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CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

ADOPTED: September 15, 1959 **RELEASED:** September 20, 1959

EASTERN AIR LINES, INC., LOCKHEED 1049G,
N 6240G, MIAMI INTERNATIONAL AIRPORT
MIAMI, FLORIDA, JANUARY 17, 1959

SYNOPSIS

About 1623, January 17, 1959, Eastern Air Lines Flight 704 made an emergency landing on runway 9R of the Miami International Airport. The landing was made because of an engine failure and uncontrollable fire immediately after takeoff. Of the 5 crew members and 12 passengers, one passenger received minor injuries. The aircraft, a Lockheed 1049G, N 6240G, was badly damaged by inflight and ground fire, and by impact when the right main gear collapsed.

It is the Board's analysis of this accident that the No. 3 engine failure resulted from an initial failure of a connecting rod, probably No. 10. It is believed that during the engine failure progression an abnormal exhaust flame occurred which ignited a flammable discharge from the outboard breather exit of the engine. The resulting flame then penetrated the aluminum wheel well doors igniting a fire in zone 3-A of the nacelle, an area not presently serviced with fire extinguishing agents or fire detection.

As corrective measures the Board has recommended to the Federal Aviation Agency that consideration be given to a requirement that zone 3-A be serviced with fire detection and extinguishing equipment; also, that action be taken to insure that an abnormal exhaust flame cannot ignite an unusual breather discharge. The Board further recommended that the wheel well doors be replaced with those made of fireproof materials.

In connection with the accident, the Board investigated and found the Dade County Port Authority Airport rescue and fire-fighting department deficient because of a lack of equipment capability. The Board was informed that this deficiency will soon be corrected by additions to the equipment.

Investigation

Eastern Air Lines Flight 704 is a daily nonstop flight from Miami, Florida, to Detroit, Michigan, scheduled to originate at 1555[1/] and terminate at 1948. On January 17, 1959, the assigned flight crew consisted of Captain James W. Rush, Pilot Robert P. Harkless, Flight Engineer Russel E. Eshbach, and Flight Attendants Esther M. Tharpe and Wanda Carr.

1/ All times herein are eastern standard based on the 24-hour clock.

The necessary documents preparatory to the trip were completed in a routine manner and well in advance of flight time. A review of these papers showed they were complete and properly executed. The flight plan showed the flight was planned in accordance with instrument flight rules, although weather conditions at Miami were clear except for a few distant cumulus clouds and the visibility was 12 miles. The load manifest showed the gross takeoff weight of the aircraft was 107,776 pounds; the maximum allowable weight for takeoff for the proposed operation was 124,310 pounds, and the maximum weight for landing was 124,310 pounds. The load was properly distributed.

Flight Engineer Eshbach performed a preflight inspection of N 6240C. He stated that while inspecting the right main landing gear wheel well and No. 3 nacelle area he found a considerable amount of oil accumulation in the wheel well and streaking the sides of the nacelle and wheel well doors. The engineer said the oil accumulation and streaking was quite normal and in characteristic patterns from the No. 3 engine and engine breather exits. He said the same conditions existed in and around the left wheel well and were normally existent on all aircraft of this model and make. The flight engineer added that he found some hydraulic fluid on the right main gear strut. This was not unusual because the right strut was repacked during an 18-hour layover period for the aircraft before Flight 704. He stated that his preflight was complete and he was satisfied there were no leaks.

At 1559 Flight 704 received taxi clearance to runway 27R for takeoff. The distance involved was short; however, because of heavy traffic, both ground and air, it was about 20 minutes before Flight 704 was No. 1 for departure. The crew members stated that during this time, while in runup position, a thorough and satisfactory pretakeoff check was made and, because of the delay, a plug defouling and burnout procedure was accomplished.

Pilot Harkless made the takeoff at 1621. All crew members said that powerplant response was normal and the aircraft accelerated properly. They stated that the throttles were closely aligned at takeoff power and power and pressure indications were equal and stable. The engineer found the engine temperature indications within the normal range. When the aircraft was airborne the landing gear control was positioned to "gear up," and while the gear was in transit maximum continuous power was established. Again the crew found the power indications equal and stable from all powerplants.

Captain Rush stated that about 150 feet above the runway and about the time the gear was retracted he saw a fluctuation of the No. 3 engine tachometer. The r. p. m. dropped from 2,600 to 2,300 and returned. Simultaneously he noted a power decay for the engine. The flight engineer saw these conditions and noted that the engine ignition analyzer, then set to the No. 3, showed two secondary shorts in the No. 12 cylinder. Captain Rush ordered the engine shut down. The engineer stated that he closed the throttle, cut the mixture, and depressed the No. 3 feathering button, holding it until he saw the propeller stop. He then turned off the No. 3 fuel boost pump, the generator, and the No. 3 fuel tank selector valve and closed the engine cowl flaps. According to the Eastern Air Lines emergency procedure, unless a fire is known to exist the emergency firewall shutoff valve is not to be actuated; therefore, because no fire was indicated at this time, this was not done.

As near as can be determined, about the time the engine failure procedure was in progress Miami tower personnel saw smoke, then flames, trailing the aircraft from the No. 3 engine nacelle area. The local controller informed the flight and cleared it to land using any runway. The airport emergency equipment was alerted at the same time.

