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CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

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UNITED AIR LINES, INC., DOUGLAS DC-8,
N 8040U, STAPLETON AIRFIELD,
DENVER, COLORADO, JULY 11, 1961

SYNOPSIS

On July 11, 1961, at 1136 M.S.T., a United Air Lines DC-8 crashed during its landing roll at Stapleton Airfield, Denver, Colorado. None of the 122 occupants was severely injured as an immediate result of the impact; however, there were 16 passenger fatalities as a result of carbon monoxide poisoning when the aircraft burned. One other passenger, an elderly woman, broke both ankles during evacuation of the airplane and later succumbed to shock. In addition, the driver of a panel truck, which the aircraft struck after leaving the runway, also suffered fatal injuries.

After experiencing hydraulic difficulties following takeoff from Omaha, Nebraska, the crew of N 8040U continued the flight to Denver, using procedures set forth in the flight manual for abnormal hydraulic situations. When the flight arrived in the Denver area, preparations were made for landing. The ejectors were extended hydraulically, however, when an attempt was made to extend flaps to 25 degrees the hydraulic pressure dropped to zero. The hydraulic system selector was then placed in the No. 3 position (flap and gear downlock), and the approach was continued. After touchdown, the throttles were placed in the idle reverse thrust position and when power was applied, an uncontrollable deviation from the runway occurred.

Subsequent to this accident, extensive modifications to the DC-8 hydraulic system were made mandatory in an Airworthiness Directive issued by the Federal Aviation Agency. Another Airworthiness Directive required that all DC-8 aircraft be equipped with a throttle thrust brake interlock to prevent unintentional application of asymmetric reverse thrust.

The Board determines the probable cause of this accident was the asymmetric thrust which, during a hydraulic emergency, resulted from the failure of the thrust reversers on engines Nos. 1 and 2 when reverse thrust was selected. A contributing factor was the failure of the first officer to monitor the thrust reverse indicator lights when applying reverse thrust.

Investigation

Flight 859 originated in Philadelphia on July 11, 1961, and proceeded uneventfully to Chicago. Captain John Gro[illegible], First Officer Arthur F. Putz, and Second Officer (Flight Engineer) James M. Beatie took over the flight crew duties for the remainder of the trip to Omaha and Denver. Normal preflight preparations were completed at Chicago and the flight to Omaha was uneventful.

At Omaha the aircraft was serviced to a total of 39,000 pounds of fuel. The gross weight was calculated to be 192,901 pounds, which was under the gross takeoff weight for the proposed flight, and the center of gravity was within limits.

After normal flight preparations were completed, ramp clearance was received and the engines were started. The aircraft was pushed back from the loading dock by a tug, and the flight taxied out for takeoff which was at 1012.[1/]

The crew stated all aircraft operations and systems were normal during taxi, takeoff, and climb. As the aircraft reached about 20,000 feet altitude in the vicinity of Wolbach, Nebraska, both the first and second officers said they felt a very slight yaw to the right. At the same instant, the captain said he felt a brief tapping in the control wheel. The crew then noticed the manual reversion lights were indicating the hydraulic boost controls had reverted to manual system and the hydraulic fluid quantity gauge indication was decreasing rapidly. They said they immediately isolated all hydraulic systems by placing the system selector lever in the No. 1 position, and placed engine-driven hydraulic pump bypass switches to the "off" position. The reading on the hydraulic quantity gauge stabilized at the midpoint of the low range of the instrument.

The captain, who had been flying the aircraft manually, turned the controls over to the first officer while he and the second officer evaluated the situation. After consulting the aircraft and operating manuals and a UAL training bulletin, they decided they had an abnormal rather than an emergency hydraulic situation. The captain said he therefore elected to continue to Denver but if he had thought it was an emergency situation he would have returned to Chicago to take advantage of the longer runway at that airport.

The crew said the senior stewardesses in the first class and tourist sections were briefed on the situation and were told they would be informed of any change in conditions in adequate time for any emergency preparations which might be necessary.

During the time the flight was continuing to Denver the crew contacted the company dispatcher and discussed the situation. Air Traffic Control and airport personnel were advised that the condition was not an emergency but that it was abnormal.

The second officer calculated their expected landing weight, maneuvering speed, approach speeds, and threshold speeds for normal flap and no flap conditions. In addition, he informed the captain of the maximum engine pressure ratio data for go-around and reversing.

As the flight progressed toward the Strasburg Intersection, the captain and second officer continued to monitor the situation and review the procedures to be followed during the landing. As a further precaution, after starting descent into Denver, the flight requested permission to hold at 15,000 feet at Strasburg in order to check out the hydraulic system in preparation for landing. Clearance was given to hold at 14,000 feet.

1/ All times herein are Mountain Standard based on the 24-hour clock.

