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WASHINGTON, D.C.

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT

by

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NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

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POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

NTSB ID No.: DCA96MA070

A. ACCIDENT

Location: East Moriches, New York

Date: July 17, 1996

Time: 2031 eastern daylight time (EDT)

Aircraft: Boeing 747-131, N93119, Trans World Airlines, Flight 800

B. POWERPLANTS GROUP

Gordon J. Hookey Group Chairman	National Transportation Safety Board Washington, D.C.
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C. SUMMARY

On July 17, 1996, at about 2031 eastern daylight time (EDT), a Boeing 747-131 airplane, N93119, operated by Trans World Airlines (TWA) as flight No. 800, crashed into the Atlantic Ocean, south of East Moriches, New York. The airplane experienced an in-flight explosion and break-up before it crashed into the ocean. The airplane was operating on an instrument flight rules (IFR) flight plan under the provisions of Title 14 Code of Federal Regulations (CFR) Part 121 as a regularly scheduled flight from John F. Kennedy International Airport, Jamaica, New York (JFK) to Charles de Gaulle Airport, Paris, France. The 230 passengers and crew members on board were fatally injured.

The four engines were recovered from the Atlantic Ocean by the U.S. Navy's USS Grasp and Grapple under the direction of the U.S. Navy Supervisor of Salvage. After the engines were recovered, they were transported to the former Grumman facility at Calverton, New York, for disassembly. The disassembly of the engines commenced on August 12, 1996, in the presence of the Powerplants Group. The disassembly was completed on August 16, 1996.

The disassembly of the engines consisted of removing the cowling, external components, fan, and low pressure compressor (LPC) to expose the high pressure compressor (HPC), diffuser, combustor, high pressure turbine (HPT), low pressure turbine (LPT), and turbine exhaust cases. Engine No. 3 was disassembled further to remove and partially disassemble the HPC. The disassembly of the engines did not show any indications that any of the engines had sustained any uncontainments, case ruptures, fires, or penetrations. The inlet cowlings, fan blades, and LPC blades for all four engines were examined with an ultraviolet light, or black light, and none of the surfaces examined fluoresced.

Fuel samples that were collected from the four engines during the disassembly, in addition to a fuel sample that was drained from a TWA 747 that had arrived from Athens, Greece, were analyzed by Saybolt, a petrochemical laboratory in Kenilworth, New Jersey, on October 17, 1996. The analysis showed that the fuel from the engines of flight 800 had a flash point of 123^{o}F and the fuel from the flight from Athens had a flash point of 114^{o}F. Both of the flash points conformed to the specifications for jet fuel manufactured in the United States and Europe, respectively.

A fuel sample that had been collected from the JFK fuel supply system immediately following the crash of flight 800, and some of the fuel sample that had been drained from the TWA 747, which had arrived from Athens, were analyzed by Saybolt, on December 17, 1996, for electrical conductivity. The electrical conductivity readings for the fuel samples were 90 picosiemens per meter (pS/m) for the fuel from Athens and 0 pS/m for the fuel from JFK.

D. DETAILS OF INVESTIGATION

1.0 Engine Information

1.1 Engine History

The Boeing 747-131 airplane, N93119, was equipped with four Pratt & Whitney (P&W) JT9D-7AH engines. The engines were installed on the airplane as follows:

POSITION	TWA NO.	SERIAL NUMBER	TOTAL TIME	TOTAL CYCLES	DATE INSTALLED
1	4293	662209	47,989	9,684	12/31/95
2	4151	662593	80,884	14,609	12/6/95
3	4133	662426	80,336	14,632	6/18/96
4	4142	662463	77,061	14,016	5/11/96

TWA provided a copy of the list of serial numbers of the modules on the installed engines. Those serial numbers were used to identify each of the four engines as each was recovered. A copy of the list of module serial numbers that TWA provided is attached.

For more detailed information regarding the engines' history, refer to the Maintenance Records Group Chairperson's Factual Report of Investigation.

1.2 Engine Description

The P&W JT9D-7AH engine is a dual spool, axial flow high bypass turbofan that has a 1-stage fan, 3-stage low pressure compressor (LPC), 11-stage high pressure compressor (HPC), annular combustor with 20 fuel nozzles, 2-stage high pressure turbine (HPT), and a 4-stage low pressure turbine (LPT). The fan and LPC, and the HPC are interconnected with drive shafts to the LPT and the HPT, respectively. The JT9D-7AH turbofan engine has a normal takeoff thrust rating of 46,150 pounds, flat-rated to 80^{o}F.[1]

2.0 Engine No. 1 Serial Number (SN) 662209

2.1 Pylon

The pylon was still attached to the engine. The recovered piece of pylon was the structure between the forward and aft engine mounts. The pylon did not have any indications of any fire damage, sooting, or penetrations. Examination of the ends of the wires on the pylon by the on-site National Transportation Safety Board metallurgist did not disclose any indications of arcing.

2.2 Nacelle

Two pieces of the inlet cowling, each about 90 to 100° in circumference, were recovered, separated from the engine at the fan case forward flange, "A" flange.[2] The full length of the inlet cowling was crushed on the bottom, centered around the 5:30 to 6:00 location.[3] The outer diameter (OD) lip of the inlet cowl was crushed on the bottom, but retained its shape for the remainder of the circumference. The cowling structure and the inner diameter (ID) and OD skin on the fractured ends of the cowling were peeled back towards the top of the cowling.

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[1]Flat-rated to a specific temperature indicates the engine will be capable of reaching the rated thrust level up to the specified temperature.

[2]Gas turbine engine industry convention is to identify the engine case flanges alphabetically from front to rear. A copy of a cross section of the JT9D engine with the flange locations identified is attached.

[3]All locations on the engine, or direction, as referenced to the clock are as viewed from the rear, looking forward, unless otherwise specified.

The painted OD surface of the cowling and the acoustic liner of the inlet duct did not have any indications of sooting. The engine cowling did not have any indications of any penetrations or damage from a fractured fan blade.

A portion of the outboard fan cowl, which was tagged has having been recovered floating on the surface, had fire damage on the interior and exterior surfaces about 2-feet in diameter on each side.

Three of the four thrust reverser actuators were recovered. All had the jackscrew drives at the forward end of the jackscrews, which is the stowed position.

2.3 Fan

The fan case was intact, although it was twisted and ovalized from the bottom. There were no indications of any containment challenges or penetrations through the fan case. The fan rub strip was almost completely missing from 3:30 to 8:00, with only intermittent sections of the forward edge and one section of the rear of the of rub strip remaining. The fan rub strip was rubbed down to the fan case wall, with metal to metal contact with the fan blades, from 4:30 to 7:00. There were no apparent new rub marks on the rub strip from about 9:00 to 10:00. The rub strip had a series of impact marks of the fan blade tips spaced at about 6 1/2-inch intervals from about 4:00 to 8:00 and 11:00 to 1:00. The fan blade tip stagger is about 6 1/2 inches. The front and rear edges of the fan blade rub marks on the rub strip were axially located aft of "A" flange as follows (all dimensions are in inches):

LOCATION	FRONT	REAR
12:00	1 3/16	5 7/16
3:00	1 3/16	5 3/4
6:00	1 3/16	NA
9:00	1 3/16	5 3/16

NA: Not available. The rear dimension at the 6:00 location was not obtainable because the rubstrip material was missing.