The crew stated that before the aircraft was over the west end of the runway and when the last steps in the engine-out procedure were taken, the master fire-warning bell sounded and the No. 3 engine zone 1 fire-warning light came on. The zones 2 and 3 light quickly followed, at which time Captain Rush took control of the aircraft. The flight engineer positioned the fire extinguisher selector to the No. 3 engine and when Captain Rush ordered him to "fight the fire" the first of two Freon bottles was discharged. Captain Rush estimated the aircraft was then just past the west end of the runway. The warnings continued and the second bottle was discharged. The action was ineffective although, sometime in this sequence, the zone 1 warning light went out. Pilot Harkless saw fire from the No. 3 engine nacelle area reflected on the inboard side of the No. 4 nacelle. Also about this time the odor of smoke permeated the cockpit.

At this time fire was known to exist and extinguishing action had been taken. Therefore, the company's emergency procedure required that the emergency firewall shutoff valve be pulled and the cowl flaps be opened. This was not done. The flight engineer stated he recognized the requirement and omission. In essence, he credited the rapidly occurring events and the compounded emergency as part of the reason for the omission. He also said the emergency steps taken were not checked against the cockpit checklist as there was little opportunity for such action in the short time available.

Numerous aeronautically qualified witnesses saw the aircraft during the phase of flight just described. Many furnished statements and several testified as to their observations before the Board in public hearing. From this source it was learned that an abnormal dense gray-white smoke was seen emanating from the No. 3 nacelle during the last part of the takeoff roll just before the aircraft became airborne. One witness who saw this smoke stated he saw flames on the right side of the nacelle just after the aircraft became airborne. Another witness saw the flames immediately thereafter and stated that as the aircraft passed his position, affording a side view of the outboard side of the nacelle, it was his impression the flames were coming from the right (No. 1) PRT (power recovery turbine) exhaust outlet. Both of these witnesses were qualified mechanics and stated the flames were abnormal. They described them as intermittent and a dirty orange-red color trailing rearward along the nacelle area and visible even when viewed into the sun.

A few seconds later, when the aircraft was near the west end of the runway and about 250 feet above the ground, flames burst out of the nacelle area and, viewed from the rear, seemed to come from and surround the aft nacelle area. Tower personnel, located on the opposite side of the nacelle, first saw gray-white smoke and then flames shortly after the aircraft became airborne. One stated that when viewed from a quartering rear position the flames extended below and to the rear of the nacelle. Many other witnesses saw the smoke and flames about this time. Most agreed the gray-white smoke was observed first and became heavier as the aircraft continued; also, when the flames appeared they were intermittently visible in the smoke. Of all these witnesses, none could recall the landing gear position or

whether or not the No. 3 propeller was stopped. Several explained this was because their observations were almost hypnotically fixed to the smoke and fire.

In the Constellation, Captain Rush turned left as soon as possible to establish a base leg for landing on runway 9R, the parallel runway to 27R in the opposite direction of takeoff. He stated that the pattern speed did not exceed 140 knots, the altitude did not exceed 400 feet, and the pattern was as close as possible. He also estimated the first Freon discharge was before the first left turn and the second was shortly after this turn. The landing gear was extended during the left turn to final approach and landing flaps were extended shortly thereafter. Both operations were accomplished normally. The captain said the touchdown was smooth and very close to the approach end of the runway. He said that during the rollout normal system braking rapidly "faded out" and became ineffective. All four throttles were pulled into reverse range, at which time the aircraft yawed to the left. About this time it was learned the No. 4 engine had stopped and nose wheel steering was inoperative. Secondary braking was initiated but also quickly faded out although the auxiliary hydraulic pump and manual pump were operated. It was also noted the primary and secondary hydraulic quantity indications were zero.

With the partial braking available, some reverse thrust and normal rolling deceleration, the aircraft slowed appreciably but did not stop until it overran the east end of the runway about 75 feet. Then the right main landing gear collapsed.

From variously positioned ground witnesses, who saw the flight from the first left turn to landing, it was established that flames were visible most of the time as the aircraft progressed through the pattern. None saw any parts fall from the aircraft in flight. The fire became much worse on the final approach and during the landing roll flaming metal fell from the aircraft and flaming fluid poured down the main gear onto the runway leaving a pat of fire. One witness said that on final approach the No. 3 propeller was turning slowly; another said it was stopped. A photograph taken during the ground roll showed heavy flame pouring out of the aft nacelle area behind the extended main gear strut and passing the trailing edge of the wing above and below the flaps.

The stewardesses prepared for cabin evacuation before the aircraft stopped, cautioning passengers to use the left side and to remove their shoes and glasses before using the emergency slide chute. The main cabin door was opened and the chute hooked up while two male passengers left the cabin through window exit 17-A. At a request from Stewardess Tharpe they came to the cabin door, and held the bottom of the emergency slide chute for the others to slide down. The crew also used the chute, with Captain Rush last after a final check of the cabin. One elderly and partially disabled passenger received aggravation to his existing condition during the evacuation. Though none of the crew could estimate the evacuation time the rapidity and efficiency described by passengers and witnesses indicated it could not have taken much more than a minute.

The Dade County Port Authority airport emergency rescue and firefighting equipment intercepted the aircraft from a crossing runway (17-35) before it stopped. After learning that all occupants were safely out of the aircraft the emergency personnel began to fight the fire, which was not extinguished for approximately 30 minutes and not until assistance was received from off-airport fire departments from Miami, Miami Springs, Hialeah, and Dade County. As a result,

a part of the accident investigation and public hearing was devoted to a determining what equipment was available to the rescue and firefighting department, the capabilities of this equipment, and the tactical manner in which it was used to fight the fire in this accident.