The crew then tried to extend the ejectors[2/] by letting the airstream blow them back. This was unsuccessful even when they increased speed from about 180 knots to 260 knots. This action undertaken by the crew was of no value because the system is designed to prevent, by mechanical means, blowback of the ejectors under aerodynamic loads. After reducing speed again, they turned on the auxiliary hydraulic pump. Pressure built up to 3,000 p.s.i., steady blue lights indicated the ejectors had extended properly, and the hydraulic fluid quantity indicator remained constant.

The captain then called for 15 degrees of flaps. The flap control was placed in the 15-degree detent and the flaps extended. At the same time the slot extend indicator light came on and then went out, indicating that the wing slots were open and locked. The hydraulic pressure gauge indicated 3,000 p.s.i., and the quantity remained constant. After completing the approach descent checklist, the crew requested clearance to the airport. The clearance was received and the captain took over the controls as the aircraft departed Strasburg toward the outer marker. The flap handle was then placed in the 25-degree detent. At this time, the hydraulic pressure fluctuated rapidly and then fell to zero; the hydraulic fluid quantity gauge indication fell to a point about 1/8 inch from the bottom of the scale. The second officer immediately called for the flap handle to be returned to the 15-degree detent and turned off the auxiliary pump. The second officer said he decided at this time that the hydraulic fluid level was just below the taller standpipe of the auxiliary pump supply line.

It was then decided to allow the gear to free-fall, and this was done. The three green landing gear indicator lights came on, indicating that the gear was down and locked. At this time there was zero hydraulic pressure and the quantity remained constant. The hydraulic system selector control was then placed in position No. 3 and the captain said he called for 25 degrees of flap. The auxiliary pump was turned on, the flap handle was put in the 25-degree detent, and the flap extended to 25 degrees. The captain said he had decided to use runway 26L so as to avoid flying over the city and because he could make a flatter approach to the field. After the final checklist was completed, Captain Grosso called for 40 degrees, and 40 degrees of flap was obtained. He announced to the passengers a normal landing was expected and they should not be alarmed at the rescue vehicles which they might see waiting. The captain kept the approach speed at approximately 155 knots so as to be prepared for a no-flap landing in the event that aerodynamic loads should force the flaps to return toward their retracted position. Approximately one-half mile from the threshold he reduced airspeed and called for 50 degrees of flap. The handle was put in that detent and flap extended to 50 degrees. The aircraft crossed the runway threshold at a speed of 125-128 knots and a normal touchdown was made at about 120 knots. It was later determined from the flight recorder data that touchdown was about 1,650 feet from the threshold.

The crew stated that their normal procedure after touchdown was to place all four power levers into the idle reverse position, without command, prior to touchdown of the nose gear. When the first officer felt the nose gear on the runway, and on the captain's command, he would apply reverse power to engines Nos. 2 and 3, and then to Nos. 1 and 4 which could be used differentially for directional control. This, according to testimony, was the procedure followed.

2/ Engine thrust reversing assemblies.

The crew stated that everything was normal after main landing gear touchdown. The power levers were brought to the idle reverse position, and all four amber reverse indicator lights came on. The first officer said as the nosewheel touched down he applied reverse power to Nos. 2 and 3 engines[3] and was reaching for power levers Nos. 1 and 4. He felt the aircraft lurch to the right, looked out the window and saw the aircraft was going off the runway, so he immediately advanced power levers Nos. 3 and 4 to the forward thrust range. He said this action had no effect on the aircraft track, and it continued to skid across the grass strip, turning until it was heading approximately northeast when it hit a newly constructed taxiway and came to rest.

Captain Grosso said that touchdown was normal and that he called for reverse. He said when the nose gear touched down the aircraft swerved to the right. He immediately applied full left brake and full left rudder. The anti-skid foot thumper signal was activated and he eased off brake pressure to prevent loss of hydraulic pressure from the brake accumulator.

When this action failed to straighten the landing roll he knew the aircraft was going to leave the runway. He said he used the emergency airbrakes to slow the airplane as much as possible before leaving the runway. He said that just after the aircraft left the runway he heard a loud snap and felt the aircraft drop right wing down. The aircraft then continued to skid off the runway, turning to a northeasterly heading before hitting the raised concrete taxiway.

The second officer said he had been instructed by the captain to watch only the flap indicator during the approach and to warn him immediately if the flaps started to come up. He was further instructed to swivel his seat immediately to the side upon landing and to call out brake accumulator pressures. He said the approach and landing were normal. The second officer said that after touchdown a series of events occurred which he could not place in sequence with any degree of certainty. He saw ejector indicator lights blinking, heard a foot thumper, saw the captain reach for the emergency airbrake handle, and saw that the aircraft was heading about 30 degrees off the runway. The last brake accumulator pressure he recalled seeing was 2,200 p.s.i.

