NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

May 21, 2008

Systems Group Chairman's Factual Report

DCA-07-MA-310

A. ACCIDENT

Operator: American Airlines
Location: Lambert – St. Louis International Airport, St. Louis, MO
Date: September 28, 2007
Time: 1:16 PM Central Daylight Time
Airplane: McDonnell Douglas DC-9-82 (MD-82), N454AA

B. SYSTEMS GROUP

Chairman: Scott Warren
National Transportation Safety Board
Washington, D.C.

Member: Greg Magnuson
American Airlines
Tulsa, OK

Member: Ken Sujishi
Federal Aviation Administration
Los Angeles, CA

Member: William Mutz
The Boeing Company
Long Beach, CA

Member: Dave Stewart
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Fort Worth, TX

C. SUMMARY

On September 28, 2007, at 1316 central daylight time, a McDonnell Douglas DC-9-82 (MD-82), N454AA, operated by American Airlines as flight 1400, executed an emergency landing at Lambert-St Louis International Airport (STL), St. Louis, Missouri, after the flight crew received a left engine fire warning during departure climb from the airport. The airplane sustained substantial damage. Visual meteorological conditions prevailed and an instrument flight rules flight plan was filed for the 14 CFR Part 121 scheduled domestic flight. After landing, the 2 flight crew, 3 flight attendants, and 138 passengers deplaned via airstairs and no occupant injuries were reported. The intended destination of the flight was Chicago O'Hare International Airport (ORD), Chicago, Illinois.

Upon receiving the left engine fire warning during climb, the flight crew discharged the aircraft engine fire bottles into the affected engine. During the visual return and single-engine approach to the airport, the nose landing gear did not extend. The flight crew then extended the nose landing gear using the emergency landing gear extension procedure. The airplane returned and then landed on runway 30L (11,019 feet by 200 feet, grooved concrete) and was met by STL Airport Rescue and Fire Fighting Vehicles.

The systems group chairman did not travel to the scene, but worked with the other systems group members to gather on-scene testing results, to identify components of interest, and to insure that those components were examined as required.

D. DETAILS OF THE INVESTIGATION

1.0 On-Scene Documentation and Testing

According to the operator, a number of post-incident checks were conducted on the aircraft. One of these checks involved recording the hydraulic system pressure when the auxiliary pump was providing hydraulic pressure and the power transfer unit (PTU) was selected on. This test was conducted prior to the left hydraulic system being serviced, and when the PTU was on, the pressure available on the right side system was approximately 100-200 psi. When the PTU was not on, the full pressure of the auxiliary pump (2200-2750 psi) was available on the right side.

Additional checks and their results are given below:

1. Check accumulator pre-charge pressures:

Position	Component	Gage Indication (psi)	Limit (psi)
Left	Brake	625	675 +/- 25
Right	Brake	650	675 +/- 25
Left	Thrust Rev	1000	1000 +/- 50
Right	Thrust Rev	1000	1000 +/- 50
	Elevator	1800	2000 +/- 50
	Rudder	1000	1000 +/- 50

2. Check level of fluid (in inches) in Left Reservoir Overflow Bottle: 1 inch.

3. Check area around and below Power Transfer Unit and Left Hydraulic Reservoir for the presence of residual hydraulic fluid. No residual fluid found.

4. Take samples of Left and Right Hydraulic System Fluid and label bottles. Ship to Solutia per card instructions. Obtained samples and shipped.

5. Remove the following components and send to AA shop for testing, teardown and evaluation:

Position	Component	Serial Number
Left	Hyd Reservoir	EEI7434
	Power Transfer Unit	246C
	PTU Shutoff Valve	1215
	Aux Pump	MX591418
Right	Engine Driven Pump	MX155920PVZZ

6. Check Right Hydraulic Reservoir Fluid Quantity: Checked and found full.

7. Check Left Hydraulic Reservoir Fluid Quantity: Checked and found empty after gear cycle.

8. Weigh #1 fire bottle as removed from aircraft: 9.5 lbs

9. Weigh #2 fire bottle as removed from aircraft: 9.5 lbs

10. Check operation of Left Hydraulic Reservoir Low Level Switch: Performed Ops Check of low level switch. When reservoir went to empty the transfer pump shut-off.