From competent witnesses of the Airport Fire Department it was learned that foam was used as the principal extinguishing agent and the total capacity of the four pieces of equipment manned at the accident was about 2,150 gallons of water-foam mixed in a 10 to 1 ratio. This total capacity could be discharged in about five minutes. Additional foam concentrate was not carried to the accident scene and other than hand extinguishers the department had no extinguishing agent to supplement the foam. Water, however, was available to any part of the airport through a system of wells and hydrants.

Compared to NFPA (National Fire Protection Association) suggestions, which, in this field, are widely accepted in the absence of any regulatory matter, the amount of foam available at the scene was well below the amount suggested. As indicated, the suggested amount of supplementary extinguishing agent, such as dry chemical or carbon dioxide, was not possessed. The discharge rate capacity of the equipment was about one-half that of the NFPA suggested rate. In addition, the Port Authority lacked such important rescue equipment as power saws and escape stairs.

During the investigation comparisons were also made between the Miami International Airport rescue and firefighting equipment and equipment capabilities and those of other airports of similar size and generating comparable traffic factors. The comparison showed Miami was far below New York, Los Angeles, San Francisco, and Chicago.

The equipment reached the aircraft before it stopped and the prime piece of equipment was positioned at the cabin door to carry out the first and all important mission of protecting and assisting the evacuating occupants. When this was assured, the equipment was moved in front of the burning wing, close to the fuselage. Another foam truck was positioned behind the wing and at the same time hose lines were laid to water sources. Both foam trucks laid foam on the fire according to accepted techniques. According to nearly all observers, in a few minutes the fire, then being fed by about 1,700 gallons of fuel from the right wing fuel cells, was under control and nearly out. At this time the foam supply at the scene was exhausted. Two flashbacks of the fire then occurred and it rekindled to its original intensity. The lieutenant in charge of the airport equipment at the scene stated, in essence, that when the fire was nearly out and despite the flashbacks only a small amount of additional foam would have enabled his personnel to have put out the fire. Without it, extinguishment took the combined efforts of his equipment and the off-airport equipment that reached the scene about the time the fire rekindled. The fire was finally extinguished by using several thousand gallons of water. The evidence indicates that the difficulty encountered in extinguishing the fire was caused by the lack of equipment rather than improper firefighting techniques and tactics.

Concerning future plans, the airport superintendent of maintenance and fire protection stated at the public hearing that bids would soon be advertised for the purchase of a new firefighter and a chemical truck. He said that specifications for the firefighter included a foam concentrate capacity of 250 gallons, a water capacity of at least 1,000 gallons and a discharge rate of 1,000 gallons per

minute. A specification for the chemical unit was 500 pounds of dry chemical, which is considered equivalent to 1,500 gallons of foam.

At the accident scene N 6240G stopped on a heading of 110 degrees resting on the left main gear, nose gear, the outboard portion of the right wing and engine nacelles, and the right vertical fin. Inflight and ground fire severely damaged the right wing and powerplants and heat rippled the fuselage skin on the right side of the aircraft from the rear pressure bulkhead to the crew entrance door. Fire trailing rearward during the approach and ground roll burned the right side of the empennage. When the gear collapsed impact forces buckled the right wing and right horizontal stabilizer upward and crushed the lower part of the right vertical fin.

Examination of the aircraft and the crew statements established that the inflight fire was confined to the No. 3 nacelle and adjacent areas aft of the nacelle. The other powerplants and structure did not cause or contribute to cause of the accident. Despite this advantage the severity of the fire in the areas most important to the investigation destroyed much valuable evidence and the ground fire damage made it most difficult to ascertain and trace the inflight fire patterns with certainty.

On the L-1049-series aircraft the No. 3 engine nacelle installation is divided into four zones. Briefly, zone 1 is the engine power section which is located forward of the engine fire seal; zone 2 is the engine accessory section located between the fire seal and the stainless steel fire wall; zone 3 is the area from the firewall rearward to the auxiliary fire shield (some fluid-carrying lines are routed through this zone and it houses the right main gear wheels and the lower portion of the gear strut when the gear is retracted); zone 3-A is the area aft of the auxiliary fire shield, located just in front of the front wing spar, rearward to the rear wing spar. The right main landing gear strut is hinged to the rear spar.

Testimony of a Lockheed representative at the public hearing was that the auxiliary fire shield which divides zone 3 and 3-A in the No. 3 nacelle of the L-1049 was for the purpose of additional safety beyond regulatory requirements. The installation, he said, was not dictated by any adverse operational experience. He stated that with the landing gear up and wheel well doors closed a fire seal was formed between the two zones; however, with the landing gear down both zones were open to the atmosphere and to each other.

The fire detector system used in the aircraft engine nacelle is a double loop detector system routed through zones 1, 2, and 3. Zone 3-A is not served by the detector circuit. Following the accident, examination revealed the system even though badly burned was capable of functioning satisfactorily.

The aircraft's fire extinguishing system is a dibromodifluoromethane (commonly referred to as Freon) type, which, as it pertains to the No. 3 nacelle consisted of two Freon bottles located in the upper section of zone 3-A from which the extinguishant is routed to zones 1, 2, and 3. The system does not route the extinguishant to zone 3-A, and thus would not be available to this area with the landing gear up and the wheel well doors closed. From the evidence available and from the tests performed following the accident it was determined that the system operated normally when actuated by the flight engineer although, obviously, the fire which existed at that time was not extinguished.

