Party Submission of American Airlines To the National Transportation Safety Board

American Airlines Flight 1400
September 28, 2007, St. Louis, Missouri

McDonnell Douglas MD-82 N454AA

NTSB Identification DCA07MA310

Pursuant to 49 C.F.R. §831.14, American Airlines, Inc., submits to the National Transportation Safety Board the following comments and recommendations relating to the investigation of the accident involving Flight 1400 at St. Louis, Missouri, on September 28, 2007.

Summary

The events leading to the accident began with the internal deterioration of the air filter for the left engine's air turbine start valve. This type of filter came as original equipment on MD80's, and neither the aircraft manufacturer nor the filter manufacturer assigned it a life-limit or gave American any recommendations for inspecting, replacing, or tracking the filters beyond cleaning them at aircraft "C" checks.

The deterioration of the filter element on this aircraft caused occasional restriction or blockage of airflow to, and also deposited debris in, the sensitive start valve solenoid, intermittently preventing the valve from opening properly. Since there was no reason to expect a filter problem, these start-valve malfunctions caused the mechanics to replace the start valve on this engine multiple times in the weeks before Flight 1400 and also required the mechanics to start the engine air turbine by opening the start valve manually.

The MD80 start valve included a manual-override (manual-start) pushbutton, though use of the pushbutton was not an American-approved method for manual starts. Because of a defect in design, pushing the manual-override pushbutton in fully (flush with its housing) with a lever apparently could cause damage that, along with debris from the filter element, would prevent the solenoid switcher ball from properly seating. The normal peak take-off/climb-out air pressure in the start-valve control-air line would then force the switcher ball off its seat and cause an uncommanded opening of the start valve during flight. Boeing, however, issued inconsistent and insufficient directions and recommendations for manual starts, and neither Boeing nor Honeywell directed that the manual-override pushbutton be deactivated. As a result of this confusing guidance, some mechanics used the most practical and safest (for them) method of manually opening the start-valve – using a lever to push the manual-start pushbutton.

On climb-out, the left-engine start-valve-open light illuminated, and seconds later there was a fire warning for that engine. The left-engine fire handle was pulled, shutting off the fuel to that engine, and the fire extinguisher bottles were discharged into the engine. The flight crew declared an emergency, obtained the needed clearance, and flew the aircraft back to STL.

Configuring the aircraft for a single-engine approach to landing, the pilots had to deal with multiple aircraft system malfunctions, and they have indicated that they did not have time to complete all of the applicable checklists. Upon turning downwind for landing, air traffic control offered the pilots an immediate landing on Runway 24 or a landing on 30R or 30L. Worried that the flight attendants and passengers would be unprepared for an emergency evacuation if needed, the Captain temporarily suspended the Engine Fire/Damage/Separation checklist to brief the flight attendants. American emphasizes prioritizing all that has to be accomplished and the completion of critical checklists such as the Engine Fire/Damage/Separation checklist before accomplishing less critical items such as briefing of flight attendants.

On the first approach to landing, it appeared to the pilots that the nose gear might not have extended, and the controller confirmed this. Under the circumstances, the Captain decided it would be safer to go around and manually extend the nose gear.

Despite the loss of electrical power, the loss of hydraulic power, the loss of certain flight controls (especially the loss of normal rudder control), the inaccurate and erratic instrument readings, the distraction of the unexpected opening of the cockpit door, the Captain recovered and landed the crippled aircraft with no injuries or deaths and with minimal damage to the aircraft.

On landing, the left-engine fire-warning light was still illuminated, but aircraft rescue fire fighting (ARFF) was present in force and immediately foamed the engine. ARFF indicated to the Captain that there was no significant concern and that they had everything under control. Since there was no smoke or fumes in the cabin, since ARFF saw no reason for an emergency evacuation, and since an emergency evacuation usually results in some passenger injuries, the Captain decided against an emergency evacuation.

Later, in trying to turn on the air conditioning, the First Officer inadvertently pushed the fire handle back in, which dumped fuel into the left engine. This was quickly remedied, but in order to head off any problems from any further fuel dump, ARFF wanted to deplane the passengers before moving the aircraft. The Captain agreed and informed the passengers, who left the airplane without incident using mobile air stairs and were bussed back to the terminal.

The Probable Cause

The probable cause of this accident was the internal deterioration of the air filter for the left engine's air-turbine start valve. This deteriorated filter occasionally restricted or blocked air flow to, and also deposited debris in, the air-turbine start valve's solenoid switcher ball, which caused intermittent failures of the start valve to properly open. These malfunctions required mechanics to manually start the engine. Due to defective design, the manual-override pushbutton, when pressed to its fullest extent, caused damage that, along with debris from the filter element, prevented the solenoid switcher ball from properly seating. The normal peak take-off/climb-out air pressure in the start-valve control-air line forced the switcher ball off its seat and caused an uncommanded opening of the start valve during flight.

The resulting "free run" operation and mechanical distress/failure of the starter generated heat, fire, and/or sparks, and this led to the introduction of jet fuel, engine oil, and/or hydraulic fluid from an undetermined source and location that started an engine fire, which in turn caused associated system components to fail and to feed the fire with additional fuel, oil, and hydraulic fluid.