11. Check left engine fire control pull handle ENG FIRE lights for continuity: Verified aircraft wiring from handle to firewall connector P1-1361 normal. Removed connector P1-1361 at aft fuselage firewall. Lights extinguished. Problem fault on engine side fire loops A & B, burned, shorted.

12. Performed emergency shutdown system adjustment and test for left engine per AMM 76-20-00-5, para. 5A, Item 16, pull test. Requires 21 lbs pull to aft position and 32 lbs to fire bottles. (AMM 76-20-00-5 limit is 25 lbs to pull handle to aft position. No limit given for discharge, just ensure “ease of operation”).

13. Performed emergency shutdown system adjustment and test for right engine per AMM 76-20-00-5, para. 5A, Item 16, pull test. Requires 26 lbs pull to aft position and 22 lbs to fire bottles. (AMM 76-20-00-5 limit is 25 lbs to pull handle to aft position. No limit given for discharge, just ensure “ease of operation”).

14. Verify proper operation of left engine start switch. Verified left engine start switch S1-1 for proper operation. Verified continuity in the ON position and switch spring loaded back to OFF position and switch was open. No defects noted.

2.0 Fire Extinguishing System

The fixed fire extinguishing system is used to extinguish fires in the engine and APU compartments. The system consists of two fire extinguisher containers, fire extinguishing agent deployment lines, fire extinguishing discharge controls and circuits, and the low agent indicating lights. The two 536 cubic inch fire extinguisher containers are installed in the aircraft aft accessory compartment. The containers are charged with 14.6 (+/-1) pounds of bromochlorodifluoromethane extinguishing agent at 600 psig. Each container provides one extinguishing shot. The containers are identical, and consist of a spherical steel container and a pressure switch. Three outlet ports on the container provide for agent release to any one of the fire areas. A discharge valve bonnet is installed on each outlet port. The discharge valves serve as an adapter between the container and deployment lines, and provide for installation of the explosive cartridge. Each outlet port is sealed by a seal disc to retain the pressurized extinguishing agent. The fully charged containers (less discharge heads and cartridges, and with protective caps) each weigh 22.95 pounds.

Each engine is equipped with an independent fire control handle mounted on the upper instrument panel. Lights within the handle are designed to come on when an engine fire is detected. Pulling the fire control handle is designed to shut off various aircraft systems in order to confine an existing fire to a local area. With the selected fire control handles in the full extended detent, the fuel fire shutoff valve located in the wing root, aft of the rear spar, and the hydraulic oil fire shutoff valve in the wheel well will close and these closures are intended to restrict any additional fluid distribution. Movement of the fire control handle to the fully extended positon will also close the pneumatic crossfeed valve, located in the aft accessory compartment, and this closure is intended to restrict any additional air distribution. Movement of the pneumatic crossfeed valve control lever (in the cockpit) back to the open position, after it has moved to the closed position as a result of the pulled fire control handle, will result in the retraction of the fire control handle. When the fire control handle is retracted, the fuel fire shutoff valve and the hydraulic oil fire shutoff valve will be moved to the open position.

A guide is incorporated for each fire control handle rod to prevent any rotation until the handle is in the full extended detent. Turning the handle counterclockwise will fire a discharge cartridge, which in turn will discharge fire extinguishing container number 1. Turning the handle clockwise will discharge the fire extinguishing container number 2. Once a container has been discharged, the extinguishing agent will be completely depleted in that container. According to the manufacturer, each container, if fired one at a time, will discharge in under 30 seconds. The discharge plumbing controls the discharge flow rate of the fire extinguishing container and is designed to flow the discharge from each container one at a time. If both containers are fired simultaneously, the total rate of extinguishing agent flow into the engine nacelle would be at the same rate as if a single container were discharged, however, the time required to discharge both containers will be double the normal discharge time of a single container. In this situation, each container will discharge at a reduced rate, but the flow rate to the engine nacelle remains constant.