Examination of the No. 3 engine controls revealed the throttle was about one-half open and the mixture control for this engine was in the fifth notch from cutoff.

External examination of the No. 3 engine showed it was completely intact and remained securely mounted in the nacelle. The cowling was extensively damaged by fire and the nearly downward flow of molten metal clearly distinguished the damage as that from ground fire. The No. 3 powercase sections were intact and all cylinders remained securely mounted on the powercases. Both the induction and exhaust manifolds were intact and showed no evidence of leakage. From outward appearance it was impossible to determine that this engine had failed internally.

The front and rear sumps, however, contained large amounts of ferrous and nonferrous metals later identified as pieces from the front row master rod, connecting rods, pistons, and piston rings, and from the front main bearing. The Nos. 1 and 2 PRT turbine wheels were nicked by metal which passed through these assemblies. The No. 2 wheel was oil soaked; the No. 3 was undamaged. All PRT flight hoods were undamaged, properly aligned, and securely mounted.

Internal examination of the engine showed a flange failure of the inner race of the front main bearing. The rear flange of the outer race was broken away in several areas. Metal pieces were also located in the main bearing raceway and there was indication the pieces created binding causing the outer race of the bearing assembly to spin in its retainer. Laboratory examination of these parts indicated the failures resulted from overload conditions rather than a fatigue or faulty condition of the parts.

Examination of the front row power section disclosed that all connecting rods and the master rod were broken off. All of the front row pistons, excepting Nos. 6 and 12, were lodged in their respective cylinders. Nos. 6 and 12, which were badly deformed and crushed into balls, were found in the front case section. Nearly all pistons showed a damage pattern in the form of polishing on the rear side of the top ring lands and breaking of nearly all piston skirts on the front side. This damage pattern showed that the pistons were cocked in the cylinders while the failure of the engine was in progress. The broken master rod was flared as a result of unbalanced operating loads. The stub end of the master rod was wedged against the crankshaft counterweight so that the crankshaft could not be rotated. Relatively the assemblies and components of the rear row of the engine were in good condition.

Examination of the failed connecting rods showed all except No. 10 were broken off cleanly about six inches from the piston pin. The No. 10 rod indicated a splitting type failure in the blade section about 5 inches from the piston.

Except for ground fire damage and a rearward bend in the No. 1 blade, the No. 3 propeller and related mechanisms were in good condition. The stop rings were properly set at 81 degrees, full feathering, and minus 21-1/2 degrees, full reverse. Impact markings on the shim plates showed that when the right gear collapsed the blade position was 67 degrees, or 14 degrees less than full feathering. Some molten metal particles were found on the governor side of the No. 3 governor screen and in the auxiliary check valve.

In zone 1, between the Nos. 2 and 3 PRT's, the HRD (high rate discharge) line of the Freon extinguisher system was torn apart by an explosive-like force.

The nature of this damage led to an investigation of the possibility that the system might have contained material other than Freon. It was learned that the filler fitting for the aircraft Freon system mated only with the filler fitting on the Freon supply source so that the fitting on the supply source of any other material, such as oxygen, etc., would not fit. The possibility, under consideration, was therefore remote. A specific cause was indeterminable.

The fire shield separating zones 1 and 2 was intact and showed no evidence of inflight fire. In zone 2, however, fire damage was found to the engine breather, vacuum suction, vacuum exhaust, and fuel suction lines. In an area below and close to the vacuum pump these lines were open to the atmosphere. The vacuum pump contained pieces of molten aluminum, some of which seized the pump causing the drive shaft to shear at the shear section. Because the pump is engine driven it is evident that inflight fire existed which melted the metal that was drawn into the pump before the engine was stopped.

Zone 3 is constructed mainly of stainless steel except for the wheel well doors and its aft portion. Within the zone most lines are stainless steel except the aluminum alloy vacuum lines and a fire-resistant flexible hydraulic pressure line. Examination showed the zone was exposed to fire and major portions of the aluminum alloy and fire-resistant flexible lines were burned away. The stainless steel lines were intact.

The magnesium wheels, which were retracted into zone 3 during part of the flight and while inflight fire existed, showed evidence of heat but were not burned. The gear strut piston and brakes showed no evidence of excessive heat or fire damage although the tires were fire damaged to a minor extent. Two small flexible lines, one located on the outer side of each brake, were burned through.

The front left and right wheel well doors were melted away except for a considerable portion of the leading edge and lower area of the right door and a similar portion of the leading edge and hinge area of the left door. Examination of the right door remaining structure showed that molten aluminum moving rearward had impinged in layers on the front surface of a vertical member of the right front door located about opposite the auxiliary fire shield that divides zones 3 and 3-A. A study of the photograph of the aircraft during the landing roll indicated that the lower center portion of the right front wheel well door was burned away although the fire at this time was pouring from the nacelle well behind the door.

There were three areas of molten aluminum spatterings on the zone 3 side of the auxiliary fire shield. These areas were the right center of the fire shield, the angled right edge of the fire shield pan covering the gear uplock, and the angled left edge of the cutout in the fire shield for the main gear strut when the gear is retracted. There was no splattering found on the fire shield plate located on the gear strut which covers the cutout when the gear is up although a little was found on the strut, brake housing, and the wheels and tires of the right main gear.