The fan hub was intact and still attached to the low pressure turbine (LPT) shaft.

Of the 46 fan blades installed in the fan rotor, 31 complete airfoils were recovered, either intact or fractured. There were 15 fan blade roots recovered, some of which had sections of airfoil. The broken airfoils were fractured at various lengths from just above the blade root platform to just outboard of the mid span shrouds. The fan blades that were oriented towards the bottom of the engine were fractured transversely across the airfoil just above the blade root platforms. The other blades in the clockwise and counter-clockwise directions from the bottom of the engine were full length and bent over towards and away from the direction of engine rotation, respectively. The fracture surfaces on the fractured fan blades were not remarkable. The leading edges (LEs) and trailing edges (TEs) of the fan blades were undamaged except for some randomly located impact damage. The fan blade tips were blackened at the very end and most of the blades had a gold tint at the convex LE tip under the blackened area and along the full chord length on the concave side from contact with the fan case rub strip.

The fan exit case struts were all fractured transversely about 3 to 4 inches from the intermediate case, except for the strut at the 1:30 location, which was fractured transversely about 17 inches outboard of the intermediate case. The thrust yoke was intact and attached to the rear mount, but was separated from the left and right forward attachments.

2.4 Low Pressure Compressor

The LPC case was crushed from the bottom and did not have any indications of any uncontainments or penetrations. The second, third, and fourth stage compressor disks were intact. Almost all of the compressor airfoils were full length, with about a 150^{o} arc of blades that were bent over away from the direction of rotation. The blades did not have any damage to the leading or trailing edges.

2.5 High Pressure Compressor

The HPC cases were crushed inward from about 3:30 to 8:00 and were separated at the HPC case split line flange, "J" flange. The cases did not have any indications of penetrations or uncontainments. The rear HPC case had a 4 ½-inch long axial fracture from the rear flange at about 7:30 that "teed" to a circumferential fracture that ran from the 4:00 to 8:00 location.

The HPC inlet guide vanes (IGVs) were in the closed position, except for a sector of nine adjacent vanes at the 7:00 location that were rotated to nearly perpendicular to the engine centerline. The IGVs were lightly sooted on the inner half of the airfoil on the convex and concave surfaces.

The fifth stage compressor blades, which were visible through the HPC IGVs, had the blade tips curled into the direction of rotation and had nicks on the LE near the tips. The eighth stage compressor blades, which were visible through the ninth stage compressor bleed port at 9:00, were bent over away from the direction of engine rotation adjacent to the blade root platform.

2.6 Diffuser/Combustor

The diffuser and combustor cases were crushed inward from about 3:00 to 7:00. The diffuser case was fractured circumferentially from about the 3:00 to 9:00 location, just forward of the fuel nozzle mount pads. The diffuser case rear skirt and combustor case were fractured axially at 4:00. The upper right portions of the cases, from about 12:30 to the fractured ends, were bent up almost vertically against the pylon. The lower portions of the cases were pushed inward against the combustor liner. The fracture surfaces on the diffuser and combustor cases were examined by the on-site Safety Board metallurgist and determined to be rapid tensile overload type fractures with no indications of fatigue. There was no apparent indication of heat distress on the inner surfaces of the cases. The center of the boss plug at the 6:00 location was missing, with the fracture surface oriented towards the OD. The cases did not have any penetrations.

The combustor liner was crushed flat against the inner combustor case on the bottom and lower right side of the engine. The liner did not have any metallization or indication of any thermal distress.

The fuel nozzles and external fuel manifolds did not have indication of fire damage. The backs of the fuel nozzles did not have any metallization.

2.7 High Pressure Turbine

The high pressure turbine (HPT) case was intact and did not have any uncontainments or penetrations.

The first and second stage turbine blades were fractured at about mid span and bent over away from the direction of engine rotation adjacent to the blade root platforms. The first and second stage turbine vanes had nicks and dents to the leading and trailing edges and the vanes at the bottom of the case were crushed. The HPT airfoils did not have any metallization.

2.8 Low Pressure Turbine

The LPT shaft was intact. The shaft was bent about 29-inches aft of the spacer face reference just aft of a 3 1/4-inch long (axial) x 7-inch wide (circumferential) rub from the sixth stage compressor hub bore ID. The shaft also had two localized rubs at 24 ½- to 26 ½- and 77- to 79 ¾-inches aft of the spacer face. The shaft had two 360^o circumferential rubs at 13 ½- to 15-inches aft of the spacer face and on the front OD face of the bell flare at the rear of the shaft.

The LPT case was fractured circumferentially 360^o around between the plane of the second stage turbine rotor and the third stage turbine vane front lugs. The forward portion of the LPT case remained bolted to the HPT case and the aft portion was bolted to the turbine exhaust case (TEC). The front and rear portions of the LPT case did not have any indications of uncontainments or penetrations.

The third, fourth, and sixth stage turbine disks and the fifth stage turbine hub were intact. The fourth stage turbine disk rim was bent rearward in line with the section of the LPT case that was crushed. The fifth stage hub and sixth stage turbine disk, which were recovered several weeks after the engine, also had the rims bent rearward for a similar arc length as the fourth stage turbine disk rim.

All of the third stage turbine blades remained in the disk. About half of the blades, in a continuous arc with the exception of a cluster of four blades and one single blade, were fractured transversely at various lengths that ranged from adjacent to the blade root platform to about mid span. The intact third stage blades were all full length and had very little damage to the leading and trailing edges. Of the 110 fourth stage turbine blades, 81 remained in the disk. There was a 180^o arc of fourth stage blades that were full length, except for a continuous sector of 13 blades in the center that were fractured at varying lengths from adjacent to the blade root platform to about mid span. The blades that were full length had very little damage to the tip shrouds and to the leading and trailing edges. The other blades that were broken were fractured transversely across the airfoil adjacent to the blade root platform. About half of the blades in the fifth stage turbine hub and sixth stage turbine disk remained in the blade slots and all were fractured transversely across the airfoil just above the blade root platforms. There was no metallization on any of the LPT airfoils.