3.0 Pneumatic System

The pneumatic system consists of two identical subsystems, each complete and operable independently of the other or interconnected to provide a common pressure source for the using systems. Engine bleed air from the 8^{th} stage low-pressure compressor, and from the 13^{th} stage high-pressure compressor is bled off through bleed ports into separate bleed air manifolds and into the pneumatic system ducting. The left and right systems each contain a crossfeed valve, which isolates the interconnecting ducting from the supply ducts. The right engine normally supplies engine bleed air to the right system up to the right crossfeed valve; the left engine supplies the left system up to the left crossfeed valve. The auxiliary power unit or a ground pneumatic source can also supply pressure to the left or right system or to both.

The pneumatic crossfeed valve is located just downstream of the junction of the 8^{th} and 13^{th} stage ducting, at each end of the crossfeed ducting. The control levers are mounted on the control pedestal in the flight compartment. Each control lever is connected by an adjustable pushrod to cable drums located below the control pedestal under the flight compartment floor. The control cables extend along the center-line of the aircraft above the lower cargo compartment ceiling.

4.0 Hydraulic System

The hydraulic power system consists of two main systems, an auxiliary system, and an indicating system. The hydraulic main and auxiliary systems provide primary and backup power for operating hydraulically actuated systems and subsystems on the airplane. Main hydraulic power is provided by two, separate, closed circuit hydraulic systems identified as the left and right systems. One engine driven hydraulic pump, on each engine, supplies power to the corresponding system. The hydraulic systems are filled with hydraulic fluid and are normally pressurized by the engine driven pumps to approximately 3000 psi. Hydraulic power is required for the operation of the elevator boost, rudder, flaps, slats, flight spoilers, ground spoilers, ventral stairway, engine thrust reversers, landing gear, brake and nosewheel steering systems. Schematic views of the left and right hydraulic systems are shown in figures 1 and 2.

The engine driven hydraulic pumps are mounted on the accessory gear cases of their respective engines and controlled by switches in the flight compartment. Each reservoir contains a supply of hydraulic fluid for the system it serves. System return fluid, except for brake fluid, flows through the system return line filters into the reservoir. The reservoir has a relief and bleed valve, direct fluid level indicator, fluid quantity transmitter, low level switch and temperature sensor.

The hydraulic oil fire shutoff valve, one for each system supply line, is mechanically operated and is normally in the open position. The valve in each system is controlled by the fire control handle in the flight compartment and when the fire control handle is pulled, the hydraulic oil fire shutoff valve is closed and is designed to stop the flow of hydraulic fluid to the engine driven pumps.

A backup means of pressurizing both the left and right hydraulic systems is provided by one, electric motor driven auxiliary pump and one hydraulically operated power transfer unit. The electric motor driven pump pressurizes the right system only. The electric motor driven pump is capable of supplying a continuous flow of hydraulic fluid at 8 gpm and approximately 2200 psi or 6 gpm and approximately 2750 psi.

