Aviation Investigation Final Report

Location:	Key West, Florida	**Incident Number:**	ERA12IA060
Date & Time:	November 3, 2011, 12:13 Local	**Registration:**	N938D
Aircraft:	Cessna 550	**Aircraft Damage:**	Minor
Defining Event:	Unknown or undetermined	**Injuries:**	5 None
Flight Conducted Under:	Part 91: General aviation		

Analysis

The pilot-in-command (PIC) stated that he flew the downwind leg at 1,500 feet at 130 knots indicated airspeed and turned onto final approach at 1,000 feet, which he flew at 106 knots. He then touched down 800 feet down the runway at 95 to 100 knots. At touchdown, he extended the speed brakes, and, after traveling another 800 feet, he began to apply wheel braking, but the brake pedals felt "hard" and would not move. He then attempted to apply the emergency brake, but there was no braking action when he pulled it. The airline transport pilot who was in the right seat and acting as the second-in-command reported also trying to apply wheel braking after the PIC was unsuccessful and stated that it did not work. The airplane then overran the runway into the engineered material arresting system.

Review of the radar data for the descent and approach portions of the flight indicated that at times the airplane was fast and the approach was unstabilized. However, the touchdown occurred at a reference speed of 103 to 106 knots. Examination of airport security camera images and deceleration values (determined by using time, distance, and velocity calculations) indicated that the airplane's deceleration was consistent with a lack of braking. Examination of the normal hydraulic braking system and antiskid system did not reveal any malfunctions or failures that would have precluded normal operation of the brakes. Examination of the cockpit revealed that the T-handle for the emergency gear extension system had been activated. This handle is located immediately to the right of the emergency braking handle and was most likely pulled during the incident landing instead of the emergency brake handle. Examination of the emergency braking/landing gear blow-down nitrogen bottle revealed that it was empty; no indication of leakage was discovered, and the witness wire on the landing gear blow-down cable at the nitrogen bottle was intact, indicating that the bottle was most likely empty before the incident flight, since adequate nitrogen should have been available from a properly serviced air bottle even if the landing gear had been extended pneumatically.

Review of maintenance records that were provided by the operator nonetheless listed the airplane's most recent inspection as being completed on September 5, 2011, "in accordance with the instructions and procedures of a current manufacturer's recommended inspection program." According to a signed inspection document, 13 phase inspections were completed, including a phase 5 inspection containing 126 separate tasks, comprising inspection of the emergency brake control valve, the brake reservoir, the antiskid components, and the antiskid system, as well as replacement of the antiskid motor/pump filter, operational check of the antiskid brake system, operational check of the emergency brake system, replacement of the brake reservoir air filter, and cleaning of the brake reservoir supply line and system filter. The document also indicated that servicing of the "emergency brake and gear Nitrogen" had been accomplished.

The landing checklist in the airplane flight manual cautions that if a "hard brake pedal-no braking condition" is encountered during landing, the pilot should operate the emergency brake system. It also noted that to obtain maximum braking performance from the antiskid system, the pilot must apply continuous maximum effort (no modulation) to the brake pedals. The Pilot's Abbreviated Checklist also contains emergency procedures for wheel brake failure and antiskid failure. However, examination of the incident airplane revealed that neither of these documents was in the cockpit. Instead, the cockpit contained a double-sided laminated checklist from a training provider titled "Normal Procedures." No emergency procedures were printed on the checklist and "For Training Purposes Only" appeared at the bottom.

Based on the available evidence, it could not be determined that a failure of the normal braking system occurred or that the pilots applied maximum braking effort, as indicated by the airplane manufacturer's guidance. Further, had the braking system actually failed, the pilots did not apply the emergency brakes, instead activating the landing gear extension handle.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:

The pilots' failure to appropriately apply the landing gear wheel brakes after landing, to properly perform the hard brake pedal-no braking condition procedure following the reported brake failure and to apply the emergency brakes. The reason for the reported brake failure could not be determined because postincident examination did not reveal any malfunctions or failures that would have precluded normal operation of the brakes.

Findings

Personnel issues	Use of equip/system - Flight crew
Personnel issues	Use of policy/procedure - Flight crew
Personnel issues	Lack of action - Flight crew

Factual Information

History of Flight

Landing-landing roll	Unknown or undetermined (Defining event)
Landing-landing roll	Runway excursion
Landing-landing roll	Collision with terr/obj (non-CFIT)

On November 3, 2011, about 1213 eastern daylight time, a Cessna 550, N938D, operated by South Aviation, received minor damage during a runway overrun at Key West International Airport (EYW), Key West, Florida. The two certificated airline transport pilots and their three passengers were uninjured. Visual meteorological conditions prevailed, and an IFR flight plan had been filed for the business flight, which departed Fort Lauderdale/Hollywood International Airport (FLL), Fort Lauderdale, Florida, and was conducted under the provisions of Title 14 Code of Federal Regulations Part 91.