As the aircraft skidded across the grass strip between the runway and new taxiway, the second officer unbuckled his seat belt and started back to the passenger loading door, anticipating an emergency evacuation of the aircraft. A violent lurch of the aircraft pitched him into the observer's seat but he regained his footing and proceeded to the forward passenger loading door, arriving there about the time the aircraft came to rest on its belly. After opening the door and installing the emergency slide he began to help passengers to the exit. He noticed a fire burning on the left side of the aircraft and the cabin beginning to fill with smoke.

The first officer and two male passengers jumped to the ground from the forward loading door and held the uninflated slide to assist other passengers out of the aircraft. Meanwhile, the captain and second officer were making repeated trips into the smoke-filled cabin to assist passengers to the exit. Finally the captain and second officer could find no other passengers in the first-class section. By this time the flames completely covered the front passenger loading door.

3/ The first officer subsequently stated that he had not noticed the amber indicator lights and did not apply any reverse thrust on any engine.

The senior stewardess in the first-class section described the motions during landing as a turn to the left and then to the right. When the aircraft had come to rest, she got up to open the galley door but saw flames outside to the right of the fuselage and therefore did not attempt to open this exit. She then went back to ensure that the divider door between the first-class and tourist sections was open. The stewardess was attempting to lift a paralytic passenger out of his seat when the second officer came up to assist. She then assisted other passengers through the emergency over-the-wing exits until the second officer told her to get out of the airplane.

The junior stewardess in the first-class section said she hooked the forward loading door emergency slide and then got out to assist passengers.

The senior stewardess in the tourist section described the landing as the hardest she had ever experienced. The stewardesses opened the rear galley exit and installed and inflated the emergency slide. They then assisted passengers out and away from the burning wreckage.

Several goundwitnesses, some of them pilots, who saw the aircraft during landing stated that the approach appeared to be normal. They said that the wings were level, and the touchdown, accompanied by blue-white smoke from the tires, was normal.

One witness said the aircraft rolled straight down the runway for a distance of 700 to 800 feet and then started to swerve to the right with the left wing higher than the right. This witness also said he had the impression there was considerably more black smoke on the right side than on the left.

Another witness described essentially the same thing except he did not see any black smoke from the aircraft. In addition, he added that, as the airplane swerved off the runway, the left wing lifted quite high.

One passenger who was seated in the forward lounge had a good view of engines Nos. 1 and 2. He said he heard the power cut and the aircraft touch down on the runway with what he described as a hard landing. He said he also felt the nose gear touch down and immediately thereafter heard power reapplied. This witness stated positively that the thrust reverser buckets on both 1 and 2 engines did not close. At the time he heard the sound of power he had the impression of acceleration and thought the pilot was executing a go-around. He said the aircraft then swerved and he could see they were going off the runway.

As previously mentioned, the crew had alerted ground personnel of the abnormal situation. Under such circumstances the airport firefighting personnel are alerted and the fire trucks take up standby positions on the ramp near the passenger terminal. In accordance with this plan the fire trucks took up these positions. The aircraft came to rest approximately one mile from this point. There was substantial variation in the estimated elapsed time between the accident and the firefighting personnel being in position to fight the fire. Eyewitness estimates of the elapsed time prior to the arrival of the first fire trucks varied from 5 to 10 minutes, and up to 15 minutes before any effective equipment was in position.

The members of the Stapleton Airfield firefighting crews stated that their equipment was moving to the airplane before it had come to rest and that foam and fog were being applied to the fire within one to two minutes. The Aurora Fire Chief, who had been notified by the Aurora Police Department, said his equipment arrived at the scene about 6 to 8 minutes after the crash. He also said that when he arrived the Stapleton crew was already fighting the fire. Lowry Air Force Base and Buckley Field had been advised of the accident immediately and had dispatched their firefighting and rescue personnel to the scene. Their equipment arrived within about 15 minutes and also assisted in fighting the fire. It was estimated that it took approximately 30 minutes to bring the fire under control.

Investigation revealed that the airplane had slid in a curved path to the right, off the runway, across a grass strip, hit the raised edge of a newly constructed concrete taxistrip, and had come to rest on the taxistrip about 4,950 feet from the threshold of runway 26L and 400 feet to the right of its centerline. Tire marks on the runway were clearly visible as were the tracks across the intervening grass strip. It could be seen that the path of the aircraft over the ground curved from a westerly to a northwesterly heading while the aircraft's heading changed from approximately 260 to 026 degrees magnetic.