Contributing Factors:

The failure of the aircraft type certificate holder (TCH) Boeing, and the filter manufacturer, PTI Technologies, Inc., to assign the filter a life-limit or to provide American any recommendation for inspecting, replacing, or tracking the filters aside from cleaning them at aircraft "C" checks.

Boeing not comprehensively revising its Aircraft Maintenance Manual (AMM) to eliminate inconsistent and insufficient directions and recommendations for the availability and use of the manual-override pushbutton for manual engine starts.

Boeing not adding a caution-note to its Dispatch Deviation Guide (DDG) to notify maintenance personnel that use of the manual-override pushbutton was no longer an acceptable procedure for starting engines, and Boeing not issuing a subsequent All Operators' Letter (AOL) to notify maintenance personnel that the DDG had been revised to eliminate use of the manual-override pushbuttons for starting engines.

The failure of Boeing and the start-valve manufacturer PTI to direct the deactivation or removal of the manual-override pushbutton.

The line-maintenance use of a manual engine-start procedure that had not been approved by American.

The relative inconspicuousness of the start-valve-open light on the overhead annunciator panel in the MD80 cockpit, which may have delayed the pilots' recognition of the situation and their accomplishment of the appropriate procedures.

The Air Filter and the Air Turbine Start Valve

The initiating cause of this accident was the internal deterioration of the air turbine start-valve air filter, commonly called the air filter, whose wire-mesh "cloth" element was supposed to prevent particles in the control-air supply line from entering the air turbine start valve's solenoid switcher-ball valve. The NTSB's investigation of the Flight 1400 accident identified this internal deterioration. Materials Laboratory Report No. 08-049 described the Flight 1400 filter element as having "major separations through the cloth adjacent to the braze joints at the fitting and the end cap." The report also discusses seven "exemplar" filter elements, one of which displayed separation through the element. Several of these exemplar filter elements had fractured wires in the outer screens. These fractures revealed oxidation and materials damage consistent with fatigue initiation and propagation, and a consistent failure pattern has been detected on many filter elements.

It is apparent that the filter element design was not adequate for its long-term application and/or that the manufacturing process quality control was deficient, so American has installed new filters on all of its MD80-series aircraft and has instituted new filter-inspection criteria.

This type of filter came as original equipment on MD80s, and neither Boeing nor the filter manufacturer assigned it a life limit. In addition, Boeing's Maintenance Review Board Report and the associated Boeing Maintenance Task Cards on which American's maintenance program is based did not contain any inspection, replacement, or tracking recommendations for the filter. The only recommendation was for the filter elements to be cleaned at aircraft "C" checks. Otherwise, with no life limit, no requirement or recommendation to inspect filters for structural degradation, and with no reports to American of filter-element degradation before Flight 1400, American was not aware of any filter-element degradation issues and did not incorporate a filter-element structural inspection into its MD80 maintenance program. Accordingly, a filter appeared to be a concern only if a pressure check revealed that it was restricting or blocking the control air flowing through it to the air turbine start valve. If a filter passed a pressurized airflow check, it was permitted to be reinstalled. (A mechanic in Chicago made a maintenance-log entry that he had removed and replaced the start valve and the air filter, but the physical evidence indicates that the filter was not replaced, and he has clarified that he replaced the starter valve but reinstalled the filter after visually checking it and, without disassembling it, blowing air through it to test the airflow.)

The start valve has a pneumatically operated butterfly valve and is electrically controlled by a cockpit spring-loaded momentary-on toggle switch operating a solenoid-operated ball valve that directs airflow pressure into a cylinder that opens and closes the butterfly valve as desired by the pilots when starting and stopping the starter turbine, which is used to start the engine. The NTSB investigation has determined that the solenoid ball valve is sensitive to small particles. Honeywell, the manufacturer of the start valve (including its ball valve), has reported to the NTSB that particles as small as 0.0025" can keep the ball from seating properly in the valve. Subsequent to Flight 1400, there was a start-valve problem on another MD80 aircraft, 4YL, at Salt Lake City, that also resulted in a start-valve-open light and an engine-fire warning light during climb-out. The filter in that aircraft was not exposed to any fire, and the start valve was found to have metallic debris from the filter element, which an internal inspection revealed was completely detached from its base. [1]

In any event, on the filter removed after the accident from the left engine of aircraft 454 (the airplane that was being operated as Flight 1400), the internal wire mesh "cloth" was found almost completely deteriorated. This would have been visible only if the filter had been disassembled and inspected internally. Moreover, the mesh had deteriorated to the point that its nickel-sized cap was liberated and allowed to move around inside the filter and to intermittently restrict or block the airflow through the filter. Neither Boeing nor PTI provided American any maintenance-manual procedures for troubleshooting and detecting restriction or blockage of the control-air supply line, and American had not been informed of any previous history of restriction or blockage of the control-air supply line. Consequently, maintenance personnel would not have had cause to suspect restriction or blockage of this line.