The most forward damage in zone 3-A was in the narrow area between the auxiliary fire shield rearward to the front wing spar and adjacent to the aforementioned cutout in the auxiliary fire shield. Here aluminum lines and fittings were melted away and the spar web and an area of heavy aluminum alloy wing surface below it were melted through. Directly aft of the cutout the stainless steel hydraulic extension and retraction lines for the gear showed evidence of intensive heat

and the aluminum alloy "B" nut on the retracting line was split. A number of hydraulic lines and fittings of the system were burned through and a "B" nut of a landing gear down line, located on the front face of the front spar, was melted.

The number 3 and 4 engine fuel lines in the area aft and somewhat higher than the top of the fireshield cutout were burned away allowing the associated fuel filters and fuel tank selector valves to fall free. Of these, the No. 3 filter fell free before the aircraft stopped; the others were found on the ground below their normal positions. Except the No. 3 selector valve, which was closed, the others were fully or partially open. The emergency fuel shutoff valve, located in zone 3-A was found in the open position as were the hydraulic and oil valves associated with the emergency shutoff system.

The large aluminum alloy fuel crossover line which connects the right fuel tanks through zone 3-A was distorted by heat and the rubber hose connection at the right end was disconnected by fire damage. Obviously this damage and that to the hydraulic and other fuel lines would release large quantities of flammable fluids into the fire.

In the aft part of zone 3-A the heavy aluminum alloy fitting located at the right end of the landing gear trunnion fitting received such intense heat that the bearing pulled out and fell to the ground before the aircraft stopped. This permitted the right main gear to collapse rearward.

Other than hinges, only small fragments were found of the left and right wheel well doors which normally close zone 3-A. One hinge was found on the landing runway and the others were found on the ground below their normal positions. All evidence indicated the rest of the door structure had melted away.

Because of the considerable probative evidence (most of which has already been described), found during the investigation of this accident, the investigators were acutely aware of the possibility that an abnormal exhaust flame may have occurred in conjunction with the engine failure. It was further thought that this flame then entered the nacelle igniting flammables causing the fire. This possibility was therefore pursued during the public hearing in which the Board sought technical information and experience data from highly qualified personnel of the engine manufacturer, Curtiss-Wright Corporation; the airframe manufacturer, Lockheed Aircraft Corporation; and the operator, Eastern Air Lines. This possibility was also discussed by a highly recognized and experienced witness in the field of flammables and conditions under which flammables can be ignited in flight.

In essence, it was the testimony of the representative of the engine manufacturer that during an engine failure of the nature that occurred it would be reasonable to expect some engine oil to be forced by case pressure into the exhaust system and into the airstream from the engine breather exits, located about 6 inches below, 8 inches inboard, and 8 inches behind the Nos. 1 and 2 exhaust exits. The amount of oil, he said, would depend upon the internal condition of the engine during failure and the nature of the failure. For example, if pistons were torn out of their cylinders, oil could freely pass into the cylinders through the exhaust valves and into the exhaust system. Similarly, increased case pressure would result in oil and oil vapor being forced into the atmosphere through the engine breather exits. Obviously, both situations could occur simultaneously. The witness stated

that accepting one or both situations he would not expect an exhaust flame which could ignite flammables in the interior of the nacelle. He emphasized this by stating there are literally hundreds of case histories of oil being forced into the exhaust and from the breather by combustion chamber failures, oil-locked pumps, and a variety of other engine troubles but there was no case, excepting the one under study, where a nacelle fire occurred during such difficulty. He concluded that, in his opinion, another element must have been present to cause the fire. Such element could be a fuel or hydraulic leak in the nacelle.

To determine and show the effect of oil forced into the exhaust system, the Curtiss-Wright Corporation ran tests for the Board. Conducted in a test cell, the tests were made by injecting oil at controlled flow rates into the front exhaust extension of the No. 12 cylinder of an engine operating at METO power. Color motion pictures were taken of the exhaust flame as increasing amounts of oil were forced into the exhaust system. The pictures showed that with a small amount of oil the flame from the PRT became a dirty orange-red color. The flame, however, did not broaden or lengthen appreciably. As the flow rate was increased the flame diminished as the mixture obviously became too rich to burn. At this time a dense gray-white smoke appeared in place of the flame.

The Lockheed Aircraft Corporation representative, a powerplant staff engineer, testified that it was a regulatory requirement for the airframe manufacturer to determine that an exhaust flame does not enter an area, such as the wheel well, where flammables could be ignited and to determine that flammables do not enter the interior of the nacelle in hazardous quantities. The witness said that both determinations in the instance of the L-1049 were made from experience with earlier Constellations and by wind-tunnel tests which demonstrate the air flow patterns in and around the nacelle. He said the tests showed the exhaust flame would not enter the No. 3 nacelle or impinge the wheel well doors. He described the flow of the exhaust flame as being rearward and bending sharply upward away from the wheel well opening. He stated that with the wheel well doors open the airflow below the exhaust pattern would enter the interior of the No. 3 nacelle. He said the airflow is rearward against the auxiliary fire shield where it deflects upward to the top of zone 3. The flow is then forward along the top of the zone to the fire wall where it deflects downward and out of the nacelle. The witness said that during takeoff he would expect a turbulent airflow as a result of the ground effect, propeller blast, and the wheel well door being open at this time.

The witness stated that the engine breather location is a compromise of several considerations and because of this some engine oil does enter the No. 3 nacelle interior. This is most evident upon examination of the interior of the nacelle.

