeed, engine fire, APU bleed air duct leak, APU over temperature and several other faults. The APU fault light on the engineer's panel will come on anytime the APU shuts down automatically for any of the monitored faults.

AIR CONDITIONING

GENERAL

The Boeing 747-131 aircraft is divided into four temperature control zones. Zone 1 is the cockpit and zones 2,3, and 4 are the main cabin.

The cabin is also divided into passenger seating sections. These are lettered alphabetically from front to rear. Cabin zones 2 and 3 each contain two seating sections. There is also a small passenger seating section on the upper deck directly behind the cockpit.

The air-conditioning system provides complete environmental control (pressurization, ventilation, and temperature) for the flight deck, upper deck, and main cabin zones of the aircraft. The system uses three air cycle packs to cool and condition bleed air from the pneumatic manifold. Catalytic converters are installed in the bleed air ducting ahead of the packs to reduce the level of ozone entering the aircraft.

Air to the pneumatic manifold is normally provided by engine bleed air. On the ground, when the engines are not operating air may be provided by either the auxiliary power unit (APU) or high pressure ground carts. Low pressure ground pre-conditioned air may also be connected directly to air plenum.

AIR DISTRIBUTION

Air from the pneumatic manifold is routed through the packs and then collected in a common plenum located below the main cabin floor. Vertical risers in the side walls carry the air to the area above the main cabin ceiling for distribution into each zone. Air enters the main cabin through nozzles located beneath the outboard hat racks. Upper deck air enters through nozzles on the centerline of the ceiling. The flight deck has controllable outlets in the ceiling, along the window ledges, and at the foot level of each crew position. Air leaves the main cabin through floor level grills and flows aft, behind the side wall liners of each cargo compartment, to the cabin pressurization outflow valves.

RECIRCULATING FANS

Four electric recirculating fans are provided to improve ventilation and supplement airflow.

A zone 1 cockpit fan is installed in the supply ducting in the lower fuselage. The fan draws air for recirculation from the cavity between the forward cargo compartment lining and the insulated fuselage of the aircraft.

Three cabin recirculating fans are installed in the distribution ducting above the cabin ceiling. Air is drawn from the overhead area surrounding the fan and recirculated into the cabin zone.

The fans are controlled by individual switches located on the engineer's panel.

GASPER AIR

In addition to normal ventilation, a gasper air outlet is provided for each crew position. Gasper air is supplied by a single electric fan located above the main cabin ceiling. The air source is from the air plenum.

TEMPERATURE REGULATION

Air from the pneumatic manifold is preconditioned by three pack that control the amount of cool air delivered to the plenum. The temperature of the plenum air is maintained at a level that satisfies the zone requiring the coolest air. Since this plenum air is distributed to all the compartments at the same temperature, each zone and the upper deck may add supplement heat to satisfy their own requirements.

SUPPLEMENTAL HEAT

Supplemental heating is accomplished in several ways. The cockpit, cabin zones, and aft cargo compartment use hot manifold air. The upper deck uses electric heaters. The forward cargo compartment uses the hot air exhaust of the equipment cooling. System.

TEMPERATURE CONTROL

Independent control systems are provided for each compartment. Cabin temperature control is automatic. Manual backup control is provided for each zone and air conditioning pack.

The cockpit and cabin zone temperature controllers regulate hot trim air to warm plenum air to the selected temperature. The zone requiring the coolest air determines the base temperature for the plenum supply.

Upper deck electric heaters cycle on and off to warm plenum air to the desired temperature.

The aft cargo heat system automatically regulates the supply of bleed air to maintain the compartment within a controlled range.

The forward cargo heat is uncontrolled.

AIR CONDITIONING PACKS

GENERAL

The packs provide aircraft pressurization and cool the high temperature engine bleed air as required to satisfy the heating and cooling requirements of the individual aircraft zones. The major pack components are: a pack flow control valve, dual heat exchanger package, an air cycle machine, and an electronic temperature control system. During minimum cooling requirements, ram air passing over the primary and secondary heat exchangers provides sufficient cooling. When additional cooling is required, the partially cooled air from the heat exchangers passes through the air cycle machine (ACM) to provide additional cooling.

PACK FLOW CONTROL VALVE

The pack flow control valve is an electrically controlled and pneumatically actuated air flow regulating valve. It controls the volume of air supplied to its respective pack and zone trim system. The valve control unit is a solenoid device that requires electrical power to close the pack valve. Control is through the pack valve switch. When a pack valve is open, it arms its respective temperature controller and all four zone controllers. A pack trip automatically closes the pack valve and turns on the pack trip light.

PACK VALVE SWITCH

The pack valve switch energizes the control solenoid to close the pack valve. In the open position, the power to the solenoid is removed and the valve is free to open pneumatically. A minimum duct pressure of 12 psi is needed to open the pack valve and hold it open.

HEAT EXCHANGER

Each pack has a dual element heat exchanger. All the air going through the pack must pass through both the primary and secondary sides of the heat exchanger before leaving the pack. Heat exchanger cooling air is provided by ram air in flight and by an ACM fan on the ground. A check valve in the ram air duct prevents fan air from reversing through the inlet.