2.9 Exhaust

The TEC was fractured axially at the 10:00 location and the fractured ends were opened outward away from the engine center line. There was an axial fracture at the 4:00 location and the case wall pieces remained attached to the case by the mount rails. The TEC was crushed up against the turbine exhaust inner duct, which was also crushed. The case rails on the bottom of the case were separated from the walls and pushed rearward. The two bottom turbine exhaust struts were folded over. The other struts remained attached to the inner duct, although all were bent and partially torn from the inner standup welds and completely separated from the outer case wall. The turbine exhaust case and duct walls and turbine exhaust struts did not have any indications of any uncontainments or penetrations.

The No. 4 bearing housing was still in the turbine exhaust duct (inner case). The bearing compartment cover was in place and did not have any penetrations. The No. 4 bearing cage was intact, although all of the bearing rollers were missing from the cage pockets. One roller was found loose in the No. 4 bearing housing sump. The roller and outer race did not show any indication of rotational distress.

3.0 Engine No. 2 SN 662593

3.1 Pylon

The pylon was separated from the engine, although it was recovered and returned to the Grumman facility with the engine. The right side of the pylon had crushing damage with the skin pushed inward around the internal structure. The skin on the lower left side of the pylon was bent outward. The pylon did not have any fire damage, sooting, or penetrations. The ends of the wires in the pylon were examined by the on-site Safety Board metallurgist and there was no indication of arcing noted.

The engine mounts had separated from the engine and remained attached to the pylon.

3.2 Nacelle

Two large pieces of the inlet cowling, each about 90 to 100^{o} in circumference, were recovered. These pieces had separated from the engine at the fan case front flange, "A" flange. The full length of the right side of the inlet cowling, centered around 3:30, was crushed. The OD lip of the inlet cowl was crushed on the right side, but retained its shape for the remainder of the circumference. The ID and OD skin on the fractured ends of the cowling were peeled back towards the left side of the cowling. The painted OD surface of the cowling and the acoustic liner of the inlet duct did not have any indications of sooting. The recovered portions of the inlet cowling did not have any indications of any penetrations or damage from a fractured fan blade.

All four of the thrust reverser actuators were recovered. All had the jackscrew drives at the forward end of the jackscrews, which is the stowed position.

3.3 Fan

The fan case was fractured axially at about the 6:30 location. The case was crushed from the right side from about the 12:00 to 6:00 location. Sections of the fan exit case, thrust reverser ring, forward engine mount, and front section of the pylon remained attached to the fan case. The fan case did not have any indications of any containment challenge or penetrations. The fan rub strip material was almost completely missing from about 12:30 to about 6:30. Within this arc, there were indications of metal-to-metal contact between the blade tip and the fan case ID wall at 3:30 and 6:30. Also, within the 12:30 to 6:30 arc, the rub strip was rubbed down to below the bottom of the axial skewed groove (ASG) pockets, though not down to bare metal, between 4:00 and 6:00. There was a separate rub, which was out of the fan plane of rotation, through the rub strip down to the case wall from 9:00 to 10:00, and the rub intersected the fan case rub strip forward retaining lip, causing a burr on the lip from 10:00 to 11:30. The front and rear edges of the fan blade rub marks on the rub strip were axially located aft of "A" flange as follows (all dimensions are in inches):

LOCATION	FRONT	REAR
12:00	0	5 1/2
3:00	NA	NA
6:00	1 11/16	NA
9:00	7/8	6 1/8

NA: Not Available. The front and rear dimension at 3:00 and the rear dimension at the 6:00 location was not obtainable because the rubstrip material was missing.

The fan hub was intact and still attached to the LPT shaft.

Of the 46 fan blades, 43 were recovered. The fan blades that were oriented towards the bottom of the engine were fractured transversely across the airfoil adjacent to the blade root platform. The fracture surfaces of the fan blades that were fractured were not remarkable. The other blades in the clockwise and counterclockwise directions from the bottom of the engine were full length and were bent over towards and away from the direction of engine rotation, respectively. The blades located on the left side of the engine were relatively straight and full length. The fan rotor had a few randomly located blades that had impact damage to the leading and trailing edges. All of the fan blades were rubbed on the convex side tip from the LE, aft about 1- to 2 ½- inches and from the tip inboard about ^{3}/8-inch. The fan case rub strip front retaining lip was approximately ^{3}/8-inches high. The concave side of the airfoil tip had a gold tint from the tip inboard about ^{5}/8-inch for the full chord length of the airfoil from contact with the rub strip.

The fan exit case had all but two of the struts broken off about 3-inches outboard of the case at the standup weld. The struts that remained on the case were at the bottom of the engine were full length and were buckled on the left side at the inner end.

3.4 Low Pressure Compressor

The LPC was crushed on the right side. There were no indications of any uncontainments or penetrations. The second, third, and fourth stage compressor disks were intact. The second, third, and fourth stage compressor blades were all in place and full length. The blades on the right side of the engine were bent over both towards and away from the direction of rotation. The other LPC blades were not bent.

3.5 High Pressure Compressor

The HPC cases were intact and did not have any indications of any uncontainments or penetrations. The HPC case split line flange, "J" flange was open on the right side. The HPC cases were crushed from 2:00 to 5:00.

The HPC IGVs were rotated so the airfoils were almost perpendicular to the centerline of the engine with the convex side facing forward. The inner half of the airfoils were lightly coated with soot.

The thrust yoke was fractured from the right side of the intermediate case, but remained attached at the left side and also to the rear mount.

3.6 Diffuser/Combustor

The diffuser and combustor cases were crushed inward from the 2:00 to 5:00 location. The diffuser case skirt had a 17-inch long circumferential split that was 4 1/2-inches forward of the diffuser case rear flange at the 8:00 location. The cases did not have any indications of ruptures, penetrations, or thermal distress. The center of the combustor case boss plug at the 6:00 location was missing with the fracture surface oriented towards the OD of the engine.

The fuel nozzles and external manifolds did not have any indications of fire damage. The backs of the fuel nozzles did not have any metallization.

3.7 High Pressure Turbine

The HPT case was intact and did not have any indications of uncontainments or penetrations.

The first and second stage turbine blades, which were visible through the separation between the combustor case and the HPT case, had the tips bent away from the direction of rotation. The visible HPT blades and vanes did not have any metallization on the airfoil surfaces.

3.8 Low Pressure Turbine

The LPT case was fractured circumferentially in the plane of the fourth stage turbine rotor. The rear portion of the LPT case remained bolted to the TEC. The LPT case did not have any indications of any uncontainments or penetrations.

The fourth and sixth stage turbine disks and the fifth stage turbine hub were intact, but the rims were bent rearward about 20 to 30^o over an arc of about 45^o that was centered around the 3:30 location.