In light of the above, there is every reason to conclude that the degraded filter not only did not sufficiently filter out particles that could prevent proper seating of the solenoid ball but also actually deposited in the solenoid ball valve the larger debris of its own deteriorated wire mesh. The mesh's liberated cap also intermittently restricted or blocked the flow of control air to the start valve. All this contributed to a series of start valve problems on aircraft 454 during the weeks before the Flight 1400 accident, and Boeing's MD80 Aircraft Maintenance Manual (AMM) did not provide any guidance for troubleshooting an inoperative start valve after removing it from an aircraft.

When the cap restricted or blocked the flow of control air through the filter, this would keep the start-valve controls from opening the butterfly valve to allow

[1] Because of the newly discovered potential for mesh debris and other particles coming from a degraded filter into a solenoid valve of a start valve, American has adopted a precautionary procedure requiring solenoid valves to be cleaned every time they are removed during aircraft overhaul. In addition, whenever an inspection of a filter finds that it is dirty, the start valve is now to be removed, disassembled, and cleaned.

the flow of primary air needed to run the air turbine that starts the engine. This would require maintenance personnel to open the butterfly valve manually. A mechanic can use a specialized wrench to turn the shaft of the butterfly valve directly, but this approved method requires unlatching and opening the entire forward lower nacelle. This requires several minutes to perform and then requires the mechanic to close this lower nacelle door while the engine is running, and this area is uncomfortably close to the engine inlet.

For these reasons, mechanics apparently sometimes used the start valve's manual-override (manual-start) pushbutton that was, as its name indicates, designed as an alternative means of manually opening the butterfly valve. The pushbutton incorporates a pin that contacts and unseats the ball in the starter's solenoid valve and allows the flow of control air through that valve and into the cylinder that opens the butterfly valve. This manual-override pushbutton can be reached by an easily opened small access door in the nacelle. This button can be pushed with a finger, but it is very difficult to continuously push the button for the full time required (approximately forty seconds) to start the engine. If the pushbutton is inadvertently released during this time, the start attempt must be abandoned and the engine rotation allowed to come to a complete stop before making another start attempt. It is painful to push the button for a full forty seconds with a thumb or finger because the pushbutton has a very small diameter and also because the valve body becomes painfully hot when starter pneumatic air flows through it. Although it was not authorized by American, in order to make more reliable and less painful use of the manual-override pushbutton, mechanics sometimes used a lever to push the button.

The design of the pushbutton allows the button's pin that contacts the ball in the solenoid valve to become bent or to damage the ball when the button is fully pushed in (flush with its housing). This (along with the contamination from filter-element debris or other particles that come from the air filter) can cause the ball to be improperly seated. When the airflow through the solenoid valve builds up pressure, an improperly seated ball can cause the butterfly valve to open when it should be closed. (Accordingly, American is modifying its start valves by shortening the pushbutton to minimize the possibility of damage to the pin or the ball. After this change is made across the fleet, use of the pushbutton will become American-approved.)

The Boeing MD80 Aircraft Maintenance Manual (AMM) did not provide any instructions on how to accomplish a manual start. It provided instructions on how to replace and test an installed start valve and referred to depressing the manual-override pushbutton in one step of the test, and in this connection Boeing cautioned that only hand pressure should be used to push the button during the test. After an engine-fire warning light event in 1996, a similar caution had been included a year later in a Boeing All Operators Letter (AOL) about start-valve procedures, but also without any indication that the manual-override pushbutton should not be used. The AOL stated that the AMM would be revised to include a caution and note to prevent deformation of the pushbutton. In July 1998, the Boeing Dispatch Deviation Guide (DDG) 80-2 indicated that the specialized wrench should be used for manual starts, but again there was no caution not to use the pushbutton, and no service bulletin has ever addressed its use.

Since the DDG controls, and since the AMM's caution-note was never incorporated in DDG 80-2, American did not add the caution-note to American's Maintenance Procedures Manual (MPM) 80-2. In addition, Boeing and Honeywell also never recommended that the pushbutton be deactivated or removed, and from the 1996 event until the Flight 1400 event, there evidently had been no incidents or accidents resulting from any use of the manual-override pushbutton, with or without the use of a lever to push the button. In fact, the Boeing AMM "Description and Operation" section for the engine start valve still contains text that discusses the availability and use of the pushbutton to accomplish manual engine starts.

The Boeing AMM did not contain troubleshooting procedures for start valves and also did not raise the possibility of a failed filter. When an MD80 start-valve presented problems, the mechanics, who had no reason to suspect that the air filter should be changed, would usually just change the start valve. American had no previous line-maintenance history of internally bent pushbuttons or internally degraded air-filter elements, and the Boeing MD80 AMM does not contain troubleshooting procedures for detecting bent pushbuttons or degraded air-filter elements, so replacement of an inoperative start valve with a serviceable start valve was a common (and justified) corrective action. When start-valve problems occurred on aircraft 454 during the weeks before Flight 1400, there were multiple changes of the start valves on 454's left engine. This series of start-valve replacements culminated in the placarding of the start valve (which includes the manual-start pushbutton) as inoperative under the MEL,[2] and the STL mechanic used the specialized wrench instead of the inoperative pushbutton to manually start the left engine for Flight 1400.