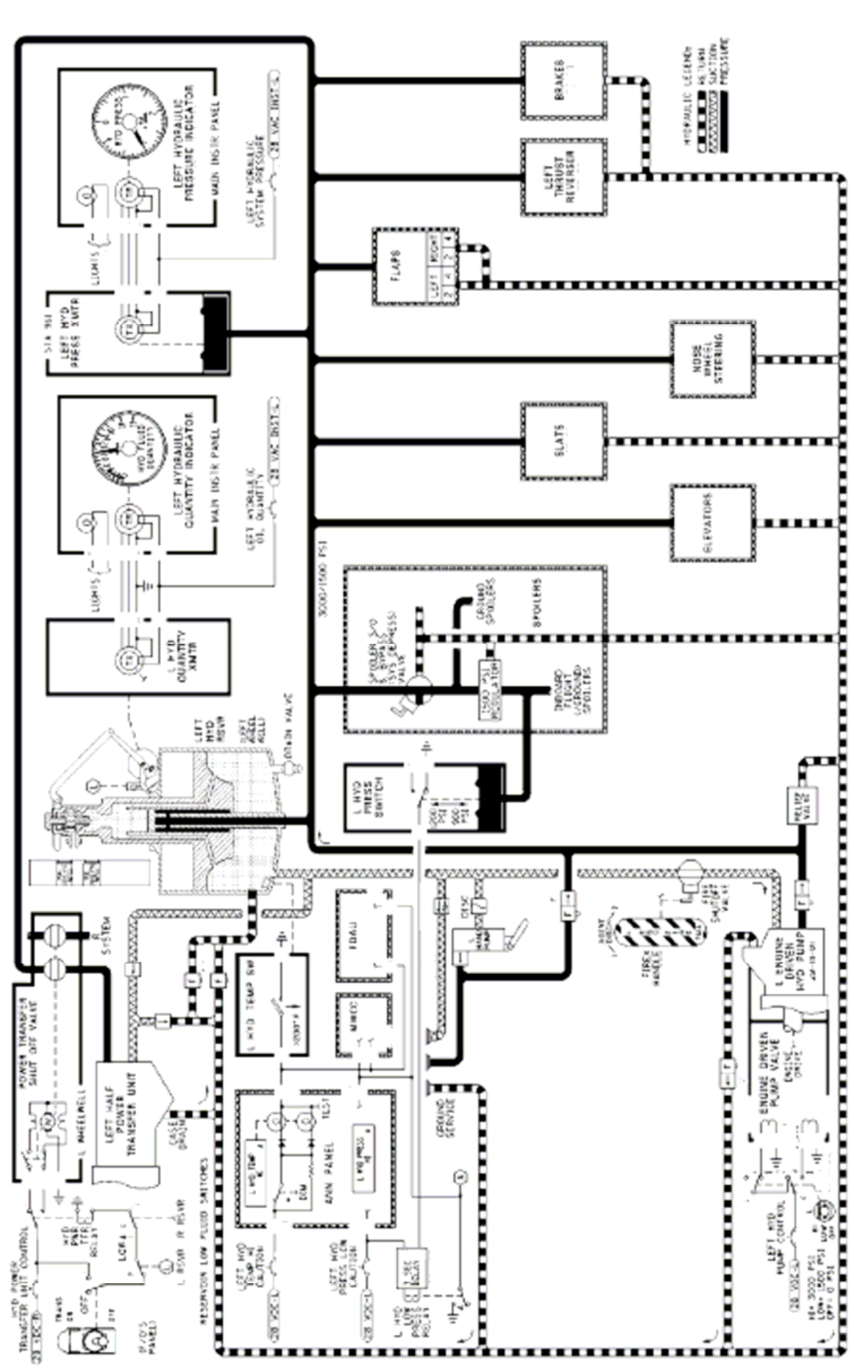

Figure 1 - Left Hydraulic System - Schematic

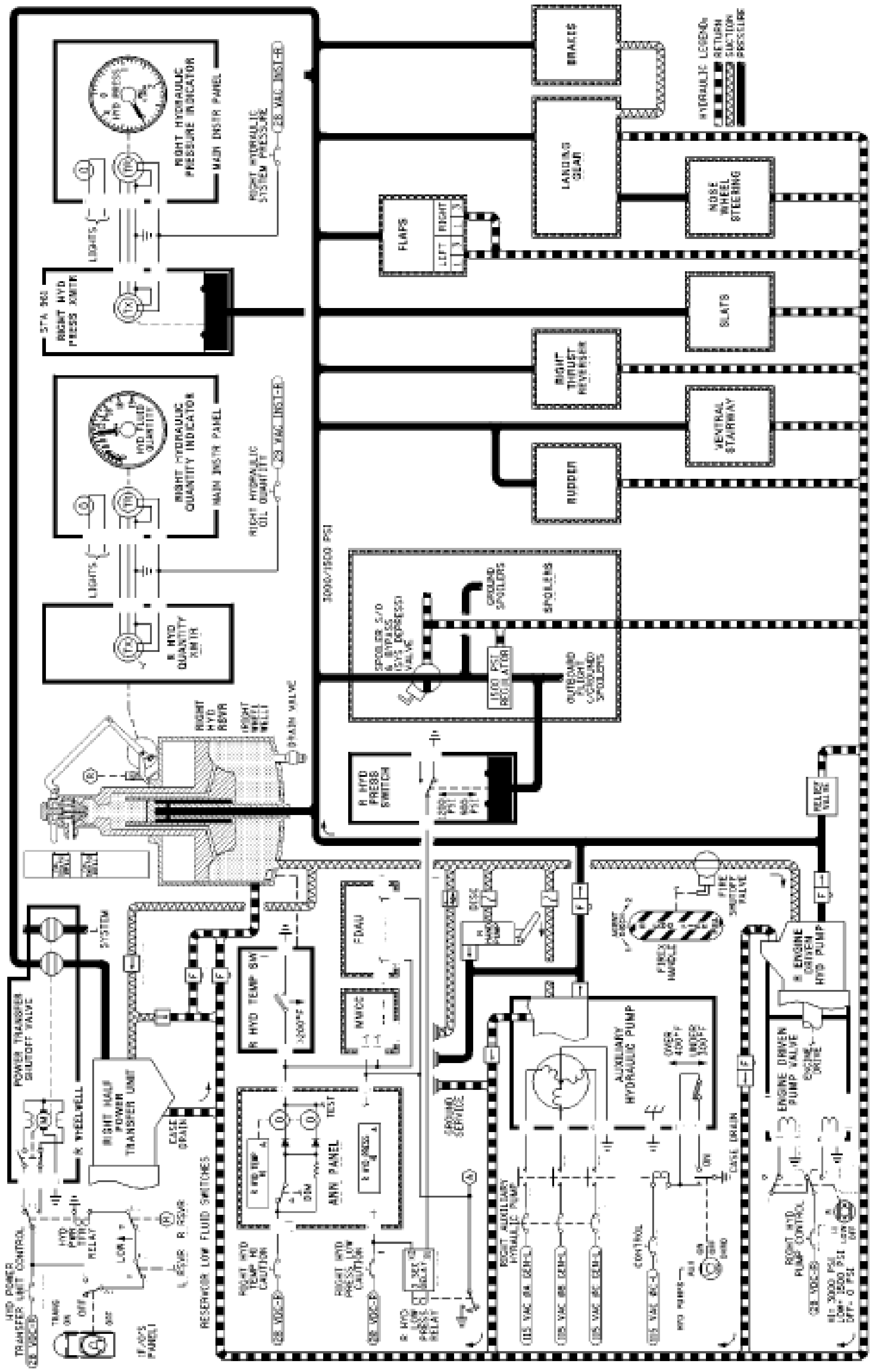

Figure 2 - Right Hydraulic System - Schematic

4.1 Power Transfer Unit

The hydraulic power transfer unit (PTU) is a device used to transfer hydraulic power from one hydraulic system to another without mixing the fluid from the two systems. The power transfer unit mechanically connects the two systems and enables hydraulic power to be transferred from the higher pressure systems to the lower pressure system (higher pressure side operates as a motor and lower pressure side as a pump) and supplies a flow of hydraulic fluid at approximately 8 gpm, and the pressure that may fluctuate within 2000 to 3000 psi. The unit is controlled by a single motor operating two shutoff valves, one in each system. Operation is controlled by a separate switch located on the hydraulic control panel on the First Officer's instrument panel. The motor operated shutoff valves are also connected electrically to the low level switch on each reservoir, and the appropriate shutoff valve is designed to automatically close if the indicated fluid level in either system reservoir is below 1-1/3 quarts. The unit and control valves are located in the left main landing gear well.