Discussing the possibility that the exhaust flame entered the nacelle or ignited a discharge of oil from the oil breather, the witness said that tests indicated the exhaust and nacelle skin temperatures decreased sharply in the area of the wheel well. To him it seemed impossible to ignite flammables in the wheel well by an exhaust flame. He stated, however, he could not rule out the possibility that oil flowing out of the breather and streaking the nacelle was somehow ignited and entered the nacelle, or that a leak in the nacelle existed and was somehow ignited. The witness said that case histories showed only one zone 3 fire on the L-1049 series aircraft and this was determined to have been caused by an overheated brake which ignited flammables in zone 3 when, after takeoff, it was retracted into the zone.

The expert witness in the field of aircraft fires stated that he would not expect an extensive and sustaining flame from the PRT as the result of engine oil being introduced into the assembly. He said that without something for the flame to stick to or adhere to both the flame and flammable would blow away in the slipstream before much of a flame could develop. He indicated, however, that in such circumstance flecks of flame could be expected. For the same reasons he said a sustaining flame would not be expected on a smooth surface in the slipstream even though the surface was being continuously smeared with a flammable fluid.

In considering the possibility of a hot exhaust stream contacting and igniting a stream of hot engine oil from the breather exit in the airstream, the witness stated this was possible but not probable. He said the improbability was because of the inherent difficulty of igniting a flammable in the slipstream, the stratification which tends to keep the two streams apart, and, in such circumstances, the lack of something to which the flame could adhere.

The witness indicated that his statement was qualified because a stream of hot exhaust gasses can ignite a stream of flammables if the streams can make contact. Considering the turbulent and disrupted airflow created by the propeller swirl and by the wheel well doors being open, such contact could occur. Further, if ignited the flame could develop and be sustained if it attached to the breather exit. Assuming such conditions, an oil-fed fire would be capable of burning through aluminum skin structure in about 20 seconds or even less if the structure was heated on both sides. Because of the improbability of the aforestated conditions occurring the witness seemed to believe that flecks of flame, as previously described in his testimony, entering the nacelle and igniting an existing leak of flammables in zone 3 or 3-A was a more plausible explanation for the fire.

Commenting on the observations of witnesses to the accident, this witness indicated that burning oil would produce a dirty orange-red flame and the gray-white smoke reported by some observers would indicate oil that was beginning to get hot.

An incident occurred March 25, 1959, which is significant and has an important bearing on this accident. It involved Flight 134, an Eastern Air Lines Constellation and a model which has identical engine and nacelle installations to N 6240G. Shortly after takeoff, Flight 134 experienced a failure of the No. 2 engine which, upon examination, showed nearly identical internal damage to the engine involved in the accident under consideration, except the damage involved the rear row of the power section instead of the front row.

A CAB investigator who witnessed this incident stated that after the engine was shut down and the propeller feathered, he observed a flame which emanated in the area of the exhaust and breather exits and trailed rearward at least to the trailing edge of the wing and continued to burn for nearly a minute while the flight made a pattern around the airport (Miami International) to land.

Examination of the front and rear outboard wheel well doors revealed heat damage coincident with the exhaust stains on the doors. Heat blisters and heat damage existed on the outside surface of the front door, and oil coating and charring was found on the leading edge of this door. Similar coking was found on the inside of the rear door in the area adjacent to the opening between the front and rear doors. The seal between the doors was undamaged. Examination also disclosed

that the entire outside surface of the fire damaged doors was coated with engine oil and there was an abnormal accumulation of oil on the inside of the doors. Further, oil was dripping from the No. 1 PRT and the breather exit on the same side.

Examinations of the engine in this incident revealed no leaks and there was no release of exhaust flame and gasses except through the normal exhaust system exits. It was evident that an exhaust flame during the type failure involved did impinge against the wheel well doors. The incident also proved that such exhaust flame can and did enter the nacelle between the front and rear doors with sufficient heat to coke oil deposits on the inside of the rear door as far rearward as a point just aft of the leading edge.

Analysis

Analysis of the damage and damage patterns found in the No. 3 engine strongly indicates that the initial failure was a connecting rod, most probably No. 10. Failure of a connecting rod and/or the front main bearing could produce all of the engine damage that occurred; however, it is believed only a connecting rod failure could have produced this damage in the sequence indicated. Because the No. 10 rod showed a splitting-type failure while all others showed clean overload breaks, it is logical to believe that this rod failed first.

Failure of the No. 10 rod would undoubtedly add reciprocating loads on the front master rod; therefore, it most likely failed next. Similarly, with one or more rod failures the remaining pistons would begin to overtravel permitting the bottom rings to pass below the cylinder skirts progressively failing the piston rings, pistons, and connecting rods as indicated by damage found. Obviously, the unbalanced loads would produce flaring of the master rod until it failed. During the flaring, which was clearly shown on the front master rod, cocking of the connecting rods and pistons could take place which would reasonably account for the heavy wear patterns found on the top land of one side of the pistons and on the piston skirt on the opposite side.

Initial failure of the connecting rod was also evident by the damage to the front main bearing itself. All of the failures in the bearing assembly were overload as the result of jamming and restricting the normal bearing function. The only parts and pieces which would have jammed the bearing were those found in the assembly and these were from the front row pistons, connecting rods, and rings. In addition to this evidence, parts of the bearing found in the oil sumps were free of the heat indications that are normally characteristic of a bearing failure. Finally, had bearing failure been the initial occurrence, damage should have been found to the center and rear main bearings as well as to the reciprocating assemblies of the rear row; none was found. For these reasons the Board is of the opinion that failure of a connecting rod, probably No. 10, caused the engine failure.