All four tires on the right main landing gear were blown out. The skid marks made by these tires were visible continuously, curving off the runway to the right and across the grass section to the point where the gear failed and separated from the aircraft. The marks left on the runway by the left main landing gear tires were intermittent and were not discernible as the aircraft curved off the runway and across the grass section. Three of the tires blew out during the skid and the fourth, the forward outboard, was ruptured by impact with the taxiway after the left gear had failed and separated from the aircraft. The tracks left by the nose gear tires were identified on the runway and into the grass to the point where this gear failed and separated from the airplane. An additional track to the right of the gear track through the grass divider was determined to have been made by the No. 4 engine nacelle.

The No. 1 engine was torn from its pylon at the lower firewall. The engine and nacelle were found under the forward left baggage compartment and had sustained severe fire damage in addition to the impact damage. The low pressure (N_1) compressor blades and vanes showed no evidence of rotational damage. The high pressure (N_2) compressor had extensive blade and stator damage from the 12th to the 15th stage. Severe damage was noted to all turbine wheels. All blades were broken but no evidence of overtemperature conditions was found. The sound suppressor was crushed into the nozzle case. The thrust reverser was separated from the aircraft and the thrust reverser buckets were in the forward thrust position. The thrust brake selector valve was extensively damaged; however, it was possible to determine that it was in the reverse thrust position. The lower portion of the pylon was consumed by ground fire except for the ejector actuator and its steel and titanium fittings. The ejector actuator was fully extended. All damage to the engine appeared to be the result of impact and/or fire.

The No. 2 engine, which separated from the aircraft, apparently passed under the forward portion of the fuselage and came to rest about 40 feet to the right of the nose. This engine sustained light-to-moderate fire damage but severe impact damage. Rotational damage to the N_1 rotor was moderate with damage confined to the first and second stages of the compressor. The N_2 compressor was intact and undamaged and could be rotated freely. All blades of the turbine wheel assemblies were broken and bent opposite to the direction of rotation, however, there was no indication of overtemperature or in-service damage. The sound suppressor was separated from the engine and severely damaged by impact. The thrust reverser, which also separated from the aircraft, and the thrust brake selector valve were found in the open or forward thrust positions. All damage appeared to be the result of impact and/or fire.

Engine No. 3 was twisted outward on its pylon, and the structural attachments failed by impact. There was no fire damage and only light impact damage to the engine. The N_1 and N_2 compressors were intact and rotated freely. All turbine wheels and blades were also intact and the wheels could be rotated freely. The thrust reverser was separated from the aircraft. The thrust brake selector valve was positioned for forward thrust. All accessories were intact and appeared to have been lightly damaged from impact.

The No. 4 engine was located about 175 feet to the right of the aircraft. It had sustained light-to-moderate impact damage but no fire damage. The first stage of the N_1 compressor had its heaviest damage and greatest blade and vane interference between the 5 and 7 o'clock positions. The N_2 compressor was intact and could be rotated. The turbine wheel assemblies were intact with no over-temperature indications. The sound suppressor was crushed into the turbine exhaust case. The thrust reverser, which had sustained light damage, separated from the aircraft and was found aft of the right wing. The thrust reverser buckets were in the forward thrust position and the thrust brake selector valve was also positioned for forward thrust. All other damage appeared to have resulted from impact.

No evidence was found in any of the four engines to indicate any in-service failures of bearings, gear trains, accessories or accessory drives.

The cockpit power lever positions, as noted at the scene, were: No. 1 - slightly off reverse idle in reverse direction; No. 2 - full forward thrust; No. 3 - forward idle position, reverse lock down; and No. 4 - idle reverse. The fuel shutoff levers were off, except No. 3, which was one inch from the off position.

The extensive fire after impact destroyed a major portion of the left wing and left side of the fuselage from the cockpit area aft to the rear passenger loading door. In addition, the entire inside of the cabin was gutted. The fuselage area aft of the rear passenger loading door was crushed inward, due to contact with a surveyor's panel truck parked 300 feet from the runway centerline. In addition, the force of this impact distorted the lower frame of the loading door and rendered this exit inoperable from the inside.

It was determined that the landing gear was down and locked prior to separation from the aircraft. It was also determined that the main landing gear doors were open at impact. The flap sections were extended symmetrically to 50 degrees and the wing slots were open. The ground spoilers on both wings were in the retracted position. The in-flight spoilers on the right wing were also retracted; however, the left wing in-flight spoiler actuating cylinder piston was fully retracted, corresponding to the spoiler extended position.

Both left and right wings were still attached to the fuselage, however, the left wing was largely consumed by fire. There were very few scrape marks or gouges on the lower skins and relatively few dents or buckles. The bottom of the right wing was ruptured spanwise about 4 or 5 feet. This damage permitted the remaining fuel in the affected tank to drain onto the ground. Fire damage on the right wing was confined to the trailing edge and flap. The empennage was intact and the control surfaces undamaged.