The fourth stage turbine blades had a 90^o arc of blades that were fractured transversely across the airfoil at varying lengths. The remaining fourth stage turbine blades were all full length, although they had nicks and dents on the leading and trailing edges. About 50 percent of the fifth stage turbine blades and about 40 percent of the sixth stage turbine blades were intact with complete airfoils. The fractured fifth stage blades had all of the roots remaining in the disk and were fractured from just above the blade root platform to about 4 1/2-inches above the blade root platforms. The sixth stage turbine rotor had arcs of 17 and 31 blade roots with the airfoils fractured adjacent to the blade root platforms that were separated by a continuous sector of 11 blade slots that had only the rivets remaining in the slots. The rivets showed the blades had been pushed out from front to rear. The LPT airfoils did not have any metallization.

3.9 Exhaust

The TEC was crushed against the turbine exhaust duct from about 2:00 to 6:00. The turbine exhaust struts on the right side were folded over and telescoped into the strut. The four struts from about the 6:00 to 9:00 location were fractured transversely, alternately from the inner and outer standup welds.

The No. 4 bearing cage was intact, but six of the rollers were missing from the pockets. Two of the rollers were found in the No. 4 bearing sump. The rollers did not show any apparent rotational distress. The No. 4 bearing housing rear cover did not have any penetrations.

The exhaust duct was crushed almost flat from the right side from about 12:30 to 6:00. There was about a 2-foot long section of the turbine exhaust plug that was crushed flat in the turbine exhaust duct.

4.0 Engine No. 3 SN 662426

4.1 Pylon

The pylon remained attached to the engine. The recovered pylon structure extended from just aft of the fan struts to in-line with the turbine exhaust case mount rails on the left side of the pylon and two rib bays further aft on the right side and bottom. The nose section of the pylon was missing and the fractured upper skin on the pylon was bent upwards and towards the rear. The bottom of the pylon over the engine mount was buckled and the adjacent skin on the right side was buckled inward. The pylon did not have any indication of fire damage, sooting, or penetrations. The ends of the wires in the pylon were examined by the on-site Safety Board metallurgist and there was no indication of arcing noted.

The pylon was received with two Halon fire bottles, with the squibs attached, still installed. After the bottles were removed from the pylon, the squibs were removed, and the bottles and squibs were turned over to a bomb technician for storage in the on-site explosive ordinance (EOD) bunker.

4.2 Nacelle

The inlet was separated from the engine and broken into several pieces. A piece of the inlet support structure had a 3-foot section of the inlet lip that was crushed from impact on the front and bottom. The white-painted areas on the OD of the inlet were sooted. The inlet case did not have any indications of any penetrations or damage from a fractured fan blade.

One of the four thrust reverser actuators was recovered. The jackscrew drive was at the forward end of the jackscrew, which is the stowed position.

4.3 Fan

The fan case was intact and had very little deformation. The fan blade rub strip was in place and had a relatively uniform rub around the entire circumference. The rub strip was rubbed down to where the bottom of the ASG was visible for most of the circumference. The deepest rub into the rub strip was down flush to the bottom of the ASG from 4:30 to 7:00. The fan case did not have any indications of any containment challenges or penetrations. The front and rear edges of the fan blade rub marks on the rub strip were axially located aft of "A" flange as follows (all dimensions are in inches):

LOCATION	FRONT	REAR
12:00	1	5 7/16
3:00	1 5/16	5 1/2
6:00	1 5/16	5 11/16
9:00	1 1/4	5 1/2

The fan hub had a 360^o circumferential fracture in the web just outboard of the hub and the rim was completely separated from the hub. The rim section was recovered with the engine and the hub remained attached to the LPT shaft. The fracture surfaces on the hub and rim sections were not smeared. The rim section, which was a complete ring, had two fractures into the web: a circumferential fracture about 14 1/4-inches long and an "S"-shaped fracture that was about 9-inches long. A comparison of the fracture surfaces on the hub and the rim showed that some of the hub pieces were not recovered.

Of the 46 fan blades in the fan rotor, 21 blades with complete or partial airfoils and 6 root sections were recovered. All of the fan blades had sooting on the convex airfoil surfaces. Most of the full length airfoils were bent rearward and the tips outboard of the outer midspan shroud were bent forward slightly. About half of the fan blades had impact damage to the leading and trailing edges. Almost all of the impact damage to the airfoils could be matched to contact with the midspan shroud on an adjacent blade. One full length blade had four soft body impacts along the leading edge and a partial airfoil had a soft body impact, which had some streaking extending rearward. The fracture surfaces on the fractured fan blades were not remarkable. The fan blades had a very slight gold tint on the concave surface adjacent to the tips from rubbing the rub strip.

The fan exit case was intact. All of the fan exit struts were fractured transversely from the case about 2 1/2-inches outboard from the inner ring.

4.4 Low Pressure Compressor

The LPC was compressed axially so that the LPC hub was forced aft of the stub shaft. The LPC did not have any indications of any uncontainments or penetrations.

The second and third stage compressor disks were intact. The fourth stage compressor disk was fractured with the rim separated from the conical section. About half of the fourth stage compressor disk rim was missing.

The second stage compressor rotor was displaced rearward so that the second stage compressor blades were intermeshed with the second stage stator vanes. All of the second stage blades were pushed out of the slots, except for a group of 11 blades that had the tips curled towards the direction of engine rotation. All of the third stage compressor blades remained in the disk. Most of the third stage blades were bent over away from the direction of rotation, except for a continuous sector of 17 blades that were bent over towards the direction of engine rotation. The fourth stage compressor blades, which were in the piece of rim section that remained attached to the disk, were bent over towards the direction of engine rotation.

4.5 High Pressure Compressor

The HPC cases were crushed from the bottom. The HPC cases were separated at the split line flange, "J" flange. The HPC case had a 360^{o} circumferential fracture in line with the seventh stage compressor stator vane unison ring. The HPC cases did not have any indications of any uncontainments or penetrations. The thrust yoke was still attached to the front right and rear attachments, but was separated from the front left attachment.

The HPC IGVs were rotated so that the airfoils were almost perpendicular to the engine centerline with the convex side facing forward. The IGVs had sooting on the inner half of the airfoil surfaces. The HPC blades were bent over away from the direction of engine rotation.

4.6 Diffuser/Combustor

The diffuser and combustor cases were intact. The cases did not have any indications of any uncontainments, penetrations, or fire damage.

The external fuel nozzle manifolds did not have any indication of fire damage. The backs of the fuel nozzles did not have any metallization.

4.7 High Pressure Turbine

The HPT case was intact and did not have any indications of any uncontainments or penetrations.

4.8 Low Pressure Turbine

The LPT case was intact, but was crushed on the bottom and lower right side. The LPT case did not have any indications of any uncontainments or penetrations.

The fifth stage turbine hub and sixth stage turbine disk were intact. A 180^{o} arc of the fifth stage turbine blades, at the top of the engine, were full length. The fifth stage blades at the bottom of the engine were bent in both the clockwise and counterclockwise directions and fractured at various lengths. The sixth stage turbine blades had two sectors of 15 and 20 blades at 3:00 and 9:00, respectively, that were full length. The only other sixth stage turbine blades that remained in the disk were a group of eight blades, which were located on the lower right side of the engine, that were fractured adjacent to the blade root platform. The LPT airfoils did not have any metallization.