Sufficient hydraulic fluid volume must be present in the system for the power transfer unit to be able to pressurize that system. When there is no fluid or insufficient fluid volume is present in the hydraulic system, the PTU will free-wheel and lower the pressure in the pressurized hydraulic system. When sufficient hydraulic fluid volume is not present in the system, the PTU is designed to be selected to the "off" position to preserve the pressure in the pressurized hydraulic system.

According to the operator, the PTU in the accident aircraft was removed and examined at American Airlines maintenance facility in Tulsa, OK. The part number on the unit was MPN 4100310-6, and the serial number on the unit was 246C. The fluid in the unit was drained prior to any testing, and there were no signs of burnt fluid or metal fragments in the drained fluid. The unit was tested in accordance with the component maintenance manual chapter 29-09-01 test requirements, and all internal and external leakage requirements were met. The unit was bench tested, and the operational test results were as follows:

TEST	MOTOR INLET (PSIG)	PUMP FLOW (GPM)	PUMP OUTLET (PSIG)
#1 MTR. SIDE "A"	2950	0.5	**2825** (2580 Min. All.)
#2 MTR. SIDE "A"	2950	10	**2730** (2700 Min. All.)
#1 MTR. SIDE "B"	2950	0.5	**2820** (2580 Min. All.)
#2 MTR. SIDE "B"	2950	10	**2740** (2700 Min. All.)

BREAKOUT TEST

MTR. SIDE "A"	3000 PSIG MOTOR INLET	BREAKOUT DIFF. PSI	400 (580 Max All.)
MTR. SIDE "B"	3000 PSIG MOTOR INLET	BREAKOUT DIFF. PSI	400 (580 Max All.)

4.2 Right Engine Driven Hydraulic Pump

According to the operator, the right engine driven hydraulic pump in the accident aircraft was removed and examined at the American Airlines maintenance facility in Tulsa, OK. The part number on the unit was MPN 314195, and the serial number on the unit was MX155920PVZZ. The unit was tested in accordance with the component maintenance manual chapter 29-10-03 test requirements, and all internal and external leakage requirements were met. The unit was bench tested, and the component maintenance manual operational test requirements were met.

4.3 Power Transfer Unit Shutoff Valve

According to the operator, the power transfer unit shutoff valve in the accident aircraft was removed and examined at the American Airlines maintenance facility in Tulsa, OK. The part number on the unit was MPN 240695-2, and the serial number on the unit was 1148AC. The unit was tested in accordance with the component maintenance manual chapter 29-12-03 test requirements, and all internal and external leakage requirements were met. The unit was bench tested, and the component maintenance manual operational test requirements were as follows:

> At 3000 +/- 60 psig and 5 GPM flow, cycle test at 18, 28, and 30 V dc maximum allowable running current draw is 3 amps. Unit passed at 0.5 amp draw and valve shut off flow at each cycle.
>
> At same inlet pressure and flow with Pin A only energized at valve positioned midway between open and closed. Unit passed by actuator opening and closing valve repeated times.
>
> Repeat test with Pin B only. Unit passed by actuator opening and closing valve repeated times.
>
> Although unit passed operational functional tests, motor operated actuator failed 500 V Insulation Resistance Test between Pins A and E.
>
> NOTE:
> According to the operator, failing the Insulation Resistance Test is a normal shop finding. Almost all valves that pass operational test requirements, will fail the Insulation Resistance Test of the motor actuator, as in this case. This is only an indication of fluid or water contamination, or wire insulation break down in the motor but the unit will still function normally on the aircraft and on the bench.