Because of the nature of the original en route difficulty encountered by the flight, attention was concentrated on the entire hydraulic system. All existing lines and actuators were documented on the scene. Many were then shipped to the UAL Engineering and Overhaul Base in San Francisco for detailed study by the Board.

The hydraulic reservoir was found intact. On disassembly it was found that the heat of the ground fire had left a mark on the inside of the reservoir in such a manner that it was possible to determine the height of liquid in the tank at the time of the heat application. This mark represented a quantity of 3.37 gallons. In addition, the quantity gauge float assembly evidenced the same type of marking, indicating it was half submerged in fluid. It was found that downward movement of the float arm was restricted by interference with a baffle plate due to insufficient clearance. As a result, a decrease in the hydraulic fluid quantity would not be reflected on the quantity indicator at the flight engineer's station.

The Nos. 1, 3, and 4 ejector control valves were ported to the extend position. The No. 2 ejector control valve was not found.

All wheel brakes and associated components were examined for evidence of malfunction. Nothing was found to indicate any such difficulty. Brake clearances were within prescribed limits. Hydraulic actuators, anti-skid controls, and air-brake controls were in an operable condition except for damage caused by separation of the landing gear from the aircraft.

The torque link apex bolt of the left landing gear assembly and the upper portion of the landing strut pistons were broken. These breaks were examined and found to have been caused by impact forces. There was no evidence of fatigue, corrosion damage, or defective material. The entire right landing gear was separated from the airplane. The torque link on this assembly was intact. The bogie lock mechanisms on both main gears were undamaged and in the locked position.

The nose gear and strut were torn from the aircraft. The right nose steering cylinder was bulged. The left nose steering cylinder had separated from the cap at the threaded connection. Hydraulic lines to both cylinders were intact between the gland valves and cylinders. The nosewheel steering control valve and inlet check valve restrictor unit were intact.

All other systems of the aircraft were examined. Although extensive damage occurred during breakup and fire, no evidence was found to indicate malfunction of any of the systems. Fire damage to the No. 2 engine-driven hydraulic pump rendered it inoperative and it could not be tested. The No. 3 pump was found to be undamaged and operated within allowable limits during functional bench test. In the feathered or bypass, position the pump produced a pressure of 350 p.s.i., and a rate of flow of 6 gallons per minute.

During the investigation the possibility of reverse nosewheel steering was encountered. To demonstrate this condition, a simulated loss of system pressure and a failure of the nosewheel steering inlet restrictor check valve were required.

In static tests with the torque link disconnected, pressure line disconnected at the control valve, control valve neutral, and nosewheel steering accumulator charged, there was no movement of the steering collar. With left rudder pedal movement, the collar rotated to the right and with right rudder pedal movement the collar rotated to the left, indicating a reversed steering condition.

Taxi tests were then conducted at 80 and 118 knots. In these tests a momentary movement of the nosewheels of two or three degrees opposite to the rudder movement was noted. However, in all cases, directional control of the airplane was easily maintained with brakes or rudder. It was subsequently determined that, in any event, the inlet restrictor check valve from N 8040U was capable of normal operation.

An extensive investigation of the crash injury and emergency evacuation aspects of this accident was conducted. It was learned from the survivors and from the pathological study of bodies that the deceleration of the airplane was not excessively high and that no apparent traumatic injuries were sustained by the crew or passengers as a result thereof. Sixteen of the deceased were found in the fuselage after the fire was brought under control. These fatalities resulted from carbon monoxide poisoning. One passenger, an 87-year old woman, broke both of her ankles during the evacuation of the airplane and subsequently died in the hospital as a result of shock. The other fatality was an individual who was part of the groundwork force on the airport when the airplane hit the panel truck during its ground slide.

The crew members opened the forward left main entrance door and the aft right galley door, while passengers opened both of the overwing exits on the right side of the cabin. Through these exits 106 of the occupants evacuated the airplane. All of the 39 first-class passengers, three flight crew members, and two stewardesses evacuated through the forward lefthand door or through the overwing exits. Sixty-two of the 78 occupants of the tourist section evacuated the airplane utilizing the two door exits and the aft overwing exit on the right side. The entire evacuation was complicated by the dense smoke throughout the cabin.

The Denver weather at 1140, four minutes after the accident, was: Measured 5,000 feet broken, 19,000 broken, high overcast; visibility 40 miles; temperature 73F; dewpoint 48F; wind north-northeast 7 knots; altimeter setting 30.10 inches.

Analysis and Conclusions

The hydraulic system of the DC-8 consists of many component parts, actuating units, connectors, seals, hoses, and many feet of tubing running throughout the aircraft. The crash and fire damage sustained by N 8040U was so extensive that it was impossible to determine where the failure occurred which resulted in the initial loss of hydraulic fluid. As to the source of the leak, it is possible to eliminate various systems which were either isolated by the crew or were not utilized in normal flight.