4.9 Exhaust

The TEC was separated from the LPT case, but was returned with the engine. The only piece of the TEC that remained attached to the LPT case was a section of the front flange and duct forward of the mount rail at the 9:00 to 1:00 location. The TEC did not have any indications of any penetrations.

The turbine exhaust duct was separated from the case, but was also returned with the engine. The No. 4 bearing was intact with all of the rollers in place. The rollers did not have any indication of rotational distress.

5.0 Engine No. 4 SN 662463

5.1 Pylon

The pylon had separated from the engine, although the engine mounts remained attached to the pylon. The pylon was crushed on the right side and was buckled inward in the center of the left side. The front of the pylon was crushed aft about 2 feet. The pylon did not have any indications of fire damage, sooting, or penetrations. The ends of the wires in the pylon were examined by the on-site Safety Board metallurgist and there was no indication of arcing noted.

The pylon was received with two Halon fire bottles still installed, one of which still had a squib attached. After the Halon bottles were removed from the pylon and the squib was removed from the one bottle, the bottles and squib were turned over to a bomb technician for storage in the on-site EOD bunker.

5.2 Nacelle

Two pieces of the inlet cowling, an 8-foot long section of the outboard cowl and a 4-foot long section of the inboard cowl, were recovered. The upper left portion of the inlet cowling had soot on the white-painted surfaces. The inlet lip was crushed flat from front to back.

Three of the four thrust reverser actuators were recovered. All had the jackscrew drives at the forward end of the jackscrews, which is the stowed position.

5.3 Fan

The fan case was intact, although it was twisted and warped. Almost all of the fan blade rub strip was still in place and appeared to have fresh rubs around the entire circumference. The area of the deepest uniform rub extends from 3:00 to 6:00, which was coincident with the center of impact to the engine. The rub strip was rubbed down to the bottom of the ASG pockets from 10:30 to 3:00, but had localized areas, spaced at 6 ½-inch intervals, that were rubbed down below the ASG pockets. (The fan blade tip stagger is 6 ½ inches.) The rub strip was rubbed down to the bare metal of the fan case from 1:00 to 1:30. The front and rear edges of the fan blade rub marks on the rub strip were axially located aft of "A" flange as follows (all dimensions are in inches):

LOCATION	FRONT	REAR
12:00	1 5/16	5 1/4
3:00	1 5/16	5 1/8
6:00	1 3/8	5 1/2
9:00	1 3/8	5 3/8

The fan hub was intact and was still attached to the LPT shaft.

Of the 46 fan blades, 41 were recovered, either full length airfoils or blade roots and airfoil sections. All of the airfoils had impact damage to the leading and trailing edges. There were 13 fan blades were fractured transversely across the airfoil just above the blade root platform. The fracture surfaces of the fractured blades were not remarkable. The full length airfoils were bent rearward. The fan blades did not have any sooting on the airfoil surfaces, but the tips were blackened.

The fan exit case struts were all fractured transversely just outboard of the inner ring standup welds.

5.4 Low Pressure Compressor

The LPC was crushed inward from the right and axially from the front. The third and fourth stage compressor disks were intact. The second stage compressor disk had radial fracture at 2:00, but the disk was otherwise complete and intact.

The LPC airfoils were bent over in both the clockwise and counterclockwise directions on the right side of the compressor. Almost all of the airfoils on the left side of the compressor were full length and straight, although a few were bent slightly in both directions at the tips. The LPC did not have any indications of any uncontainments or penetrations.

5.5 High Pressure Compressor

The HPC case was buckled at the 3:00 location and was crushed slightly at around the 4:30 location. The case was fractured circumferentially in line with the seventh stage stator vane unison ring from 6:00 to 9:00. The case had a 9-inch long circumferential fracture, centered around 3:00, between the HPC case front and split line flanges, "H" and "J" flanges respectively. The HPC cases did not have any indications of any uncontainments or penetrations. The thrust yoke was attached to the three attachment points.

The HPC IGVs were rotated so the airfoils were perpendicular to the engine centerline with the convex side facing forward. The IGV airfoils did not have any sooting.

5.6 Diffuser/Combustor

The diffuser and combustor cases were crushed from about 1:00 to 4:00. The diffuser case skirt was fractured circumferentially just aft of the fuel nozzle mount pads from about 2:00 to 8:00. The combustor case was separated from the diffuser case at "L" flange, from about 1:00 to 2:00, where the cases were crushed. The combustor case was separated from the HPT case at "M" flange, from 2:00 to 4:00. The center of the combustor case boss at 6:00 was missing with the fracture surfaces oriented towards the OD. The diffuser and combustor cases did not have any indications of any ruptures, penetrations, or fire damage.

The fuel nozzles and external manifolds did not have any indications of fire damage. There was no metallization on the backs of the fuel nozzles.

5.7 High Pressure Turbine

The HPT case was intact and did not have any indications of any uncontainments or penetrations.

The first stage turbine blades were fractured above the blade root platform and the ends were bent over away from the direction of engine rotation. The HPT airfoils did not have any metallization.

5.8 Low Pressure Turbine

The LPT case was intact, except for a 9-inch long section from the rear flange from 1:00 to 6:00 that was missing. The LPT case did not have any indications of any uncontainments or penetrations.

The fourth stage turbine disk and the fifth stage turbine hub were intact, but both had a 90^o arc of the rims that were bent rearward. The sixth stage turbine disk was intact except for a 90^o arc of the rim that was fractured through the air seal bolt holes and was missing.

The fifth stage turbine blades, from about 6:00 to 1:00, were full length. The remaining fifth stage blades were either fractured transversely across the airfoil just above the blade root platform or were missing from the blade slots in the disk. The sixth stage turbine rotor had two sectors of four and nine blades located at 9:00 and 10:00, respectively, that were full length. All of the other sixth stage blades were missing from the disk except for 13 randomly located blades that were fractured at various lengths up to 2-inches from the blade root platform. The LPT airfoils did not have any metallization.

5.9 Exhaust

The TEC was fractured axially at the 11:00 location and was bent and twisted. The TEC did not have any indications of any penetrations.

The turbine exhaust duct had been separated from the case and was returned with the engine. The duct was intact and did not have any indications of any penetrations.

The No. 4 bearing housing was intact. The No. 4 bearing cage was intact, but eight of the rollers were missing from the pockets and were not recovered. The remaining rollers did not have any rotational distress.

6.0 Turbine Exhaust Plugs

The turbine exhaust plugs from all four engines were recovered. One plug was essentially undamaged, although it had a circumferential dent on one side. The remaining three plugs were broken into circumferential ring segments that were all crushed flat. None of the turbine exhaust plugs had any indications of any penetrations.