The Flight

After the manual start of the left engine, and after the flight crew completed the items on the before-takeoff checklist, the aircraft took off from STL and climbed

[2] This series of start-valve replacements generated ATBTs (Actions To Be Taken) for troubleshooting the wiring on replaced start valves. The troubleshooting was not timely accomplished, but this did not contribute to this accident because, as noted, Boeing's AMM did not contain procedures for troubleshooting the filter and start-valve problems that occurred on aircraft 454.

out. Everything seemed normal until approximately 1,400 feet altitude above ground level, when the flight crew noticed the left engine start-valve light was illuminated, showing that the start valve was open. Seconds later the left engine fire-warning bell sounded, and the left engine fire-warning light illuminated. The First Officer began the Engine Fire/Damage/Separation emergency checklist while the Captain continued to fly the airplane. The Captain said they would have to go back and land at STL, and at his request the First Officer declared an emergency to the air traffic controller and was given appropriate clearances and offered options of several runways for landing.

As directed by the emergency checklist, the First Officer tried to move the left fuel lever to the shutoff position, which would have cut off the fuel at the left engine fuel control. Apparently, the bracket supporting the cable from the fuel shutoff lever had been melted away by the engine fire, and the fuel shutoff lever did not cut fuel to the engine. With some difficulty, the First Officer then pulled the left engine fire handle, thereby silencing the aural fire warning, tripping the left engine generator control relay, closing the pneumatic cross-feed, shutting off the left engine fuel system at the fuel tank, and shutting off the flow of suction fluid to the left engine hydraulic pump. Although both fire extinguisher bottles were then discharged into the left engine, the left engine fire warning light stayed illuminated. By this time, the Captain was turning onto the base leg of the approach to STL, and the First Officer had to quickly address the single-engine approach and configuration requirements. He also performed the mechanical before-landing checklist and handled the radio communications, and he has said there was no time to do anything else.

When the left engine was shut down, the airplane's left generator and electrical bus was lost, causing the loss of the left half of the aircraft's AC and DC electrical system. The right AC system is crosstied to the left AC system and would have normally provided AC power to the left system, but in this situation a fault-detection unit locked it out from the left AC system to keep it from being adversely affected by the left AC bus problems. The left AC bus in turn provides power to two transformer rectifier units that power the left DC electrical system. Since power was lost to the left AC bus, power was also lost to the left DC bus. The cockpit door-locking solenoid is powered by the left DC bus, and the cockpit door came open when the solenoid lost power. This was a significant and loud distraction that the First Officer eventually corrected by closing and securing the door with the manual dead bolt. The Captain also started the auxiliary power unit ("APU"), but its generator did not go on-line, so it did not provide any electricity.

The cockpit instrumentation began to act "strange" and to fail. Some instrument warning lights went on, and others went off. The Captain's and the First Officer's digital flight guidance panels went blank. The Captain's primary flight display and navigation display both went off and on before they stabilized and stayed on, but they continued to give erratic displays. Other instrument readings froze in position (some at zero), were inconsistent with other instruments, or were also erratic. An estimated one-third of the overhead annunciator warning lights were illuminated.

The primary trim for the stabilizer was also not functioning because of the loss of the left generator bus. This was quite distracting because constant pressure was required on the control column to hold altitude as the airspeed changed from the airspeed that the aircraft was trimmed for when electrical power was lost. In a trimmed condition, the aircraft flight controls do not require significant pressure to maintain level flight. In a non-trimmed state, however, constant pressure must be maintained on the control column to maintain level flight. The alternate trim would have been operational, but alternate trim operates at a much slower rate, making rapid airspeed changes difficult.

At some undetermined point, the airplane's hydraulic system began to fail, and the hydraulic quantity gauges were apparently giving inaccurate readings. The loss of hydraulic pressure also precluded normal operation of the rudder. The rudder is normally hydraulically powered, but when hydraulics are lost, a mechanical tab on the rudder is released. This tab is mechanically connected to the rudder pedals and is used to fly the rudder to the desired position. This is a relatively difficult and slow process, and the rudder is not as effective when this process is used. In an engine-out configuration, this would have made control of the aircraft difficult.

Under these circumstances, and since they were in visual meteorological conditions, the Captain decided to fly a visual approach to the airport, and the controller gave them clearance. Because of the multiple and varied systems malfunctions, the Captain elected to hand-fly the airplane to avoid any further complications with control of the aircraft.

The Captain reports that he flew the airplane "with difficulty." This is an understatement, for he was facing a unique situation not in the training syllabus of any airline. This difficulty contributed to the Captain's decision to alter his usual procedure of having the pilot flying the airplane handle the radio communications while the other pilot handled the checklists. It also resulted in the First Officer not receiving all the guidance and feedback that a Captain would provide in normal circumstances.

Worried that the flight attendants and passengers would be unprepared for an emergency evacuation if needed, on the downwind leg the Captain asked the First Officer to temporarily fly the airplane while he quickly advised the flight attendants via interphone about the situation and asked them to prepare for an emergency evacuation if he gave them the appropriate signal after landing. The

Captain then resumed flying the airplane. As he later acknowledged, this did not reflect his training at American that gives priority to completing the engine-shutdown checklist.