According to the airline transport pilot (ATP) who was the pilot-in-command (PIC) of the flight, he conducted a visual approach to runway 9 at EYW. He flew the downwind leg at 1,500 feet at 130 knots indicated airspeed, turned onto final approach at 1,000 feet and flew the final approach at 106 knots and touched down 800 feet down the runway at 95 to 100 knots. At touch down he extended the speed brakes, and after traveling another 800 feet, he went to apply wheel braking but, there was no braking, and the brake pedals felt "hard" and would not move. He then attempted to apply the emergency brake but, there was "no brake at all" when he pulled it. The airplane then overran the runway. He felt that he had to stop and could not go around.

According to the ATP who was in the right seat and acting as the second-in-command (SIC), the airplane had last been operated approximately two months prior to the incident. The purpose of the incident flight was to demonstrate the airplane to a potential buyer. The PIC of the flight was a contract pilot to his company which was trying to sell the airplane on behalf of the owner. The takeoff from FLL, the cruise portion, and the approach to EYW was uneventful. The touchdown occurred at the reference speed of 103 knots and was uneventful. The PIC applied the wheel brakes, and there was no braking. He then tried them also and the brakes "were not working."

According to a passenger who was a pilot and was in the cabin, when they taxied out at FLL, the brakes were working fine. After landing in EYW he felt no braking whatsoever. He felt that they should have gone around.

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	55
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 None	**Last FAA Medical Exam:**	July 30, 2010
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	14200 hours (Total, all aircraft), 1200 hours (Total, this make and model), 13920 hours (Pilot In Command, all aircraft), 10 hours (Last 90 days, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Commercial	**Age:**	43
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 2 None	**Last FAA Medical Exam:**	December 27, 2010
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	7000 hours (Total, all aircraft)		

According to Federal Aviation Administration (FAA) records, the PIC held an airline transport certificate with ratings for airplane multi-engine land, commercial privileges for airplane single-engine land, and type ratings for the BE-300, BE-400, CE-500, CE-560XL, and MU-300. He also possessed a flight instructor certificate with ratings for airplane single-engine, and instrument airplane. His most recent FAA first-class medical certificate was issued on July 30, 2010. He reported that he had accrued 14,200 total hours of flight experience, 1,200 of which, was in the incident airplane make and model.

According to FAA records, the SIC held an airline transport certificate with ratings for airplane multi-engine land, commercial privileges for airplane single-engine land, and a type rating for the HS-125. He did not possess a type rating for the incident airplane. His most recent FAA second-class medical certificate was issued on December 27, 2010. On that date, he reported that he had accrued 7,000 total hours of flight experience.

Aircraft and Owner/Operator Information

Aircraft Make:	Cessna	**Registration:**	N938D
Model/Series:	550	**Aircraft Category:**	Airplane
Year of Manufacture:	1982	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	550-0454
Landing Gear Type:	Retractable - Tricycle	**Seats:**	8
Date/Type of Last Inspection:	September 5, 2011 Continuous airworthiness	**Certified Max Gross Wt.:**	13300 lbs
Time Since Last Inspection:	3 Hrs	**Engines:**	2 Turbo fan
Airframe Total Time:	9900 Hrs at time of accident	**Engine Manufacturer:**	P&W CANADA
ELT:	Installed, not activated	**Engine Model/Series:**	JT15D-4
Registered Owner:	JODA LLC	**Rated Power:**	2500 Lbs thrust
Operator:	South Aviation	**Operating Certificate(s) Held:**	None

The incident aircraft was a seven passenger low wing, pressurized, twin engine, airplane of conventional construction. It was certificated under 14 CFR Part 25. It was equipped with an anti-skid system and manually operated speed brakes. It was not equipped with thrust reversers. It was powered by two Pratt & Whitney Canada JT15D-4 turbofan engines, each producing 2,500 pounds of thrust. It could operate up to 43,000 feet above mean sea level, and travel up to 1,840 nautical miles at a maximum cruise speed of 385 knots. According to FAA records it was manufactured in 1982.