7.0 Auxiliary Power Unit

The auxiliary power unit (APU) was recovered intact. The cases on the left side of the APU were crushed inward. The APU's cases did not have any indications of fire damage, uncontainments, or penetrations. The compressor blades and turbine blades visible in the inlet and exhaust, respectively, did not appear to have any damage.

The APU exhaust pipe was recovered full length. The exhaust pipe was crushed on the bottom and was buckled inward at 9:00. The pipe did not have any indications of penetrations.

8.0 Fuel Analysis - Density, Specific Gravity, American Petroleum Gravity, Flash Point, and Manual Distillation, October 17, 1996

8.1 Fuel Collection

During the disassembly of the four engines, fuel was found in the fuel manifolds just upstream of the fuel nozzles. Clear glass specimen jars were obtained from the Federal Bureau of Investigation's (FBI) on-site laboratory to collect the fuel. As the "B" nuts on the manifolds were loosened and the manifold lines separated, any fluid (fuel or water) that was in those lines was drained into the jars. The jars used to store the fuel from engines No. 1, 2, and 3 were about the size of a large baby food jar. The fuel from the No. 4 engine was collected in two bottles that were about the size of a small pharmacy pill bottle. The smaller jars were used to collect the fuel from the No. 4 engine so as to not delay the disassembly of the engine because the FBI laboratory had temporarily run out of the larger jars. Immediately after the fuel was collected and the cap was secured tightly on the top of the jar, the Powerplants Group Chairman marked each jar, using a felt tip pen, to identify what engine the fuel sample came from, the date, and then initialed it. For the larger jars used for the fuel from engines No. 1, 2, and 3, the markings were placed on the cap. For the smaller containers used for the fuel from engine No. 4, the markings were placed on the sides of the bottles. The caps on each of the jars were then secured with plastic package tape. The jars of fuel were kept in the hangar used for the disassembly of the engines. At the completion of the activities of the Powerplants Group, the jars of fuel were turned over to a bomb technician, New York City Police Department Detective Joseph S. Cordaro, for storage in the on-site EOD bunker.

The amount of fuel collected from each engine varied. The fuel collected from engines No. 1 and 2 was very little, estimated to be approximately 1 milliliters (ml) and 2 ml, respectively. The fuel collected from engine No. 3 was estimated to be a total of about 24 ml, in two jars. The fuel collected from engines No. 1, 2, and 3, was also contaminated with varying amounts of a cloudy liquid that would pool up in the bottom of the fuel in each jar. The cloudy fluid in each jar had visible particles in suspension. The fuel collected from the No. 4 engine was estimated to be about 16 ml, and appeared to be clean with no readily visible particles or other fluids.

In addition, an estimated 50 ml of fuel was decanted from a 1-pint metal container, which was in the NTSB command post at the Grumman facility, into a large glass specimen jar that had been obtained from the on-site FBI laboratory. The can was labeled that the fuel had been drained from the center body fuel tank of a TWA Boeing 747, airplane No. 17134, that had just arrived at JFK from Athens, Greece (ATH), as TWA flight No. 881. TWA had drained the fuel from the airplane's center body fuel tank around October 1, 1996, and provided it to the Safety Board, at the request of Dr. Merritt Birky, Fire and Explosion Group Chairman, who had given approval to decant the 50 ml sample.

8.2 Fuel Analysis

The Powerplants Group Chairman contacted Saybolt Incorporated, a petrochemical laboratory, in Kenilworth, New Jersey, to analyze the fuel collected. Saybolt was selected after the Powerplants Group Chairman had contacted a number of airport fixed based operators (FBOs) and aviation fuel delivery companies in the New York City area and requested the name of the laboratory they use for fuel analysis. All of the companies that had been contacted indicated they used Saybolt as their fuel analysis laboratory.

On October 9, 1996, Mr. William Koeck, Saybolt District Manager, and Dr. Nabil Mohtadi, Saybolt Kenilworth Laboratory Manager, accompanied the Powerplants Group Chairman, to the Grumman facility to pick up the fuel samples. An inspection of the jars of fuel after they were returned from the EOD bunker showed that they were all still tightly sealed and the packing tape was in place, which did not appear to have been disturbed. After the samples were logged out of the facility by an FBI evidence response team member, Mr. Koeck and Dr. Mohtadi hand carried the fuel samples to Saybolt's laboratory in Kenilworth, New Jersey. They stated that upon arrival in Kenilworth, they would start an inventory list, and then store the samples in a sealed box until they were to be analyzed.

On October 17, 1996, the fuel samples from the engine of TWA flight 800 and from the center body fuel tank of the TWA 747 from Athens, flight No. 881, were analyzed by Saybolt, in the presence of the Powerplants Group Chairman. All of the investigation party coordinators had been advised that the fuel analysis was going to be conducted at Saybolt, Kenilworth, on this date, however none of the parties elected to participate in the analysis. Mr. Koeck and Dr. Mohtadi stated that when they had returned to the Saybolt laboratory in Kenilworth from Calverton on October 9, 1996, they listed each of the samples on an inventory sheet and then sealed the fuel samples in a box. An examination of the box, sealing wire, and seals, showed that all were intact. The numbers on the three seals, No. 372178, 372333, and 372089, matched the numbers listed on the inventory sheet. (A copy of the inventory log sheet is attached.) After the sealing wire and tape around the box was removed and the box opened, the jars containing the fuel samples were removed and examined. The numbers and information listed on the inventory tags and written on each of the bottles matched the numbers and information listed on the inventory sheet. The jars and plastic package tape were intact and each appeared to be in the same condition as when they were last observed at the Grumman facility.

With the limited amount of fuel that was available for analysis and upon review of the recommendations that had been solicited from Boeing and P&W as to what fuel attributes should be analyzed, it was decided to test the fuel samples from flights 800 and 881 for density, specific gravity, American Petroleum Institute gravity (APIG), flash point, and manual distillation. (Copies of Boeing's and P&W's recommendations for the fuel analysis are attached.) Because of the limited amount of fuel that was extracted from the engines of flight 800, it was necessary to combine the samples of fuel to accomplish the flash point and manual distillation tests. In addition, the cloudy liquid that was in the bottom of the fuel samples from flight 800, was believed to be salt water, and was tested for salinity. All of the laboratory work on the fuel samples was done by Mr. William Moran, a senior laboratory technician for Saybolt, under the supervision of Dr. Mohtadi.