The Captain brought the airplane around for the approach to landing. In response to the Captain's request, the First Officer attempted to extend the landing gear, but they did not receive any indication that the gear had extended. They reported that it felt like the main landing gear extended, but despite the absence of a landing-gear-not-extended aural warning, they thought the nose gear had not extended. The First Officer called the tower controller to get his assessment, and although the controller was not immediately available because he was dealing with other aircraft at the time, the controller said it appeared that the main gear was extended but that the nose gear was not. The crew was left uncertain whether the main gear were fully in the down-and-locked position. By this time, the airplane was so close to landing that there was not enough time to emergency extend the gear. The Captain was also concerned that the flight attendants and passengers were not prepared for what would be at the very least a nose-gear-up landing, if not a landing that could potentially result in collapsed main gear. Landing with a collapsed main gear could result in the airplane cart-wheeling and in potential loss of life.

Since the airplane was flying well enough, there were no reports of smoke in the cabin, and the fire was apparently contained in the engine pod at the rear of the airplane (less of a problem than a fire in a wing-mounted engine), the Captain decided it would be safer to go around and manually extend the nose gear (and confirm that extension.)

The Captain felt that there was not enough time for him and the First Officer to get everything done, and he asked a dead-heading captain who had flown the previous flights on this aircraft to join them in the cockpit and assist on public-address announcements and to serve as an extra set of eyes. Since it appeared he would have adequate climb performance, the Captain kept the main landing gear extended on the go-around because he was concerned that they might not come back down if they were retracted.

On the go-around, at the departure end of the runway, the Captain encountered problems keeping the left wing up, and, with the main landing gear down, a manually controlled rudder, and only one engine in operation, the asymmetrical thrust aggravated the situation. As the situation developed further during the go-around, the Captain advised the First Officer that he was having problems maintaining airspeed and climbing. Expressing concern about a right-engine thrust overboost that could cause the loss of that engine too, and with the First Officer checking the power settings, the Captain carefully increased the thrust on the right engine.

The loss of hydraulic pressure kept the flaps from responding to the cockpit settings, and the flaps never moved beyond eight degrees before landing. The pilots did not know what the flaps were actually doing because the electrical problems made the flap gauges difficult to interpret. There are two needles in the flap gage, and one was frozen, making the gauge inconsistent and not credible. As mentioned above, the loss of hydraulic pressure also precluded normal operation of the rudder. The Captain had to resort to using a mechanical linkage to position the rudder tab so that air pressure would force the rudder toward the desired position. This is a relatively difficult and slow process, and the rudder is not as effective when this process is used. The Captain said that the aircraft was hard to turn, and, although they had been unreliable, the instruments then showed the loss of hydraulic pressure not only on the left side but also on the right side, despite the continuing operation of the right engine. The Captain told the First Officer to ask the controller for the longest runway.

After the go-around, the First Officer executed the emergency gear extension checklist to extend and lock down the nose gear. As they approached the base leg, the dead-heading captain made an announcement advising the passengers of the situation and asking them to not be alarmed by the expected fire trucks and to follow the instructions of the flight attendants.

The crew then had a moment to assess the situation, and it was noted that the APU generator had not come online. The APU generator was then reset to bring it online, and this brought power to the left AC bus. The three landing gear down-and-locked lights then illuminated, as did some other lights. The First Officer also checked with the tower controller to confirm that the landing gear was extended. Because of the shortage of time and their familiarity with the single-engine checklist, the pilots did not read out the checklist but discussed the landing speeds for the heavy landing and the configuration needed. The crew re-accomplished the essential items in the before-landing checklist. The Captain reduced power at the end of the approach once the landing was assured. Apparently because nose-wheel steering was not operating properly due to the hydraulic pressure loss, directional control problems occurred when the nose gear touched down, so the Captain used the rudder and also took the right engine out of reverse thrust to keep the airplane on the runway. As the aircraft rolled to a stop, the passengers applauded.

After receiving the engine-fire warning, the pilots flew two patterns (including two approaches to landing) before touching down only eighteen minutes later, not a lot of time by any measure.

Although the Captain and the First Officer both had their hands full with flying the airplane and dealing with multiple malfunctions and an overload of unreliable information from the cockpit instruments, their training at American prepared them to do what needed to be done. American trains its pilots to accomplish all applicable checklists, but American's training has always emphasized the importance of prioritizing the items that need to be accomplished in any emergency situation in order to avoid trying to accomplish too much in the time available and thereby not accomplishing the truly critical items in an unrushed, methodical, thoughtful, and effective manner.