INLET AND EXIT DOORS

Outside air enters the heat exchangers through the ram air inlet scoop, passes over the two heat exchangers, and exhausts overboard through the ram air exit door. During normal in-flight conditions, the pack temperature controller modulates the ram air inlet and exit doors to provide the amount of heat exchanger cooling. The ram air cooling capability is a function of inlet and exit door positions and outside air temperature. The position of both inlet and exit doors is on the door position indicators. If cooling requirements exceed the ram air cooling capability (inlet and exit doors full open), additional cooling is provided by the ACM.

AIR CYCLE MACHINE (ACM)

The ACM consists of a fan, compressor, expansion turbine, and bypass valve. The ACM enables the pack to produce air that is colder than the ambient air. This is accomplished by temporarily raising the temperature of the air, through compression, so that the ambient (cooler) air can extract some heat as it passes through the heat exchanger. Control of the ACM is through the ACM bypass valve. The temperature controller modulates the bypass valve toward cool (closed), this forces air through the ACM turbine to drive the compressor and fan, since all are mounted on a common shaft.

On the ground, the ram air inlet and exit doors are automatically driven full open and the bypass valve positions near mid range. Aircraft cooling is provided by the ACM and the fan which blows ambient air over the heat exchangers.

COMPRESSOR BYPASS CHECK VALVE

This valve permits primary cooled air to bypass the compressor at low ACM speed. When the ACM is operating at higher speeds, compressor discharge pressure becomes higher. This closes the bypass check valve and forces all the through the compressor.

BYPASS VALVE

The bypass valve controls airflow either through or around the ACM. It is a motor operated modulating valve with a position indicator and sequence switch for manual operation. When open, all air bypasses the ACM. When closed, all air is routed through the ACM expansion turbine for maximum cooling.

During automatic operation when the aircraft is on the ground and the pack is shut down, the bypass valve moves to mid range and the inlet and exit doors remain at full cool. Pre positioning of the bypass valve at mid range prepares the pack for immediate ACM operation as the pack valve opens.

PRESSURIZATION

GENERAL

The pressurization control system regulates and maintains cabin pressure, and the rate of cabin pressure change, as a function of settings on the control panel. This is accomplished by regulating the flow of exhaust air from the cabin through two motor-driven outflow valves. The pressurization control system includes the electronic cabin outflow valves, two cabin pressure relief valves, and four negative pressure relief valves.

The pressurization control system provides necessary signals to regulate the position of the outflow valves. This can be accomplished either automatically or manually. The control panel also contains a check (CHK) mode to conduct ground checks of the system. AUTO (automatic) is the primary mode of operation with MAN (manual) as a backup mode. Manual selection overrides the automatic mode and provides control of either or both outflow valves. The system has two channels, so it is possible to operate one outflow valve in automatic and the other in manual.

OUTFLOW VALVES

The two outflow valves are variable area units that control the rate of discharge of cabin air. They are on the bottom of the fuselage just forward of the rear pressure bulkhead. Each valve has an AC motor for automatic operation and a DC motor for manual operation. Interlocks prevent both motors from being energized simultaneously.

PRESSURE CONTROLLER

The cabin pressure controller is in the main equipment center. Cabin pressure is sensed through a port on the front of the unit. Ambient pressure is supplied by an auxiliary static system.

CABIN PRESSURE SELCTOR PANEL

The cabin pressure selector panel provides the command signals for automatic or manual control. The mode selector switch offers the choice of CHK, AUTO, MAN, MAN L, or MAN R. The rate control can vary cabin rate of change from 150 to 2,500 feet per minute during climb and 85 to 1,500 feet per minute during descent. The rate knob is not calibrated but has an index for normal setting which provides 500 feet per minute during climb and 300 feet per minute during descent. Cabin altitude is selected by a knob that drives a tape. The drape is printed with a double scale. One scale shows selected cabin altitude, and the other scale shows the flight altitude at maximum differential pressure. Also on the panel are a barometric scale and correction knob, a rate limit switch, outflow valve position indicators, and toggle switches to control the outflow valves manually.

OPERATION

a. Check Mode

The CHK mode checks the automatic pressurization system on the ground. It bypasses the ground safety relay and simulates normal automatic operation. Selecting cabin altitude below local field altitude closes both outflow valves. Selecting cabin altitude above local field altitude opens both outflow valves.

b. Auto Mode

In AUTO, ground safety relay signals drive outflow valves full open when on the ground.

After takeoff, the controller changes cabin altitude at selected a selected rate until reaching the selected altitude.

During cruise, the controller maintains selected cabin altitude up to 8.9 psi differential pressure between the cabin and external pressure. If an automatic controller malfunction allows cabin altitude to climb above selected altitude, an altitude limit feature attempts to keep cabin altitude below 12,500 feet. This altitude limit is accomplished by signaling the outflow valves closed and disabling the automatic controller.

Another automatic feature, the rate limited, takes control of both outflow valves whenever cabin rate of change exceeds 3,100 feet per minute up or 2,000 feet per minute down. The rate limiter system is designed to control a runaway outflow valve AC motor. When excessive cabin rate of change is detected, the rate limiter removes AC power and reverses the direction of outflow valve movement. This is accomplished with DC motors until cabin rate of change is zero. The AUTO FAIL light is on anytime the rate limiter is in control. The system remains in this condition until the mode selector is placed to MAN. This deactivates the rate limiter and turns out the AUTO FAIL light. The rate limiter is also deactivated if cabin altitude exceeds 10,000 feet.