The liquid in the bottom of the fuel samples from TWA flight 800's No. 1, 2, and 3 engines, was believed to be salt water, and was tested for salinity using an Atago Company, Ltd. salinity refractometer, Model S-10. The fuel sample from engine No. 4 did not have any other visible liquids mixed in and so was not tested. The refractometer measures the salinity of water by placing a small amount of water on the prism on one end of the meter and then covering the prism and drop of water with a daylight plate, which was a square glass slide. The meter is held up towards a light source and by looking through the eyepiece at the opposite end from the prism, a blue bar and a scaled reticle is visible. The top of the blue bar on the reticle is the percentage of salt in the water, or salinity, in grams of salt per 100 grams of water. The meter was checked for calibration by placing a drop of distilled water on the prism, covering it with the daylight plate, and then observing that the blue bar was on the zero point on the reticle. (A copy of the instruction manual for the salinity refractometer is attached.) A small amount of the liquid was drawn from the bottom of the fuel samples from engines No. 1, 2, and 3, using a pipette and a drop was placed on the prism that was then covered with the daylight plate and the meter was held up to the light source to determine the salinity. The pipette, prism, and daylight plate were cleaned between each test of the water samples using distilled water. The results of the salinity tests were as follows:

Lab No.	Engine	Salinity
1096364	1	3.5%
1096365	2	3.5%
1096366	3	3.7%
1096356	3	3.2% *

* The initial salinity test on the sample of liquid from the second jar of fuel from engine No. 3, lab No. 1096367, was off-scale. After the glass tray of the prism and the daylight plate were cleaned with distilled water, the second test resulted in the salinity reading of 3.2%.

The density, specific gravity, and APIG of the fuel samples were measured using a Paar density meter, model No. DMA-48. The testing for density and specific gravity using a digital density tester is outlined in the American Society of Testing and Materials (ASTM) Standard D4052. (A copy of ASTM Standard D4052 is attached.) Before the start of the test, the test chamber of the unit was cleaned with acetone and blown dry with low pressure shop air. To test the fuel for density, specific gravity, and APIG, a small amount of fuel is decanted from the top of the sample using a sterile syringe. The tip of the syringe is inserted into a port on the right side of the test unit and some fuel is pumped into a glass chamber that is viewable through a small window in the front of the unit. A light in the unit is turned on and the fuel is pumped in and drawn out slightly to ensure there are no air bubbles in the sample to be tested. When it is certain there are no air bubbles in the sample, the light is turned off and the test is started. The unit automatically cools the sample down to 15.5^{o}C (the light must be off or it will warm the fuel and result in false test readings) and then measures the density, specific gravity, and APIG. After the test, the fuel sample is withdrawn from the test chamber in the unit and returned to its original container. The test chamber was cleaned after each sample was tested with the acetone and blowing the chamber dry with the low pressure shop air. Each sample was decanted from its jar using a fresh sterile syringe. The calibration of the unit is checked daily using toluene by a process known as control charting.[4] The control charting check that was accomplished just prior to the unit being used for the fuel samples from TWA's flight No. 800 and 881 resulted in a density reading of 0.8709 for the toluene test fluid. The test was accomplished on the fuel from TWA 800 No. 3 and 4 engines, and the fuel from Athens. The results of the tests were as follows:

[4]Control charting checks the density of a known test fluid to ensure the readings stay within a required range. If the readings fall out of the required range, the unit must be adjusted.

Log No.	Engine	Density	Specific Gravity	APIG
1096367	3	0.8118	0.8126	42.63
1096369	4	0.8117	0.8125	42.66
1096370	4	0.8116	0.8124	42.68
1096368	ATH	0.7979	0.7987	45.66

The fuel samples were tested to determine the flash point using a Fisher Tag Closed Cup Tester ASTM D-56. The closed cup flash point test is outlined in ASTM standard D-56. (A copy of ASTM standard D-56 is attached.) Because of the limited amount of fuel that was recovered from the four engines, it was necessary to combine all of the samples from the engines to have enough to accomplish the flash point test. The combined fuel sample was identified as a composite, Saybolt Log No. 1096630. The flash point test is accomplished by placing about 50 ml of the fuel into a clean metal cup. The cup is then set in a holder so that the bottom of the cup is setting in a bath of water at room temperature. A cover is placed over the fuel sample. The cover has a small window, which is normally closed, and a very small gas jet that is ignited. The gas jet can be rotated down to the window, which is rigged to open as the gas jet is rotated towards the window. The water bath is heated electrically to warm the fuel to produce vapors. A rheostat on the base unit controls the amount of heat input to the water to control the temperature increase of the fuel to 2°F per minute. The temperature of the fuel and water bath were measured with ASTM 9F thermometers, SN 30024 and A06043, respectively, both of which had stickers indicating they were due for calibration in April 1997. Mr. Moran used a stop watch throughout the test to ensure the temperature increase was at the required rate and had to adjust the rheostat several times to decrease or increase the rate of temperature rise to meet the 2°F per minute requirement. As the fuel is warmed and produces vapors, the lit gas jet is rotated down to the window at every 1°F increase of temperature of the fuel. The flash point of a fuel sample is the temperature of the fuel when the lit gas jet ignites the vapors in the cup. The composite fuel sample from the engines of TWA flight 800 was tested first and found to have a flash point of 123°F. The fuel from the center body fuel tank of the TWA 747 from Athens, flight No. 881, was then tested and found to have a flash point of 114°F. The barometric pressure during the flash point tests was 763 mm Hg.

The distillation was the last test accomplished to the fuel samples. The procedure for the distillation test for jet fuel is outlined in ASTM standard D86. (A copy of ASTM standard D86 is attached.) The ASTM standard specifies that 100 ml is required to accomplish the distillation test. Since the combined fuel from the four engines of flight 800 and the fuel remaining from the Athens flight after the other tests had been completed amounted to about 50 ml each, the test was accomplished using those quantities and the residual amounts were prorated. It should be noted that the sample of fuel from the engines of flight 800 that was used for the distillation test was the same composite sample that had been used for the flash point test. Dr. Mohtadi pointed out that the flash point test might have burned off some of the lighter ends of the fuel and altered the initial boiling point (IBP) part of the test. The distillation test is accomplished by placing the sample in a distillation flask. A stopper with a thermometer, which had a sticker indicating the calibration was due in April 1997, was put on to the top of the flask. The vent from the top of the flask was plugged into a condenser, which was a coiled tube through a room temperature water bath that drained into a graduated cylinder. The fuel in the flask was heated electrically to boiling. As the vapors from the boiling fuel rose, they flowed out through the vent and into the condenser. The temperature at which the first drop of liquid falls from the condenser into the graduated cylinder is recorded as the IBP. As the liquid continues to flow from the condenser into the graduated cylinder and reaches the required measurement levels, the temperature is recorded. When the fuel in the distillation flask has been almost completely boiled away, the temperature in the flask will stop rising and then drop. The maximum temperature rise before it began to drop is the end point (EP). When the residue in the distillation flask is cool, it is measured in a clean graduated cylinder. The sum of the distilled fuel in the graduated cylinder and the residue is subtracted from the starting quantity of fuel to determine the loss. The results of the distillation test were as follows:

	Flt 800	Barometric Corrected Temperature	ATH	Barometric Corrected Temperature
IBP	322°F	321.8°F	306°F	305.8°F
2.5 ml	348	347.8	322	321.8
5.0	360	359.8	339	338.8
7.5	372	371.8	350	349.8
10.0	380	379.8	361	360.8
15.0	390	389.8	372	371.8
20.0	406	405.8	384	383.8
25.0	418	417.8	394	393.8
30.0	432	431.8	406	405.8
35.0	446	445.8	420	421.8
40.0	466	465.8	434	433.8
42.5	476	475.8	446	445.8
45.0	492	491.8	454	453.8
47.5	xxx	xxx.x	472	471.8
EP	504	503.8	482	481.8

	Flt 800	ATH
Recovered-Actual	49 ml (50 ml)	48ml (49ml)(starting amount)
Recovered(percentage)	98.0	98.0
Residue(percentage)	1.6	1.4
Loss(percentage)	0.4	0.6

The barometric pressure during the distillation tests was 762 mm Hg.