The powered aileron and rudder systems were isolated and the horizontal stabilizer trim system was not used. The bogie unlock system was isolated by the control valve being closed. The power brake valve isolated the hydraulic brake system. When the auxiliary hydraulic pump was operated, the fluid loss continued; therefore, the leak probably was not in any of these systems. In addition, one-way check valves in the hydraulic system normally prevent auxiliary pump pressure from entering the engine-driven pump hydraulic lines. Thus it can be seen that the leak probably was not in these lines or in the engine-driven hydraulic pumps.

The systems which could not be isolated were the bogie trim, the landing gear retract, the ejector control valve and actuator, the inboard spoilers retract, the wing flap up, the wing slots closed, and the main landing gear door actuators on the closed side. Any one or more of these could have been the source of the loss of fluid because they received hydraulic pressure from the general system any time it was available.

Following the initial loss of fluid the crew reported that the hydraulic quantity indicator was about 1/8 inch from the bottom of the gauge. The hydraulic reservoir holds 10 gallons of fluid but the minimum fluid level which the float transmitter in the tank will sense is 3.5 gallons. The quantity gauge dial presentation consists of an arc of 120 degrees with a "low" and "normal" segment, the low end representing the 3.5-gallon level and the high end representing the 10-gallon level. A change of one gallon of fluid within these limits would be reflected by 18.5 degrees of movement of the quantity indicating needle.

When the crew extended the ejectors no change occurred in the indicated fluid quantity level, although about 3/4 gallon of fluid would be removed from the reservoir. Also, when the landing gear was allowed to free fall, about 1.6 gallons of fluid would have been returned to the reservoir, yet no increase was registered on the quantity gauge. From these indications it appears that the hydraulic fluid level must have been below the lowest level measurable by the float transmitter.

It also appears that the inability to get 25 degrees of flap was because the fluid level at that time was below the taller standpipe supplying fluid to the auxiliary hydraulic pump inlet.

The procedures followed by the crew to prepare the aircraft for landing were the approved procedures based on the information available to them during the flight. The shift to the No. 3 position of the hydraulic system selector was proper and necessary to ensure positive flap actuation during the approach. In this position there was no pressure available to the general hydraulic system, which powered, among others, the ground spoilers, nosewheel steering, and the rudder. Hydraulic braking was available from the brake accumulator.

The ejectors were fully extended and remained so during the approach, as evidenced by the four steady blue lights of the ejector indicating system. The evidence available to the Board indicates that after touchdown the thrust reverser buckets on the left side of the airplane did not rotate to the closed position. As stated before, one passenger watched the ejectors and stated that the buckets did not close. These buckets must be closed to deflect engine thrust in a forward direction. They are actuated by engine bleed air which is directed to the bucket by means of a pneumatic gland coupling when the ejector is fully extended. The gland coupling consists of a connector on the engine pylon and a slide valve mounted on the ejector which mate and compress about 3/8 inch for complete coupling when the ejector mechanism extends to the full aft position. If an ejector does not extend fully or if it should move forward as much as 3/8 inch, its gland coupling will not be engaged and the thrust reverser buckets will not close.

Normally the ejectors are operated hydraulically. There is also an emergency provision for extending the ejectors by use of the air bottle system. That system was not used. Also, the two methods are essentially similar with compressed inert gas being substituted for hydraulic fluid under emergency conditions. Each ejector mechanism has a control valve which ports system pressure to its actuating cylinder to extend or retract the ejector. Each control valve incorporates two spring-loaded poppet plunger type valves which are solenoid actuated alternately to either extend or retract. These valves are tested prior to service to operate with 3,000 p.s.i. applied and the leakage rate, after a three-minute seating time, to be within specific limits. During this test, leakage is greater at low pressure and decreases as higher pressures tend to seat the poppet valves more solidly. For this reason, following loss of system pressure, the unseating tendency will permit internal leakage to the return lines. Any internal leakage of an ejector control valve, under these conditions, has the same effect on the adjacent system. This is because both ejector control valves, on either side of the aircraft, are supplied by a common pressure line which incorporates two opposing one-way check valves. One check valve permits the introduction of fluid pressure and the other permits high pressure air to be introduced as an alternate method of ejector operation. Any leakage by either the one-way check valves or the ejector control valves will relieve the hydraulic lock feature which is designed to hold the ejectors in the extend position when system pressure is lost, and permit both ejectors on the same side of the aircraft to move forward from applied forces. These forces include pressure in the system return lines, aerodynamic loads, and the forward shifting tendency upon touchdown and during rollout.

From crew testimony it appears that the blue lights for the ejector indicating system were on steady, indicating all ejectors fully extended, until the aircraft was on the runway. At the time of touchdown on the runway, the second officer recalled seeing ejector lights blinking, indicating one or more ejectors were in transit.