At the start of descent, landing field elevation is selected. Cabin altitude descends at a selected rate, provided maximum differential is not exceeded, and it automatically goes to selected field elevation. At touchdown, the ground safety relay signals outflow valves to full open.

c. MAN Mode

In MAN, the automatic pressure controller is bypassed and both outflow valves are under direct control of switches on the control panel. DC motors position outflow valves. Manual control power is from the batter bus.

In manual mode, rate limiter, altitude limit, and differential limit are inoperative.

d. MAN L Mode

In MAN L, the left outflow valve is under manual control. The right outflow is under automatic control identical to auto mode. This is an automatic mode operation. The left outflow valve can be prepositioned toward closed and the right outflow valve controls cabin pressure.

e. MAN R Mode

The same as MAN L except the manual and automatic channels are reversed.

SAFETY PROTECTION

a. Pressure Relief

Two pneumatically operated pressure relief valves are on the left side of the fuselage, forward of the leading edge of the wing. They provide protection in manual mode and in automatic if the auto controller fails to limit differential pressure. Both valves normally open at 9.25 psi differential pressure. In case of failure of the 9.25 sensor, each valve contains backup protection set a 9.75 psi. The 9.25 psi sensing is from a common static source. The 9.75 sensing is directly from an outside port on each valve. A switch on each valve operates individual PRESS RELIEF lights on the engineer's panel.

b. Negative Relief

Each of the main cargo doors has two small doors that are spring-loaded closed and mechanically opened. These doors open against spring pressure to provide negative relief. They are also opened mechanically by the cargo door handle to bleed off any residual pressure before the main cargo door is opened.

c. Altitude Warning

An intermittent warning horn sounds if cabin altitude exceeds 10,000 feet. An altitude horn cutout button allows the horn to be silenced. When cabin altitude descends below 10,000 feet, the horn automatically stops if not cut out and the system re arms itself.

PNEUTMATICS

GENERAL

The pneumatic system consists of an assembly of ducts and valves which deliver air for air conditioning, cabin pressurization, wing anti-ice, pneumatic drives for leading edge flaps, air-driven hydraulic pumps, aft cargo compartment heat, and potable water tank pressurization. Air can be supplied from the APU, an operating engine, or a ground source.

BLEED MANIFOLD

The bleed manifold can be separated into left, right, and center (cross body) duct sections by two wing isolation valves. APU or ground source air enters the manifold at the cross body duct. Ground air connections are located just forward of the left wing landing gear wheel well. Bleed manifold duct pressure is sensed outboard of the wing isolation valves and is displayed on the duct pressure gauge as L (left) and R (right) duct pressure.

WING ISOLATION VALVES

Two wing isolation valves are AC motor operated and are controlled by switches at the engineer's panel. Either wing can be isolated from the other wing by closing either isolation valve. Both wing sections can be isolated from the center section by closing both isolation valves.

APU BLEED AIR

a. Control

When the APU is above 95 percent rpm and electrical power supplied to the busses, bleed air can be obtained from the APU by placing the bleed air switch to open. This opens the APU isolation valve and the APU bleed valve. Airflow is automatically controlled through the bleed valve. The bleed air valve varies airflow depending upon the amount of air and electrical loads imposed upon the APU. When excessive demands occur, the air supply cuts back automatically to maintain APU EGT within limits.

b. Surge Bleed System

A surge bleed system maintains sufficient airflow through the APU compressor to prevent compressor stall. This is accomplished by two valves that are energized to open when the APU reaches 95 percent rpm. The system operates automatically to prevent compressor stall when bleed air needs drop below 40 percent of the APU capability

c. Anti-icing Air

APU bleed air is used to prevent formation of ice on the APU inlet guide vanes, inlet duct surfaces, and air inlet screen. A thermal anti-icing valve opens at temperatures between 20 degrees and 39 degrees Fahrenheit. Anti-icing air is available only when the APU bleed air valve is open.

d. Thermal Switches

The APU bleed air system incorporates an overheat detection system which provides automatic APU shutdown to prevent structural damage resulting from duct failure. Thermal switches are mounted in several locations on the airplane structure in close proximity to the APU pneumatic duct.

ENGINE BLEED AIR

a. General

The primary source of engine bleed air is from the low stage compressor. Air is also available from the high stage compressor. High stage air will automatically supply system requirements when low stage air is insufficient to meet demands. Bleed air is controlled by the engine bleed valve and high stage valve and is cooled by an engine mounted pre cooler.

b. Engine Bleed Air Valve

The engine bleed air valve is electrically controlled and pneumatically operated pressure regulating valve. Due to its location, the valve is sometimes referred to as the engine bleed pylon valve. The valve is controlled at the engineer's panel by the engine bleed air switch. At the pilot's overhead panel it is controlled by the ground start switch and engine fire pull.

c. Pressure Regulator

The valve automatically modulates to limit engine bleed airflow to the pneumatic manifold to a maximum pressure of approximately 45 psi.

d. Temperature Limiter

The bleed air valve provides backup temperature protection in the event of a pre cooler failure or malfunction. If pre cooler outlet temperature gets to high, the bleed valve modulates toward closed, thereby reducing the rate off engine bleed airflow through the pre cooler.

e. Reverse Flow Check Valve

The engine bleed air valve functions as a check valve when the pneumatic manifold pressure exceeds engine bleed air pressure. If the bleed air switch is in the open position when the ground start switch is selected on, the engine bled valve is signaled to open. This overrides the check valve feature to allow airflow from the pneumatic manifold to the engine starter.