4.4 Left Hydraulic Reservoir Assembly

The hydraulic reservoir is equipped with a piston and diaphragm assembly that utilizes the system pressure of approximately 3000 psi to maintain a pressure head of approximately 30 psi on the supply fluid. The pressure head is created through a bootstrap design where system pressure is applied to a small piston, and the pressure on the reservoir fluid is created with a large diaphragm (the area ratio of the small piston to the large diaphragm is approximately 1:100). The system pressure acting on the diaphragm is required to move the diaphragm as the fluid level changes or if fluid is lost. As the diaphragm moves to the low fluid level position, the reservoir low indication is designed to be set and the hydraulic fluid low level indicating light is designed to be illuminated in the cockpit.

According to the operator, the left hydraulic reservoir assembly in the accident aircraft was removed and examined at the American Airlines maintenance facility in Tulsa, OK. The part number on the unit was MPN 5936986-5501, and the serial number on the unit was EEI7434. The unit was tested in accordance with the component maintenance manual chapter 29-10-10 test requirements, and all internal and external leakage requirements were met. The unit was bench tested, and the component maintenance manual operational test requirements were met. Pressure levels required to move the diaphragm were found to be within limits. The reservoir diaphragm was moved to the most bottom position and the reservoir lid was removed to inspect for any damage such as a dent in the shell assembly that might prevent diaphragm from moving freely. No dents were found. Hydraulic ports in the shell assembly were checked for fluid restrictions from debris and none were found.

4.5 Auxiliary Hydraulic Pump

According to the operator, the auxiliary hydraulic pump in the accident aircraft was removed and examined at the American Airlines maintenance facility in Tulsa, OK. The part number on the unit was MPN 861555, and the serial number on the unit was MX591418. The unit was tested in accordance with the component maintenance manual chapter 29-10-47 test requirements, and all internal and external leakage requirements were met. The unit was bench tested, and the component maintenance manual operational tests yielded the following results:

PUMP OUTLET (PSIG)	PUMP FLOW (GPM)	CURRENT DRAW (AMPS) all 3 phases	
2150	8.18 (7.75 minimum)	45.0, 44.3, 43.6	(45 maximum)
2750	5.65 (5.50 minimum)	40.6, 39.8, 39.1	(45 maximum)

Pressure at cut-off (0 gpm) was fluctuating between 3010-2970 psig. CMM minimum limit is 3000 psig. A very slight adjustment of the compensator brought the output above 3000 psig. According to the operator, this is normal for all pumps removed from service. No signs of metal or burnt fluid were noted when the pump was drained prior to the tests.

4.6 Hydraulic Fluid Analysis

According to the operator, hydraulic fluid samples were taken from both the left and right systems and sent to Solutia, Inc to be analyzed. According to Solutia, the results were as shown in Table 1.

Table 1
Hydraulic Fluid Sample Analysis Results

Fluid Analysis Report

Sample Information

Customer	American Airlines	Sample Number	84956
Aircraft Model	MD-80	Sample Date	02-Oct-2007
Tail Number	454	Date Received	18-Oct-2007
		Report Date	22-Oct-2007

Test Results

Sample Tests			Airframe Specs
Sample No.	84956	84956	
System	Left	Right	
Appearance	Clear	Clear	Clear Fluid
Moisture %	0.30	0.17	0.50 (max)
Neutralization No.	0.10	0.04	1.50 (max)
Particle Count (#/100ml)			
5-15 Microns	***H 1,401,482**	115,800	128000 (max)
15-25 Microns	***H 103,936**	7,658	22800 (max)
25-50 Microns	***H 16,202**	2,230	4050 (max)
50-100 Microns	***H 1,598**	342	720 (max)
> 100 Microns	***H 138**	44	128 (max)
Composition			**Comment Legend**
% Skydrol 4	98	100	*H=High, Action Required
% Skydrol 5	0	0	*M=Moderately High, Monitor
% Skydrol PE-5	0	0	*L=Low, Action Required
% Hyjet	2	0	
Total Depletion (%)	16	6	
% Contamination	0	0	

Scott Warren
Lead Aerospace Engineer