A representative of the aircraft manufacturer testified that at high airspeed the aerodynamic loads acting on the ejector are in the aft direction. He also said that at speeds of about 120 knots in the approach configuration these aft acting loads would be negligible.

Based on all the foregoing information the Board believes that the ejectors for engines Nos. 1 and 2 did shift forward after touchdown and prior to the positioning of the power levers in the idle reverse detent. It is also believed that the amount of forward movement was so slight as to be unnoticeable to the passenger observing, but sufficient to disengage the pneumatic gland coupling. As a result, when the crew positioned the power levers for reverse thrust, the thrust reverser buckets were not closed. This allowed engines Nos. 1 and 2 to develop forward thrust while engines Nos. 3 and 4 were producing reverse thrust during power applications.

There is also recorded evidence of asymmetric thrust during this landing. The flight recorder trace contained unusual fluctuation in indicated altitude beginning about 6 seconds after touchdown. Examination of many other altitude traces made during normal landings of DC-8s disclosed no example of similar aberrations; however, on detailed readouts the altitude traces of two DC-8 landings in which asymmetric reversing occurred exhibited almost identical aberration of indicated altitudes. These landings involved EAL Flight 841 at Miami, Florida, on July 12, 1961, and UAL Flight 855 at Chicago, Illinois, on June 14, 1960.

The rapidly fluctuating indicated altitude, while the airplane is at constant altitude, obviously results from the asymmetrically disturbed airflow at the static ports during asymmetric reversing. On the DC-8 this causes pressure fluctuation in the static pressure line.

In order to understand clearly the sequence of events which took place during this landing, a comprehensive analysis was made utilizing flight recorder data, tire skid marks, and crew statements. This was conducted in two phases, static and dynamic.

The static phase was initiated by relating the aircraft's flight recorder heading data to the path indicated by the ground survey. Since agreement between these two independent sources of information was good, the groundpath was judged to be a reliable basis for the analysis. The aircraft heading change with respect to time yielded the yaw rate from which angular acceleration about the aircraft's center of gravity was obtained. Using this angular acceleration and the moment of inertia of the aircraft about its vertical axis, the net yawing moment was computed By utilizing a plot of net yawing moment versus time, it was possible to evaluate the magnitude, direction, and time of occurrence of the applied yawing moments acting during this landing. An examination of this plot revealed that at 3 seconds after touchdown, a smoothly increasing, nose-right yawing moment began and developed to a maximum value of 200,000 foot-pounds at approximately 6 seconds. Between 7 and 8 seconds a nose-left yawing moment developed to a value of 400,000 foot-pounds, but was of insufficient duration to arrest the right turn to any appreciable degree. By 10 seconds a nose-right yawing moment had developed to a maximum value approaching 1,000,000 foot-pounds.

The above results, considered in conjunction with crew statements, led to the following assumptions which were used in the analog computer study·

1. At touchdown an unbalance of forces to the right developed.

2. Rudder control and asymmetric braking were applied 6 seconds after touchdown.

3. Aerodynamic braking was applied about 8.5 seconds after touchdown.

4. A large, unbalancing yawing moment developed after 8 to 10 seconds from touchdown, forcing the aircraft to the right and off the runway.

5. Roll due to yaw created a right wing-low attitude of about 8 degrees, approximately 11 seconds after touchdown.

The second phase or dynamic portion of the analysis was then conducted utilizing an analog computer to compare the information derived from the static analysis with a variety of landing conditions which might possibly have led to the accident The information for these simulated landing conditions was obtained from engine manufacturer's and flight test data. These simulated conditions, in all feasible combinations, included the effects of forward and reverse thrust situations, rudder and wheel brake applications, aerodynamic braking, and induced rolling moment.

From the results of these studies, as well as other information available to the Board, it is concluded that:

1. All four engines were at or near idle forward thrust at touchdown.

2. All four power levers were placed in their reverse idle detents 2.5 to 3 seconds after touchdown.

3. The thrust reversers for engines Nos. 1 and 2 were inoperative.

4. Maximum continuous thrust was initiated on the inboard engines 5 seconds after touchdown.

5. Full manual rudder control and differential braking were initiated 5 to 6.5 seconds after touchdown.

6. Maximum continuous thrust was initiated on the outboard engines 5.5 to 6 seconds after touchdown.

7. The application of maximum continuous power to all engines resulted in high asymmetric thrust forces causing an uncontrollable lateral deviation from the runway.

The Board has studied four other occurrences involving DC-8 aircraft which left the runway on landing rollout. In one of these cases an outboard engine thrust reverser did not operate properly and the thrust reverser buckets blew open. The other cases involved loss of general system hydraulic pressure and other common factors. It is believed that all of these aircraft left the runway as a result of asymmetric thrust. In one of the cases the cabin steward was watching the thrust reverser buckets and stated that they did not close on the landing roll. In the other cases the crew members did not recall noticing the lights which indicated that the thrust reverser buckets were closed when reverse thrust was selected.