ENGINE BLEED AIR SWITCH

The engine bleed air valve can be closed with the bleed air switch. When the switch is placed to the closed position the control solenoid is electrically signaled to close the valve. The high stage bleed air valve also receives a close signal. Both valves are closed by air pressure. The bleed air valve is also signaled to close by the fire pull handle. When the bleed air switch is place to the open position the valve control solenoid is deenergized.

OVERHEAT LIGHT

An amber overheat light comes on if the air from the engine into the pneumatic manifold gets too hot. The light is above its associated engine bleed air valve switch.

The overheat light on is an indication of a malfunction of the pre cooler system and the inability of the bleed valve to satisfactorily perform its temperature limiting feature.

VALVE CLOSED LIGHT

The bleed air valve close light is on any time the engine bleed air valve is closed.

HIGH STAGE BLEED AIR VALVE

The high stage bleed air valve is pneumatically operated and functions as a pressure regulator. It automatically opens to replace low stage air as engine rpm decreases.

As engine thrust increases, the high stage valve automatically closes as low stage air pressure increases to a usable level. The high stage valve can be closed by placing the engine bleed air switch to the closed position.

HIGH STAGE LIGHT

When the high stage valve is open a green high stage light is on. The light is below its associated engine bleed valve switch.

PRESSURE RELIEF VALVE

A pressure relief valve is installed in the engine bleed ducting to protect against over pressure damage. If the high stage valve fails to close and pressure becomes high enough to damage the pre cooler and bleed air ducts down stream of the valve, an over pressure relief valve opens allowing air to pass into the nacelle. Hot engine bleed air entering the nacelle area will be indicated by a high reading on the associated nacelle temperature indicator.

PRE COOLER

The pre cooler is a heat exchanger mounted in the flow of engine fan air. Since engine bleed air is normally too hot for direct use by the air conditioning system, the low or high stage bleed air is routed through the pre cooler and engine bleed air valve before entering the pneumatic manifold.

The temperature of bleed air leaving the pre cooler is regulated by a thermal sensor downstream of the pre cooler. The amount of cooling air passing across the pre cooler is controlled automatically by the pre cooler exit doors. The pre cooler exit doors are actuated by engine bleed air. When the engine is not running, the pre cooler doors are spring-loaded to the full open position.

ELECTRICAL SYSTEM

GENERAL

Primary electrical power is supplied by four engine-driven AC generators. Each generator has a continuous load capacity of 54 KW and a five minute load of 80 KW.

Stepdown transformers are used to reduce 115 volt AC generator power to 28 volt AC. Transformer rectifiers are used to supply 28 volt DC power.

A 28 volt battery is available to supply emergency DC power to certain critical load busses when the normal power source is not available. A DC powered static inverter is provided to convert 28 volt DC into 115 volt AC power for critical flight items when essential AC power is not available.

Auxiliary power is supplied by an APU generator or external power source. The auxiliary power sources supply power to a synchronization bus (sync bus).

SPLIT SYSTEM BREAKER

The split system breaker (SSB) in the sync bus allows the bus to split into isolated left and right sync busses. The SSB opens automatically if both external power switches are closed or a sync bus fault occurs. When using as single external power source, the bus control unit (BCU) allows the SSB to close since it senses that the other half of the sync bus has no power.

The SSB can be operated manually with a switch on the electrical panel. Whenever the SSB is open, a green light above this switch comes on.

If the SSB is open after engine start, the SSB control switch must be moved to closed to permit all engine generators to parallel. The SSB only closes when autoparallel conditions are proper or when one half of the sync bus in unpowered.

POWER DISTRIBUTION

All AC power sources feed into the main AC distribution centers: P-14 and P-15 in the main electrical and electronic compartment and the lower P-6 circuit breaker panel in the cockpit.

P-14 and P-15 are respectively on the left and right sides of the E and E compartment. The sync bus joins the two sides together. This is done through the split system breaker in the center of the E and E compartment.

The P-14 and P-15 cabinets contain the main generator relays, bus tie relays, main AC bus distribution circuit breakers and the essential AC circuit breakers. Ground handling bus circuit breakers are on P-14.

The main AC busses are divided into three segments designated W, X, and Y. The W and Y segments are distributed to loads throughout the airplane, the X segment feeds into the cockpit at lower P-6.

P-6 CIRCUIT BREAKER PANEL

The P-6 circuit breaker panel in the cockpit is divided into lower, main, and aft sections. P-6 contains circuit breakers which may require ready access in flight.

Lower P-6 circuit breaker panel contains section X circuit breakers to supply main P-6, radio bus circuit breakers, generator meter circuit breakers, and the essential circuit breakers.

Main P-6 contains circuit breakers for AC busses 1,2,3, and 4, essential AC, standby AC and DC, hot battery, and battery busses. Smoke viewing ports and internal lighting are provided for viewing inside P-6.