It may be recalled that the flight crew experienced the engine failure shortly after takeoff and thereafter were confronted with an uncontrollable fire in the same nacelle. After a careful study of all the available evidence the Board is of the view the two occurrences were related and cannot be accepted as two isolated events that happened at nearly the same time in the same nacelle. Furthermore, there was no evidence found which could account for the fire having been started from a source of ignition within the nacelle. It is therefore believed that the fire resulted from conditions and events relating to the engine failure. More specifically,

within this area of consideration, there was no physical evidence found to show that the source of ignition came from zones 1 and 2 or from within the nacelle. Thus, it is firmly believed the ignition source for the nacelle fire must have been an abnormal exhaust which ignited a flammable substance outside of the nacelle. The resulting flame penetrated the nacelle through the aluminum wheel well doors. Substantial physical evidence, as well as some expert testimony, was available to support this opinion.

During an engine failure of the nature just described, hot, highly agitated, engine oil and oil vapors would be forced into the airstream through the exhaust system and from the engine breathers. Even more so in this instance because two lower pistons had failed in a manner allowing them to fall into the crankcase where they had tumbled for some time as evidenced by the fact they were pounded into balls. This circumstance would permit crankcase oil to drain freely into the lower exhaust system. Similarly, from back pressure, oil and oil vapors would be forced from the crankcase breathers. In addition, as long as the engine controls remained at rated power, high airflow and fuel flow would be delivered to all combustion chambers since both cam drive assemblies were intact and operating. Although many of the front row pistons became incapable of compressing the mixture, it was free to pass into the exhaust and also to enter the crankcase and then into the slipstream through the engine breathers. This process probably began during the takeoff roll, as evidenced by the unusual gray-white smoke observed at this time. It would also continue and increase with the engine failure progression until the reciprocating action of the engine was stopped which, according to many eyewitnesses, was well after a major fire existed in the nacelle.

Although the tests conducted by Curtiss-Wright indicated that the introduction of oil into the exhaust system would not produce an abnormal flame, the March 25 incident and verbal pilot reports prove conclusively that under certain circumstances an abnormal flame will occur. In this incident, under similar conditions of engine failure, an abnormal flame occurred and extended rearward under the wing to the trailing edge. Investigation of the incident showed serious flame impingement on the wheel well doors, inside and outside, as far aft as the separation area between the front and rear sections. Furthermore, the flame continued for a period long after the engine was stopped and the exhaust source of flammable had discontinued. Again, compared to the tests, some differences were present in the incident. These, the Board believes, may have been the introduction of a fuel-air mixture, the slipstream effect not present in the tests, and the ignition of such a combustible mixture from the engine breather. Because more pistons were out of the cylinders in the accident situation an even more combustible fuel-air mixture would have been present.

It also appears significant that the No. 1 PRT exhaust is angled downward slightly with the opening just outboard, forward, and above the outboard breather. Also, examination of the oil breather pattern and exhaust stain shows they cross at the forward edge of the right front door. Thus, after consideration of all the aforestated conditions, the Board is of the opinion that although ignition of the breather mixture is not probable, under certain conditions, it is possible that it did occur in this accident.

Because the normal discharge of breather oil enters the nacelle in considerable amounts it is most reasonable to believe a flame from the same source would enter the interior of the nacelle while the wheel well doors were open. Als , it

is believed that such flame would impinge the doors while they were closed and, if of sufficient intensity, could burn through the aluminum structure in a few seconds. Considerable probative evidence exists leading the Board to believe the latter occurred in this instance. This opinion is supported by the layered pattern of nonferrous metal which was impinged rearward and inward on the vertical outboard forward door member. This could have occurred only in flight by a fire source outside the nacelle which burned through the aluminum doors to supply the molten metal. Although other metal splatter patterns found in zone 3 of the nacelle, were in accordance with the inflight swirl patterns with the wheel well doors open, it is believed such a pattern would exist with portions of the doors burned away. Further supporting the opinion that the doors were closed is the fact that fire warnings did not occur until well after gear retraction when the gear doors would have been closed. Finally, the photograph of the aircraft during the landing roll showed a major portion of the right front door burned away although the existing fire at that time was well behind this area. Again, this burnout, together with the impingement pattern of molten aluminum, must have been caused by a sustained flame which originated outside the nacelle earlier in the sequence of events. Thus, by this evidence and the elimination of other fire sources, the Board is of the opinion the source of the fire must have been the ignition of breather discharge which then burned through the wheel well doors.

It is also apparent that the flame penetrated zones 3 and 3-A before the engine was stopped. This is evident by the ingestion of molten metal by the engine-driven vacuum pump. It is considered probable that rotation of the propeller occurred or continued after the vacuum line, which supplied the metal, was melted. With such propeller rotation a continuation of the supply of flammables from the exhaust and PRT would exist for a longer period of time.

Even after the fire was extinguished the lines in zone 3 were intact; therefore, there could have been no continuing source of flammables in this zone which could have sustained a fire of the magnitude that occurred. Relatively light damage in zone 3 also indicates this. In view of this evidence and because there was no way for the fire to enter zone 3-A from zone 3 with the gear up and the fire shield intact, the major fire must have been ignited in zone 3-A. It is considered most probable therefore that the breather flame, after burning through the wheel well doors, entered zone 3-A traveling upward and forward behind the auxiliary fire shield to the area of several flammable fluid-carrying lines and the No. 3 fuel filter.