This sequence of events occurred over a compressed period and also was not a scenario that any airline's training anticipates. It involved compound, complex problems with the aircraft, as well as innumerable cockpit warnings, signals, lights, and readings that were either inaccurate or, at best, unreliable. There are always things that should have been done better in any emergency situation, but under the circumstances the Captain did an admirable job of recovering and landing a crippled aircraft with a completely successful outcome -- no injuries or deaths and minimal damage to the aircraft. [3]

Deplaning the Passengers

On landing, the left engine fire-warning light was still illuminated, and the Captain informed the controller that he was stopping the aircraft on the runway. Since the nose wheel steering was not operating properly, he told the First Officer that he guessed they would be towed to the terminal. The dead-heading captain made a public address announcement to the passengers that there had been a left engine fire indication, that the engine had been shut down, that the approaching fire trucks were there to make a precautionary check of the aircraft since there did not appear to be an actual engine fire, and that they should stay seated.

Since neither the flight crew nor the cabin crew had a good view of the MD-80's rear-mounted engines, ARFF was in the best position to assess the nature and scope of any fire. Because the aircraft was on the runway, the flight crew expected ARFF to be on the tower frequency, but the controller told the crew to switch to the ground frequency. Despite some confusion among ARFF personnel and the STL ground controller as to which frequency was to be used and which trucks were authorized to communicate with the aircraft, the ground controller advised the First Officer that the fire trucks were on the ground-control frequency, and the Captain contacted a truck, which informed him that there was still a "little bit" of fire in the left engine. The Captain checked with the First Officer to be sure that he had already discharged both fire bottles into the engine, and he asked for and received confirmation from the fire truck that he had properly understood their previous fire report and that ARFF was spraying foam on it.

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[3] Drug and alcohol testing of flight crews is required by the FAA after an accident, but the NTSB did not classify the Flight 1400 event as an accident until months afterward.

ARFF personnel, who did not use an interphone connection to speak to the Captain, then approached the Captain's cockpit window and motioned for him to open it, which he did. ARFF spoke directly to the Captain through that window. (Because the Captain was speaking out the window, the CVR did not record all his comments clearly.) ARFF never recommended an emergency evacuation. ARFF indicated that they were foaming a small "residual" amount of flame on a piece of fabric hanging below the engine cowling and that everything was secure. (One of the Fire Captains later described the flames as being like the flames on candles.) ARFF appeared to have everything under control. The Captain therefore advised the ground controller that after ARFF had secured the engine, the aircraft would have to be towed due to the absence of nose-wheel steering, etc.

When the ground controller asked if the aircraft was going to be evacuated, the First Officer noted there was no place for anyone to go and that ARFF "had a handle on" the fire.

There was no smoke or fumes in the cockpit, and, because of the open cockpit door and the various communications with the cabin crew in which there were no reports of anything out of the ordinary, the Captain was confident that there was no smoke or fumes in the cabin. Immediately outside the airplane were several fire trucks (some of which would have been in the way of evacuation slides), other emergency vehicles (some of which were moving), and other ARFF equipment, as well as foam. (ARFF had foamed the engine and the rear third of the aircraft both by hose and from two trucks' rooftop turrets, and the Fire Chief in command had determined that "there was no remaining fire in the engine.")

All considered, the Captain concluded that the passengers would be safer staying on board than they would be in an emergency evacuation. The Captain's conclusion was proper and was in accordance with the way pilots are trained at American, which, unlike most other airlines, has a Check Airman Instructor deliver a Human Factors Safety Training class. Each situation is different, but the principles that American has long taught are reflected in American's manuals and in its Flight Operations Technical Informational Bulletin 97-02, which is attached to this submission. American's training of pilots reflects an underlying guiding principle: Consider all available information from inside and outside the aircraft, then, armed with this information, decide whether it is safer to keep the passengers on board or to emergency evacuate. If you decide it is safer for the passengers to remain onboard, continue to assess the situation as it evolves, and revise your decision as needed.

After the Captain inquired, ARFF indicated that the fire was "basically out" and that "everything's good." The Captain then asked if he could taxi in safely, and ARFF responded, "Yeah, we gonna follow ya." The Captain had wanted to taxi the aircraft clear of the runway, but, after further analyzing what hydraulic components were available, he ultimately decided to be towed off the runway.

Mobile air stairs were then brought to the airplane, ARFF personnel came on board and inspected the cabin, and there were announcements to the passengers about this and the status of the aircraft. (At no time during this flight were the passengers panicked or unduly upset.) There were also numerous communications between the flight crew and the cabin crew and among the ARFF personnel while they were waiting for the tug to tow the aircraft clear of the runway to a pad where the passengers could deplane. Throughout, the flight crew discussed the way that the situation had developed, including the multiple instrument failures. Although the after-landing checklist covers relatively benign items and are usually done silently, usually with an oral statement of completion, it was apparently not done. The engine-shutdown checklist is to be done orally after the aircraft is parked at the gate, and this checklist was not done because the aircraft was parked on the runway and because the right engine, which was not seen as a safety threat, was kept running to have both that engine and the APU providing electrical power for lights, cabin air conditioning, etc. In American's view, the flight crew should have followed their training and prepared the aircraft for a potential evacuation if that were later required.