Aft P-6, on the lower outboard end of the main P-6 panel, contains the primary battery and hot battery bus circuit breakers and transformer rectifier (TR) circuit breakers. This panel is accessible near the crew service door.

P-12 CIRCUIT BREAKER PANEL

The P-12 panel, in the cockpit ceiling, contains the circuit breakers for DC1, DC2, DC3, and essential DC busses.

P-7 CIRCUIT BREAKER PANEL

The P-7 panel, in the cockpit ceiling, contains the circuit breakers for essential radio, essential flight instruments, radio bus number 2, flight instrument bus number 2, and standby AC and DC.

PANEL LIGHTING CIRCUIT BREAKERS

Circuit breakers for panel lighting are under cover plates at the captain's and first officer's ash trays, in the aft pedestal, and under the engineer's table.

The captain's instrument panel and the autopilot panel lights are powered through three circuit breakers under the captain's ash try. The first officer's instrument panel lights are powered through two circuit breakers under the first officer's ash tray. Two circuit breakers for the center instrument panel and two circuit breakers for the pedestal lights are under the VHF control heads. An additional 20 circuit breakers are in the electrical cabinet under the engineer's table. These circuit breakers provide protection for lights at the engineer's station.

MAIN AND APU BATTERIES

The main and APU batteries are identical. The main battery and the associated battery charger are on the cockpit floor, outboard of the engineer's station. The APU battery is in the unpressurized tail section of the airplane. The associated charger is in a rack above the left rear coat closet.

The batteries are 28V, 36 ampere-hour nickel cadmium type. Integral to each battery is a thermal switch that disconnects the battery charger if the battery overheats. The APU battery charger is disconnected during APU start.

The battery switch is normally carried in the on position. However, the main battery is not connected to the battery bus unless essential DC is unpowered.

Main battery voltage and amperage are monitored by pressing the DC meters BATT selector switch. The APU battery is monitored by pressing the APUBATT switch. Battery charging is indicated by a negative indication on the ammeter.

With the battery switch on, both batteries are available for starting the APU.

The APU battery is used to operate the APU air inlet door, APU starter, and to power the APU control circuits. The APU battery is available for APU circuit operation only when the main battery switch is on. The APU will shutdown if the battery switch is placed off.

The main battery is used for operating the APU fuel valve and APU DC fuel pump.

The APU battery has an electric heater blanket with thermostatic control to keep it at a temperature above freezing.

AUXILIARY POWER

Auxiliary power is provided by one APU generator or dual ground power units through external connections. Control of auxiliary power is by two bus power control units.

BUS POWER CONTROL UNIT

The bus power control unit (BCU) provides for APU generator, external power, and sync bus protection. The BCU provides power to open or close the APU generator field relay (GRF), APU generator relay (AGR), the external power relay, and the split system breaker. It also activates fault lights on the APU generator section of the electrical fault enunciator panel. There are two BCUs, one for each side of the sync bus.

The BCU has three power sources: External power, APU generator, or the battery bus. Using external power, a white AC CONN light at the engineer's panel comes on when the BCU senses correct voltage and frequency. The BCU also provides control power to connect external power to the sync bus and to turn on its associated green PWR ON BUS light.

The split system breaker will automatically open when both external power sources are connected to the sync bus. When using a single external power source, the BCU will allow the SSB to be closed since it senses that the other half of the sync bus has no power. Any AC load on the aux power sources will be indicated on the aux power AC amp meters. Aux power loads above 250 amps will automatically trip off all galleys connected to the source.

APU GENERATOR

The APU generator is available when the APU is running at normal speed (100% rpm) and the field relay is closed. The APU generator can power all the AC busses. KAPU generator output can be checked for normal 400 Hz and 115 volts AC power by pressing the APU GEN 1 AC meter selector switch. The generator is air cooled by air drawn by a fan from the APU inlet duct and vented overboard. The APU generator automatically powers the ground handling bus and can be selected to ground service or to the sync bus by use of the AGR.

The APU generator cannot be synchronized with the engine generators. Closing the AGR when the engine generators are powering the sync bus will trip the engine main generator relays. Conversely, closing an engine MGR when the APU generator is powering the sync bus will trip the APU AGR and GRF.

When using the APU generator, the AGR will open automatically when the APU is below 95 percent rpm. The APU GFR will open if a generator malfunctions. When an APU GFR trips, the AGR also trips.

APU GENERATOR POWER DISTRIBUTION

The APU generator can be connected to the sync bus by closing its AGR switch. The adjacent GEN OPEN light will go out when the relay closes.

The AGR switch for the APU generator is a three-position switch with the following positions:

CLOSE	--	Connects the generator to the sync bus. This position is magnetically latched.
OFF	--	Disconnects the generator from the ground service or sync bus.
GRD SERV	--	Connects the generator to the ground service bus. This position is magnetically latched.

The SSB must be closed for the APU generator to power the right half of the sync bus.

EXTERNAL POWER

There are two external power receptacles. They are located aft of the nose wheel well on the right side of the airplane. Ext pwr 1 is the aft receptacle and ext pwr 2 is the forward receptacle. When external power is connected to the airplane, the associated AC CONN light at the engineer's panel illuminates to indicate that the ground power unit is connected to the airplane and that voltage and frequency are within limits.

The voltage and frequency of the external power source(s) can be read by pressing the appropriate EXT PWR AC meter selector switch.