All of the fuel and residue remaining from the tests was saved in jars, packed in boxes, and returned to the Grumman facility at Calverton, New York, by NTSB staff.

A copy of Saybolt's laboratory report on the fuel samples is attached.

9.0 Fuel Analysis - Electrical Conductivity, December 17, 1996

On December 13, 1996, two samples of jet fuel were hand carried, by the Powerplants Group Chairman, from the Grumman facility at Calverton, New York, to Saybolt, in Kenilworth, New Jersey, to be tested for electrical conductivity. Saybolt was selected to do the fuel electrical conductivity tests because they had accomplished the previous testing of fuel from the engines of TWA flight 800 and the fuel from TWA flight 881 from Athens. On December 17, 1996, in the presence of the Powerplants Group Chairman, both of the fuel samples were tested for electrical conductivity in accordance with ASTM Standard D-2624-95, “Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels.” (A copy of the ASTM Specification D2624 is attached.) The tests were accomplished by Mr. Roy Pike, a Saybolt senior laboratory technician, under the direction of Dr. Nabil Mohtadi, Saybolt Kenilworth Laboratory Manager.

The party coordinators had been advised at the progress meeting on December 12, 1996, that this fuel testing was going to be accomplished, however none of the parties elected to participate.

The electrical conductivity of fuel is the ability of the fuel to dissipate a static charge. The unit of measure is picosiemens per meter (pS/m). A siemen, which is also called a conductivity unit (cu), is the reciprocal of an ohm, the unit of electrical resistance. A siemen is also known as a mho. (1pS/m = 1 x 10^{-12} Ω^{-1} m^{-1} = 1 cu = 1picomho/m)

The test for the electrical conductivity of fuel was accomplished in the following manner. A stainless steel cup was cleaned by rinsing it out with acetone, then washing it out with soap and water, rinsing it with distilled water, rinsing it again with acetone, and then drying out the inside of the cup with shop air. The inside of the stainless steel cup was examined and was found to have no residual moisture or odors. Fuel was poured from the respective containers into the stainless steel cup to a depth of about 4 to 5 inches. The ASTM specification stated the test should be accomplished at room temperature. Using an ASTM 12F thermometer serial number (SN) 1N4304, which had the calibration last checked on April 16, 1996, the temperature of the two fuel samples just prior to each test was 70°F. The electrical conductivity of the fuel was measured with an Emcee Electronics, Inc. Model 1152 Digital Conductivity Meter SN 14912, which had a sticker indicating that it was last calibrated on May 6, 1996, and that the next calibration was due on May 6, 1997. (A copy of the meter certification for meter SN 14912 is attached.) The meter consists of two parts: the meter box, which has a liquid crystal display (LCD) indicator and two buttons that are marked ‘M’ and ‘C’, and a probe that is inserted into a plug in the bottom of the meter. The calibration of the meter can be checked by pressing the button marked ‘C’ and it must indicate 10 times the number marked on the probe. The probe was annotated with the number 41 and the LCD indicated 410 when the ‘C’ button was pressed. The probe was rinsed off with a small amount of fuel from each sample to rinse away any potential residue. The probe was dipped into each fuel sample three times and on the third immersion, it was held steady in the sample and the ‘M’ button was pressed. The number that appeared on the LCD within three seconds after the ‘M’ button was pressed was the electrical conductivity reading for that fuel sample. The stainless steel cup was cleaned and the probe was rinsed with fuel between each of the tests. (A copy of the Emcee Electronics Model 1152 Digital Conductivity Meter operation manual is attached.) Separate from the ASTM test for electrical conductivity, the fuel in the stainless steel cup was poured into a graduated cylinder to measure how much fuel had been poured from the containers for each of the tests.

The results the electrical conductivity tests on the fuel samples were as follows:

	Athens fuel	Kennedy fuel
Source	TWA 881	Cart 856
Sampling date	October 1, 1996	July 17, 1996
Quantity of fuel tested	685 ml	645 ml
Temperature	70°F	70°F
Electrical conductivity reading	90 pS/m	0 pS/m

A copy of Saybolt’s test results is attached.

Although the specification for jet fuel has no requirement for fuel conductivity, the ASTM recommendation for conductivity in JetA fuel is 50-450 pS/m.[5] (A copy of the ASTM specification is attached.)

Gordon J. Hookey
Powerplants Group Chairman

2/25/97

[5] Jet Fuel Specifications, (Exxon, 1990), p. 6

ATTACHMENTS

1. TWA list of modules and engine serial numbers installed on Boeing 747-131, N93119.

2. Cross section of JT9D engine identifying engine case flanges.

3. Boeing letter to NTSB, dated September 26, 1996, with recommendations for fuel tests to accomplished on fuel from TWA flight 800.

4. P&W letter to NTSB, dated February 16, 1990, regarding analysis of fuel from Avianca flight 502, that was for comparison of what testing to accomplish on fuel from TWA flight 800.

5. Saybolt Inc. Sample Receipt/Retain/Disposal Log inventory sheet for fuel samples from TWA flight 800 and from TWA flight 881 from Athens.

6. Atago Co., Ltd. Salinity Refractometer, Model S-10, Instruction Manual

7. ASTM Standard D4052: "Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter."

8. ASTM Standard D56: "Standard Test Method of Flash Point by Tag Closed Tester."

9. ASTM Standard D86: "Standard Test Method for Distillation of Petroleum Products."

10. Copy of Saybolt's laboratory report on the fuel samples tested on October 17, 1996.

11. ASTM Standard D-2624-95, “Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels.”

12. Certificate of calibration for digital conductivity meter SN 14912.

13. Emcee Electronics Model 1152 Digital Conductivity Meter Operation Manual

14. Copy of Saybolt's laboratory report on the fuel samples tested on December 17, 1996.

15. ASTM Jet Fuel Specification Recommendation.