About twenty-five minutes after landing, well after the situation had stabilized and while they continued to wait for the tow tug, the First Officer tried to turn on the air conditioning to cool the increasingly uncomfortable cockpit and cabin by opening the left pneumatic cross-feed. He had forgotten that this would automatically push the fire handle back in (and allow fuel to flow to the engine), and when he saw this happen he pulled the fire handle out again. A few seconds later ARFF yelled in the cockpit window that some fuel was being dumped from the left engine, but the engine and the fuel were quickly foamed preventively, and the fuel spill soon stopped (since the First Officer had already pulled the fire handle and cut off the fuel).

Following a further delay due to an evidently unrelated medical emergency of one of the ARFF personnel, ARFF asked the crew to shut the right engine down, which they did. This was followed by efforts to pin the landing gear so the aircraft could be towed, but then ARFF indicated that, because there was still some heat and smoke coming out of the left engine, ARFF asked the Captain to deplane the passengers before the airplane was moved in case there was a further fuel dump. (The First Officer noted that the fuel dump had been his fault.) The Captain agreed that the passengers should be deplaned.

Buses were brought to the airplane, and the Captain explained the situation to the passengers and told them not to take any carry-on luggage with them when they deplaned down the stairs. The passengers exited the airplane using the stairs at door L1 without incident or injury.

(The CVR recording on this airplane lasted for two hours. The flight crew did not pull the circuit breakers until almost an hour after landing, so their post-landing discussions are included on the CVR transcript.)

American's Post-Accident Actions

Based on what was learned in the investigation of this accident, American has taken aggressive steps to minimize potential problems with the pertinent aircraft systems and components and to modify its own procedures and practices to deal with these problems. A chart of these improvements is attached.

As noted above, because of the concern about the deterioration of the air filters over time, and because American has requested but not received from Boeing or the filter manufacturer, PTI, any data about the filter's failure mode or its lifespan, American has installed new filters on all of its MD80-series aircraft.[4] American has also introduced a requirement for a close visual inspection for degradation of the wire-mesh screens inside the filters when the filters are disassembled for cleaning during "C" checks.

In addition, to prevent an uncommanded opening of start valves, American has revised its Maintenance Procedures Manual to require mechanics to disconnect and cap the control air line whenever a manual engine start is being accomplished. As a further step to head off uncommanded opening of start valves, American has also revised the shop functional test of start valves to include the simulated takeoff condition of 95 psi inlet pressure.

Because of the newly discovered potential for mesh debris and other particles coming from a filter into a solenoid valve of a start valve, American has adopted a new procedure requiring solenoid valves to be cleaned every time they are removed. In addition, whenever an inspection of a filter finds that it is degraded, the control-air line is to be blown clear of debris, and the start valve is to be removed, replaced, disassembled, and cleaned.

[4] The NTSB examined seven of the replaced filters, and PTI examined fifteen others, and they issued reports on their respective examinations. The NTSB microscopically examined all seven of the filters it received and found cracks in some that were invisible to the naked eye. In contrast, PTI's report does not indicate that it microscopically examined all fifteen filters it received; PTI apparently microscopically examined only those filters that had cracks visible to the naked eye.

As also noted above, the start valve's manual-start pushbutton is being shortened by American to eliminate the possibility that merely pushing it in all the way (flush with its housing) will cause any problems with the solenoid valve. This should minimize any concern about the use of a lever to push the button, and this will be an approved procedure.

The checklist procedure for dealing with a start-valve-open light has been revised to make the first three items "red-box" items (steps that must be memorized and taken without reference to the QRH, the Quick Reference Handbook portion of the aircraft operating manual). These items call for disconnecting the auto throttle, throttling back the affected engine to idle, and closing the pneumatic cross-feed valve lever for that engine. The remainder of the checklist calls for an engine shut-down only if the engine is obviously damaged, which is more in line with the Boeing procedure.

American has added to the QRH various caution statements and discussions relating to the operation of the pneumatic cross-feed valve lever, the fire handle, and the hydraulic power transfer unit, and to configuring an aircraft for a potential evacuation.

American has also reprogrammed its MD80-series flight simulators, expanding their capability to include the illumination of the start-valve-open light, which will be given as an optional event in the simulator. (The simulators have also been reprogrammed to present more realistic resistance when the engine fire handle is pulled.)

Currently, the start-valve-open light is an amber light on the cockpit's overhead panel. This is not a conspicuous location, and it is next to other amber lights. Because the pilots need to get notice of an illuminated start-valve-open light so they can immediately throttle back on the engine to prevent overheating of the starter, which can cause a fire, American plans to connect the start-valve-open light to the master caution panel directly ahead of the pilots and in their line of sight.

American has also revised the mechanics' treatment of a start-valve-open light that does not illuminate when the engine is being started. A start-valve-open light can be placarded as inoperative, at which point the mechanics are to remove and cap the control-air line that activates the start valve. This will eliminate any possibility of the start valve opening during flight. Additionally, the period this light can remain placarded has been reduced from ten to three days.

Although neither of the pilots had any failures during American's training and check-rides, it should further be noted that American grounded the pilots until they could be interviewed, given feed-back on concerns about their performance, given additional simulator time for going over the handling of systems involved in this accident, etc. In this connection, the pilots listened to the CVR and provided any needed explanations for their actions.