The AC CONN light is controlled by the BCU. When the AC CONN light is on, external power is available for connection to the sync bus from the respective external power source.

The ext pwr 1 control switch is a three switch similar in function to the APU gen 1 switch.

Ext pwr 2 has a two position momentary switch with the following positions:

CLOSE	--	Connects external power to the sync bus. This position is magnetically latched.
OFF	--	Disconnects external power from the sync bus.

After external power is connected to the sync bus by closing the external power control switch(es), the green PWR ON BUS light(s) will come on. If the second ext pwr switch is closed, the SSB will automatically open and the SSB OPEN light will come on. The SSB cannot be re closed when both the ext pwr sources are connected to the sync bus.

GROUND HANDLING BUS

The ground handling bus provides power for the cargo compartment doors, cargo loading equipment, and the electric hydraulic pump in system 4. It can be powered only when the airplane is on the ground and ext pwr 1 or APU gen 1 is available. There is no switch provided for this bus. It is powered automatically when the ext pwr 1 AC CONN light comes on or when the APU generator is operating with its field relay closed.

AC METERS

A single AC voltmeter and a single frequency meter are used for all engine generators, APU generator and external power. The source of voltage and frequency to be read is selected by eight interlocking and one momentary push button type switch. Normally these meters indicate voltage and frequency. When the GEN Test switch is held pressed, the AC voltmeter will indicate the permanent magnet generator voltage of the selected engine or APU generator and the CSD rpm for the selected engine generator will be indicated on the frequency meter. Since the APU generator does not have a CSD, it will indicate zero rpm when the Gen Tst switch is pressed. If the AC meters are selected to external power, they will indicate voltage and frequency. If Gen Test is pressed while selected to ext pwr 1 or ext pwr 2 the AC meters will read zero.

ENGINE GENERATOR POWER

GENERATORS

The main electrical power system consists of four 54 KW (60KVA) generators. The generators are driven a 8,000 rpm through constant speed drives on each engine. These brushless AC generators deliver three phase, 115/200 volts, 400 Hz electrical power. The generators may be operated isolated to supply their respective AC busses, but normally are operated in parallel through the sync bus.

Each engine-driven generator is controlled by three switches on the engineer's panel. Amber lights indicate when associated relays are open. All three relays have automatic tripping features.

All generators, including the APU generator, are identical. Each generator consists of a permanent magnet generator (PMG) and a main three phase electro-magnetic generator. The PMG supplies control power when the generator is rotating.

Cooling of the engine generators is accomplished by ducting engine fan air through the generator and overboard.

GENERATOR CONTROL UNIT (GCU)

Each generator is controlled by a generator control unit (GCU). The GCU converts PMG voltage through a voltage regulator into control power for generator relay operation and field excitation.

The four control units are powered primarily by the PMG in each engine generator so that the generator is capable of functioning any time it is rotating at proper rpm. An alternate power source for the GCU is provided from the battery bus so that certain control functions will operate when the generator is not rotating. The battery bus supplies power for generator relay indicator lights and for the trip and close functions of the GFR and BTR.

The GCU can automatically trip all generator relays. On engine shutdown, only the main generator relay trips when the control unit senses CSD underspeed.

When the GCU senses an abnormal condition, the generator field relay, main generator relay, and/or the bus tie relay trip. If the GCVU senses a generator voltage problem, it trips the bus tie relay, then the field and main generator relays. The bus tie relay then automatically recloses to protect the AC bus. If an AC bus short is sensed, all relays on that generator will trip and remain open.

CONSTANT SPEED DRIVE (CSD)

The constant speed drive (CSD) is on the aft side of the N2 gear box. It drives back through the N2 gear box to the AC generator which is on the forward side of the drive case. The CSD maintains generator speed at 8,000 rpm.

A speed governor controls CSD speed. If an overspeed or underspeed condition occurs, the governor trips the main generator relay to protect the bus.

The CSD PRESS light comes on when oil pressure is low. On some aircraft, a CSD OIL light is installed. The light comes on at approximately oil temperature red line. If the light comes on and a temperature problem is not indicated, the warning should be considered as a low pressure indication.

The CSD oil temperature indicator normally indicates oil out temperature, usually between 70C and 80C. Pressing the CSD oil temp rise switch causes all CSD oil temperature indicators to display the oil temperature increase as it passes through the CSD. This is the difference between oil in and oil out temperature. Normal oil temperature increase through the CSD is less than 10 C. If rise is normal and in is high, a problem in oil cooling is indicated.

To disconnect a malfunctioning CSD place the guarded disconnect switch to DISCONNECT. (**WARNING - A CSD CANNOT BE RECONNECTED IN THE AIR**).

GENERATOR FIELD RELAY (GFR)

The generator field relay (GFR turns a generator on and off electrically by controlling the excitation current from the GCU. When the relay is tripped, the adjacent FIELD OFF light comes on.

MAIN GENERATOR RELAY (MGR)

The main generator relay (MGR) connects the generator to the respective AC bus. When the relay is tripped, the adjacent GEN OPEN light comes on.

When the MGR is open, the generator is disconnected from the associated bus. The MGR can be closed only when the GCU senses the generator is up to speed, voltage normal, and either a autoparallel or dead bus conditions exist. With the MGR closed, the bus is powered, and the KW meter indicates the generator KW load.