Because of the extensive burnout that occurred in zone 3-A it is extremely difficult, if not impossible, to determine the precise source of flammable material where the uncontrollable fire began or if a pre-existing leak was present in the zone which, when ignited, sustained the flame until fire damage released the large quantities of flammable fluids. From the fire pattern and apparent airflow it is possible that the breather flame impinged the previously described heat-split B n t creating a spray of hydraulic fluid, and/or impinged upon the light aluminum alloy cover of the No. 3 fuel filter creating a spray of fuel. Considering the fire-resistant quality of the lines in zone 3-A, the rapidity with which the fire began, and the lack of precedence for such fire, the Board cannot discount the possibility of a pre-existing leak.

Believing the raging fire was principally in zone 3-A, it is immediately apparent that because this zone is not serviced with fire extinguishing agent

outlets, the fire could not be put out when the crew discharged the Freon. Also, since the source of the flammable which ignited is unknown, the effect of the flight engineer's failure to actuate the emergency fire-wall shutoff valve cannot be determined.

Conclusions

On the basis of all the available evidence the Board concludes that in this instance during an engine failure an abnormal exhaust flame occurred. It is concluded that this flame did, in fact, ignite an abnormal discharge of oil and fuel vapors from the outboard No. 3 engine breather exit. The resulting flame from the breather then impinged upon and burned through the right wheel well doors and entered the interior of the No. 3 nacelle. The Board concludes that although fire damage occurred in zone 3, the principal fire in the nacelle was ignited from a source of flammables in zone 3-A although the precise source and conditions surrounding how the flammables were released cannot be determined.

As a result of the accident the Board has submitted recommendations to the Federal Aviation Agency stating that it is believed necessary, in the interest of safety, that consideration be given to a requirement that zone 3-A of Constellation aircraft be serviced with fire-detection and fire extinguishing equipment. Also, that action is necessary which will, through directional control of the exhaust flame, ensure that an abnormal exhaust flame will not ignite a breather discharge or impinge upon the wheel well doors when they are either open or closed.

With respect to the airport rescue and firefighting activities, it is the Board's conclusion that a lack of equipment and equipment capability was the principal reason the aircraft fire was not extinguished more promptly. The record shows that the Airport Authority initiated action to increase its firefighting capability through procurement of new equipment.

Probable Cause

The Board determines that the probable cause of this accident was an uncontrollable fire ignited in zone 3-A by a burning breather discharge which was ignited by and combined with an abnormal exhaust flame during engine failure.

BY THE CIVIL AERONAUTICS BOARD:

/s/ JAMES R. DURFEE

/s/ CHAN GURNEY

/s/ HARMAR D. DENNY

/s/ G. JOSEPH MINETTI

/s/ LOUIS J. HECTOR

SUPPLEMENTAL DATA

Investigation and Hearing

The Civil Aeronautics Board was notified of this accident shortly after it occurred. An investigation was commenced in accordance with the provisions of Section 701 (a) (2) of the Federal Aviation Act of 1958. A public hearing was held in Miami Beach, Florida, on March 31 and April 1 and 2, 1959.

Air Carrier

Eastern Air Lines, Inc., is a Delaware corporation with corporate offices in New York City. The air carrier is engaged in the transportation of persons, property, and mail by virtue of current certificates of public convenience and necessity issued by the Civil Aeronautics Board. It possesses an air carrier operating certificate issued by the Federal Aviation Agency for various routes including the one involved.

Flight Personnel

Captain James W. Rush, age 43, was employed by Eastern Air Lines September 2, 1942, and became captain in 1944. He held a currently valid airman certificate with airline transport rating and aircraft ratings on DC-3, Martin 202/404, DC-6/7, Lockheed Constellation and L-188. His last line check was December 10, 1958. Captain Rush held a current medical certificate, without waivers. At the time of the accident he had a total flying time of 15,984 hours, of which 2,919 were in the Constellation equipment.

Pilot Robert P. Harkless, age 36, was employed by Eastern Air Lines January 31, 1955. He held a valid airman certificate with airline transport rating and ratings for Martin 202/404. He was checked out as first officer on L-1049G equipment August 23, 1956. His last instrument check was satisfactorily accomplished January 7, 1959, and he held a current medical certificate, without waivers. At the time of the accident Pilot Harkless had a total flying time of 6,800 hours, of which 1,974 were in Constellation equipment.

Flight Engineer Russel E. Eshbach, age 33, was employed by the company on February 8, 1955, and became a qualified flight engineer March 1, 1955. He held a valid airman certificate with flight engineer rating and aircraft and powerplant mechanic ratings. His medical certificate was current. He had completed his last line check August 26, 1958, and his last proficiency check December 10, 1958. Flight Engineer Eshbach had a total flying time of 2,217 hours, of which 1,087 were in Constellation equipment.

Flight Attendant Wanda Carr, age 23, was employed November 5, 1956, and became a qualified flight attendant for Eastern Air Lines December 8, 1956. Her last refresher emergency training was July 20, 1956.

Flight Attendant Esther Tharpe, age 30, was employed January 9, 1952, and became a qualified flight attendant February 15, 1952. Her last refresher emergency training was October 2, 1958.

e Aircraft

N 6240C, a Lockheed 1049C, manufacturer's serial number 4665, was acquired by Eastern Air Lines, new, December 8, 1956. At the time of the accident the aircraft had accumulated 7,309 flying hours, of which 116 were since the last maintenance phase check on November 24, 1958. The aircraft was powered by Wright engines, model 988TC-18EA-3, and Hamilton Standard propellers, model 43E60, blade model 6303B. The No. 3 engine had a total time of 5,579 hours, of which 19 hours were since last overhaul.