Finally, American requests that ARFF crews adopt a single, dedicated, common frequency throughout the U.S. for their communications with aircraft in emergencies. In the alternative, ARFF crews should exhibit on their vehicles some signs easily seen from the aircraft's cockpit that show the frequency on which the ARFF crews can be reached.

American-Initiated Improvements – Post-Flight 1400 Engine Fire Event

Date	Document	Description / Comments
1/17/08	ESO 80010	Added procedure to clean ball cage using CMM procedures. This action ensures oil deposits are removed from the solenoid switcher ball and seat area.
3/12/08	MCM Card 7751 / 7752	Revised step 4 to include disassembly and inspection of filter for structural degradation. Record inspection findings. Send unserviceable filters directly to MD-80 Engineering. If degraded filters found, blow line clear of debris and replace start valve. This action removes degraded filters from the control air line and removes start valves that may have been contaminated by filter mesh debris.
5/1/08 – 9/1/08	ECO K3338	ECO directed replacement of all start valve filters with new filters. This action ensures any degraded filters are removed from service.
5/28/08	MCM Card 7751 / 7752	Minor revision to card to N/A the "inspect/clean" step if ECO K3338 accomplished at this visit.
7/9/08	Operating Manual Vol. II, AIR 10.2, CAUTION.	Caution added about the pneumatic crossfeed lever and its direct mechanical linkage to the fire handle: If the pneumatic crossfeed handle is opened after an engine has been shut down with the fire handle, the fire handle will be retracted and potentially re-introduce fuel to the engine.
7/9/08	Operating Manual Vol. II, FIRE 10.2 -10.3, CAUTION.	Caution added about the pneumatic crossfeed lever and its direct mechanical linkage to the fire handle: If the pneumatic crossfeed handle is opened after an engine has been shut down with the fire handle, the fire handle will be retracted and potentially re-introduce fuel to the engine. Caution added about fire handle and the need to ensure it is at full pull travel in order to be able to rotate the handle to fire the bottles.
7/9/08	Operating Manual Vol. II, HYDRAULICS 20.1, Systems Description.	Described how hydraulic reservoir system works so that pilots can understand why the hydraulic-pump reservoir anomaly may occur.
7/9/08	Operating Manual Vol. II, HYDRAULICS 20.2, System Description and Note.	Provided pilots with information on the workings of the hydraulic reservoir system, its safety features, the anomaly that could result in complete loss of hydraulic pressure; and what to expect if the system is lost and recovered.

Date	Document	Description / Comments
8/1/08	Boeing Service Request ID# 1-930363962	American requested Boeing / PTI to specify a life limit for start valve air filter. Awaiting Boeing / PTI response.
8/8/08	ESO 80010	Revised Operational Test to include "Simulated Takeoff Condition" (95 psi inlet pressure) test of start valves. This action checks that the valve will not open uncommanded under actual take-off bleed air pressure conditions.
9/1/08	MPM 80-2	Revised procedure to disconnect and cap "control air line". This action isolates the valve from the control line air source to prevent possible uncommanded valve operation. Called out specialized wrench part number to facilitate accomplishment of task.
10/3/08	QRH, New Red Tab 15, Start Valve Open In Flight Procedure	Changed existing Start Valve Open in Flight procedure. Original QRH procedure was immediate Engine Shut Down. New procedure more in line with Boeing QRH procedure, plus the first three steps of the procedure are now an immediate-action red-box memory item.
10/3/08	QRH, Red Tab 1, Engine Fire/Damage/Separation.	Expanded the information on pneumatic crossfeed lever and its direct connection to fire handle. Due to transfer-pump anomaly, advises pilots to consider shutting off transfer pump when complete loss of hydraulic pressure follows engine failure.
10/3/08	QRH, Red Tab 2, Engine Failure/Inflight Shutdown.	Expanded the information on pneumatic crossfeed lever and its direct connection to fire handle. Due to transfer-pump anomaly, advises pilots to consider shutting off transfer pump when complete loss of hydraulic pressure follows engine failure.
10/3/08	QRH, Hydraulics 5 - 8, Transfer Pump anomalies.	Enhanced the information provided to caution crews about the transfer pump and the need to shut the pump off when one of the systems has lost all hydraulic fluid. Information given on the time to gain a system back after the pump is shut off.
10/3/08	QRH, Preface 7, Emergency Landing or Ditching and Passenger Evacuation.	Put in writing what has always been taught about the need to prepare the aircraft for a potential evacuation after landing following an in-flight emergency when an evacuation is not immediately called for but may inadvertently take place (passenger initiated) or be required as events on the ground progress.

Date	Document	Description / Comments
Begin 1/09	ESO 80010	Replace "long" manual start pushbutton with "short" pushbutton. This action will prevent "over depression" of the pushbutton and associated damage to the thin pin tip.
T/B/D	T/B/D	To improve the conspicuousness of the caution of an open start valve, which is currently an amber light on the cockpit's overhead panel that data shows is not likely to be noticed during takeoff, American plans to connect the start-valve-open light to the master caution panel directly ahead of the pilots and in their line of sight.

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