BUS DTIE RELAY (BTR)

The bus tie relay (BTR) connects the associated generator and AC bus to the sync bus. Control is through the bus tie relay control switch. When the relay is tripped, the adjacent BUS TIE OPEN light comes on.

With all MGRs and BTRs closed and the generators paralleled, KW meters should indicate equal values. When the KVARs (kilovolt-amperes reactive) switch is pressed, all KW meters switch to indicate the KVAR load for each generator. When the generators are paralleled, KVAR indications should be equal.

AC BUSSES

AC busses 1,2,3, and 4

Power from each AC bus is primarily distributed from three locations: P-6 in the cockpit and P-14 and P-15 in the E and E compartment. They can be powered by the associated engine generator or by any generator through the sync bus and associated bus tie relays.

SERVICE BUS

The service bus provides complete airplane servicing capability without energizing the entire electrical system. The service bus is a subdivision of AC bus 1. It can be powered independently of AC bus 1 by either the ext pwr 1 or APU generator when their respective switches are selected to GRD SERV.

ESSENTIAL AC BUS

AC bus 4 normally powers the essential AC bus. The essential AC bus can also be powered directly from generators

1,2, or 3. When the APU generator or an external power source is used, AC bus 4 powers the essential AC bus through the sync bus.

ESS BUS OFF red lights at the engineer's panel and on the center instrument panel indicate loss of power to the essential AC bus.

ESSENTIAL AC BUS SELECTION

AC bus 4 powers the essential bus when the essential AC bus selector switch is in NORMAL. An engine generator powers the essential AC bus directly when the essential AC bus selector switch is positioned to GEN 1,2,or3. When selected to any GEN position, and the associated MGR is open, only the essential bus load is indicated on the KW meter.

DC POWER

The 115V AC busses provide primary DC power to the DC busses through transformer rectifier (TR) units.

Four TR units supply DC power to DC busses 1,2,3, and essential. A fifth TR unit supplies 28V DC power to the ground handling bus from the APU generator or ext pwr 1.

The essential DC bus is the primary source of power to the battery bus. When essential DC is not powered, the battery bus automatically transfers to the hot batter bus if the battery switch is on. Certain priority loads that require DC power under all conditions are supplied from the hot battery bus.

The battery is normally connected to the main battery charger and hot battery bus. The battery charger is powered by the service bus. The charger is automatically disabled if the battery overheats.

With all main AC busses powered, all DC busses are powered by their associated TR units.

DC power from the main battery and the four TR units is delivered to the main DC circuit breaker panel on aft P-6 Power from the four TR units is then distributed from circuit breakers on aft P-6 to four DC busses on P-12.

DC BUSSES 1,2,3 AND ESSENTIAL

Circuit breaker protection for DC busses is on P-12. Each bus is powered through a 75 amp TR unit. The TRs operate independently or in parallel through isolation relays.

DC meter selector switches connect any DC bus and associated TR to a voltmeter and ammeter. When a TR selector switch is pressed, the associated bus voltage and TR amps are indicated. A voltage indication means the bus is powered. A positive amperage indication means the TR is supplying power. Zero amps would indicate an inoperative TR unit. When all TRs are paralleled, a bus indicates normal voltage, even though its associated TR is inoperative. This occurs because the voltage reading is taken at the bus.

DC ISOLATION CONTROL SWITCHES

DC busses may be operated isolated or in parallel. DC busses are isolated by placing DC bus isolation switches on the engineer's panel to OPEN. With the switch in open, a green light comes on. When all DC isolation switches are open, each TR unit powers its associated DC bus.

When all DC isolation relays are closed, any TR can power the essential DC bus.

BATTERY BUS

The battery bus is normally powered by the essential DC bus. The main battery provides a secondary source of power for the battery bus. This backup feature occurs automatically with the loss of essential DC, if the main battery switch is on.

HOT BATTERY BUS

The hot battery bus contains emergency circuits and is powered directly from the battery regardless of the battery switch position.

RADIO AND FLIGHT INSTRUMENT BUSSES

The radio and flight instrument bus circuit breaker protection is on P-7. The essential radio bus and essential flight instrument bus are powered by essential AC and DC busses. Radio bus number 2 and flight instrument bus number 2 are powered by the number 2 AC and DC busses.

FLIGHT INSTRUMENT BUSSES

The flight instrument busses power equipment such as autopilot/flight director computers, INS systems, and air data computers. The flight instrument busses are powered when their associated AC and DC busses are powered.

RADIO BUSSES

The radio busses power equipment such as ADF, marker beacon, weather radar, and communications radios. When the radio master switches are on, the radio busses are powered from their associated AC and DC busses.

RADIO PRIORITY BUS

The radio priority bus consists of the passenger address system, main interphone, standby horizon, and number 1 VHF communications radio. Power for these items is provided by three DC busses. The battery bus normally powers the PA, main interphone, and standby horizon. The standby DC bus normally powers the number 1 VHF communications radio. In the event of a complete loss of all AC power or in a situation where the airplane is parked with the battery and standby power switches off, the hot battery bus powers the radio priority bus when the essential radio master switch is on.

STANDBY POWER

STANDBY BUSSES

The standby AC and DC busses are normally powered by the essential AC and DC busses. With the loss of essential AC, the main battery can be used to provide an alternate source of power to the standby AC and DC busses.