From all the evidence it is concluded that in the subject case the first officer applied reverse thrust without checking to see if the amber thrust reverser indicator lights were on. The normal procedure for reversing requires that these lights be on before increasing power for reverse. Subsequent to the accident the need for close monitoring of these lights was re-emphasized by the company.

The crew's original diagnosis of the trouble was correct in that an abnormal hydraulic situation existed. Very shortly after departing the holding pattern at Strasburg en route to runway 26L, the abnormal situation abruptly developed into an emergency condition without the crew being cognizant of the fact. This occurred when 25 degrees of flap was selected with the hydraulic selector in the No. 1 position. When the complete loss of hydraulic pressure occurred, the crew should have been aware that an emergency situation had developed and that a normal landing could not be expected.

As a result of this accident the manufacturer made several modifications to the DC-8 systems. These modifications, some of which were instigated by the Civil Aeronautics Board, were made mandatory by the Federal Aviation Agency through the issuance of Airworthiness Directives. These included: a dual source of hydraulic power for actuation of all wing spoilers during landing roll; increased brake accumulator capacity; a dual source of hydraulic power for the rudder power system; a source of power to actuate nosewheel steering when the airplane hydraulic system is being operated with the hydraulic system selector handle in the No. 3 position;

additional hydraulic fluid reserve capacity with changes in the fluid reservoir quantity indicating system; dampers wherever necessary in the hydraulic system to limit pressure surges to acceptable levels; and the installation of a power lever thrust-brake interlock system to prevent application of reverse thrust until the thrust reverse buckets are in the reverse thrust position. This interlock also is designed to return a power lever to the idle detent position should the corresponding buckets move from the reverse thrust position.

Probable Cause

The Board determines the probable cause of this accident was the asymmetric thrust which, during hydraulic emergency, resulted from the failure of the thrust reversers on engines Nos. 1 and 2 when reverse thrust was selected. A contributing factor was the failure of the first officer to monitor the thrust reverse indicator lights when applying reverse thrust.

BY THE CIVIL AERONAUTICS BOARD:

/s/ ALAN S. BOYD
Chairman

/s/ ROBERT T. MURPHY
Vice Chairman

/s/ CHAN GURNEY
Member

/s/ G. JOSEPH MINETTI
Member

/s/ WHITNEY GILLILAND
Member

SUPPLEMENTAL DATA

Investigation and Hearing

The Civil Aeronautics Board was notified of this accident shortly after it occurred. An investigation was initiated in accordance with section 701(a)(2) of the Federal Aviation Act of 1958. A public hearing was held in Denver, Colorado, September 20, 21, 22, 25, and 26, 1961.

Air Carrier

United Air Lines, Inc., holds a currently effective certificate of public convenience and necessity issued by the Civil Aeronautics Board and an air carrier operating certificate issued by the Federal Aviation Agency. These authorize operation over a number of routes including the one here involved.

Flight Personnel

Captain John Grosso was employed November 5, 1940, and promoted to Captain February 16, 1945. He had a total of 17,631 flying hours, of which 168 were in the DC-8. He holds a currently effective airline transport pilot certificate with a type rating in the DC-8. His last first-class FAA physical examination was January 17, 1961.

Mr. Arthur F. Putz was employed by United Air Lines August 18, 1948, as a flight engineer. He qualified January 11, 1951 as a first officer and was promoted to captain September 25, 1959. He had a total of 9,839 flying hours, of which 1[illegible] were in the DC-8. He holds a currently effective airline transport pilot certificate with type ratings in the CV-240, CV-340, and CV-440, and the DC-6 and DC-7. His last first-class FAA physical examination was June 12, 1961.

Mr. James M. Beatie was employed September 11, 1946, as an apprentice mechanic. He became a line mechanic July 24, 1950, and was assigned as a flight engineer January 25, 1951. He has a total of 8,416 flying hours, of which 215 were in the DC-8. He holds a commercial pilot certificate and instructor's rating as well as a flight engineer's certificate. His latest second-class physical examination was January 31, 1961.

All four stewardesses had satisfactorily passed the carrier's ground training course in emergency procedures.

The Aircraft

N 8040U was manufactured June 10, 1961, and had accumulated a total of 124:39 hours up to July 10, 1961. No major checks had come due on the aircraft. All flight log discrepancies had been corrected with the exception of one item - July 10, 1961, reverse slow on No. 3. This item was carried as deferred. The powerplants installed on the aircraft were Pratt & Whitney model JT3C-6 and all had accumulated 124:39 hours except No. 1, which had a total of 499:31 hours.