STANDBY POWER SWITCHES

The standby power switch, in the center of the pilot's overhead panel, is normally in the off position. When the standby power switch is on, the battery bus activates a standby inverter. The standby inverter is powered by the essential DC bus or the hot battery bus.

The standby inverter converts the 28V DC hot battery bus or essential DC bus power to 115V AC to supply the standby AC bus.

The standby power switch also connects the hot battery bus to supply the standby DC bus.

Circuit breaker protection is on P-6 and P-7 and includes: standby ignition, nacelle anti-ice, N1, EGT, number 1 VHF, number 1 VOR/GS, interphone, PA, compass number 1, and the captain's ADI and HSI instrument power.

GALLEY POWER

The galleys are designated A through E and upper deck. Galley power switches on the engineer's panel control power to the galleys from the main AC busses. These switches are labeled bus 1, 2,3, and 4.

The galleys are powered as follows:

AC Bus 1	--	Galley C
AC Bus 2	--	Galleys A and E.
AC Bus 3	--	Galley B
AC Bus 4	--	Galley D and upper deck.

GALLEY POWER TRIP OFF PROTECTION

Each AC bus powers its galley(s) through a galley electrical load control unit This unit also provides overload protection. An amber TRIP OFF light below each galley power switch comes on if power is removed from the galley(s) due to an overload. Galley power trips off for one of the following reasons:

One TRIP OFF light	--	An overload or short in the galley feeder cables.
Two or more TRIP OFF lights	--	The current demand from an APU generator or an external power source has exceeded 250 amps. All galleys powered by the overloaded aux power source trip off to reduce the electrical load.

All galley trips can be reset after the problem has been corrected by cycling the associated galley power switch(es) to OFF and ON.

MAIN AND APU GENERATOR FAULT ANNUNCIATOR LIGHTS

The purpose of the fault enunciator lights on the engineer's panel are to indicate a faulty component that caused the generator relay(s) to trip. A light is on only when the READ switch is pressed after a fault has occurred.

MAIN GENERATOR FAULT ANNUNCIATOR LIGHTS

These lights come on if a single or combination of engine generator field, MGR, or bus tie relay(s) trip. The significance of the lights is as follows:

GEN	--	An overvoltage or undervoltage of the engine generator.
GEN CONT UNIT	--	An overexcitation or under-excitation of the engine generator or a faulty generator control unit.
CONST SP DR	--	Abnormal CSD speed or a faulty CSD speed sensing switch. This light also comes on when the CSD is operating normally but the associated N2 indicator is inoperative.
LOAD CONTROL	--	A faulty load control unit.
GEN/FEEDER	--	An open phase or short in the engine generator, generator feed lines or AC bus.

APU GENERAATOR FAULT ANNUNCIATORS

These fault lights come on if an APU generator relay, external power relay or combination split system breaker and multiple bus tie relays trip. The significance of these lights are as follows:

GEN	--	An overvoltage or under-voltage trip of the APU generator.
BUS POWER UNIT	--	An overexcitation or under-excitation of the APU generator or a faulty bus control unit.
GEN/FEEDER	--	A short in the APU generator, APU generator feeder lines or the sync bus.

V. PERFORMANCE

MAXIMUM WEIGHTS (LBS.)

TAXI	738,000
BRAKE RELEASE	734,000
LANDING	564,000
ZERO FUEL	526,500

SPEEDS

MAX OERATING

SEA LEVEL 378 KTS IAS
24,000 392 KTS IAS, .92 MACH
MACH/AIRSPEED WARNING Vmo+3 MMO +.01
LANDING GEAR OPERATING SPEED 270 KTS IAS, .82 MACH
LANDING GEAR EXTENDED SPEED 320 KTS IAS, .82 MACH
TURBULENCE PENETRATION 280-290 KTS IAS, .82 - .85 MACH
ALL LEADING EDGE FLAPS EXTENDED 240 KTS IAS

STALL SPEEDS
(AT MAXIMUM TAKEOFF WEIGHT)

FLAPS 0 - 195 KTS IAS
FLAPS 5 - 147 KTS IAS
FLAPS 10 - 144 KTS IAS

(AT MAXIMUM LANDING WEIGHT)

FLAPS 0 - 171 KTS IAS
FLAPS 5 - 126 KTS IAS
FLAPS 10 - 144 KTS IAS
FLAPS 25 - 114 KTS IAS

FLAP EXTENSION SPEEDS

1	265 KTS IAS
5	240 KTS IAS
10	225 KTS IAS
20	200 KTS IAS
25	170 KTS IAS

OBSTACLE CLEARANCE CLIMB SPEEDS

3 ENGINE	V2 + 80 KTS TO 15,000 FT
2 ENGINE	V2 + 80KTS

VI. FLIGHT 800 INFORMATION

Normal operation of the air conditioning packs on the ground in accordance with TWA procedures is two of the three packs. According to information gathered during the investigation, two packs were operated on the ground at JFK. On this ground operation, the packs were being operated by the APU.

Investigation provided information that three packs were in operation at the time the accident.

Based on a first segment cruise altitude of 37,000 feet (flight level 370), the calculated differential pressure at the time of the accident was 3.5 psi.