According to maintenance records the airplane was being maintained under the continuous inspection program which is Cessna Aircraft Company's recommended inspection program. The program was divided into five primary phases which covered all inspection requirements up through the 1200-hour interval inspection items. The Phase 1 inspection focused on the nose area, cockpit, and interior; the Phase 2 inspection on the landing gear and empennage; the Phase 3 inspection on the tail cone area; and the Phase 4 inspection on the engines. The more intensive and comprehensive Phase 5 airframe inspection was due every 1,200 hours or 36 months, whichever came first.

According to CAMP Systems maintenance tracking system records, the last Phase 1 through 4 inspections were completed on December 12, 2008. The next Phase 1 through 4 inspections were required to be completed by December 31, 2010. The last Phase 5 inspection was listed as being accomplished on December 29, 2008.

The next Phase 5 inspection which contained 126 separate tasks, included inspection of the emergency brake control valve, the brake reservoir, the antiskid components, and the antiskid system. It also included replacement of the antiskid motor/pump filter, operational check of the antiskid brake system, operational check of the emergency brake system, replacement of the brake reservoir air filter, and cleaning of the brake reservoir supply line system filter. The inspection was required to be completed by December 28, 2011.

No maintenance transaction reports had been supplied to CAMP Systems since 2009. According to maintenance records provided by the operator however, the airplane's most recent inspection was completed September 5, 2011, "in accordance with the instructions and procedures of a current manufacture's recommended inspection program". According to the signed inspection document, among other things, 13 phase inspections including a phase 5 inspection had been recently completed along with a "CVR operational test" and servicing of the "emergency brake and gear Nitrogen". At the time of the inspection, the airplane had accrued 9,896.5 total hours of operation.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	EYW,3 ft msl	**Distance from Accident Site:**	
Observation Time:	11:53 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	6 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.07 inches Hg	**Temperature/Dew Point:**	27°C / 20°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Fort Lauderdale, FL (FLL)	**Type of Flight Plan Filed:**	IFR
Destination:	Key West, FL (EYW)	**Type of Clearance:**	IFR
Departure Time:	11:36 Local	**Type of Airspace:**	

The reported weather at EYW, at 1153, included: variable winds at 6 knots, 10 miles visibility, clear, temperature 27 degrees C, dew point 20 degrees C, and an altimeter setting of 30.08 inches of mercury.

Airport Information

Airport:	Key West International EYW	**Runway Surface Type:**	Asphalt
Airport Elevation:	3 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	09	**IFR Approach:**	Visual
Runway Length/Width:	4801 ft / 100 ft	**VFR Approach/Landing:**	Full stop

Key West International Airport is located approximately 160 miles southwest of Miami on US highway 1. It is located on the last Key in the Florida Keys chain of islands, and is the southernmost airport in the continental United States.

Aircraft operations averaged 172 per day of which, 52 percent were transient general aviation, 21 percent were air taxi, 14 percent were local general aviation, 13 percent were commercial, and 1 percent were military.

There were 61 aircraft based at the field of which, 39 were single-engine airplanes, 21 were multi-engine airplanes, and 1 helicopter.

The airport covered an area of 255 acres and has one runway oriented in a 09/27 configuration. Runway 09 was asphalt, grooved, and in good condition. The total length of the runway was 4,801 feet, and its width was 100 feet. It was equipped with nonprecision runway markings, in good condition, medium intensity runway edge lights, runway end identifier lights, and a 4-box visual approach slope indicator on the left side of the runway which provided a 3-degree glide path.

Engineered Material Arresting System

Runway 09 was not equipped with a standard 1,000 foot runway safety area (RSA) on the end of the runway as required by 14 CFR Part 139 due to the proximity of a mangrove swamp near the end of the runway. As a result, an engineered material arresting system (EMAS) was installed to comply with the requirements for an RSA in less space, on the end of runway 09, which due to prevailing winds was the primary use runway.

The EMAS at EYW was designed in accordance with the system design requirements listed in Advisory Circular 150/5220-22A and consisted of a bed of customized cellular cement material, designed to crush under the weight of an aircraft, thus providing predictable controlled deceleration.

The bed was approximately 340 feet long by 121 feet wide and was setback from the end of the runway. It was designed with a predicated 70 knot stopping power for the critical aircraft (ERJ-135) operating at maximum takeoff weight and an 80 percent maximum landing weight in accordance with FAA Order 5200.9.

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Minor
Passenger Injuries:	3 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	5 None	**Latitude, Longitude:**	24.55611,-81.759445(est)

Examination of the runway revealed that after the incident airplane had left the marked area of runway 9, it traveled 35 feet across the pavement between the painted runway end line and the start of the EMAS bed, and then traveled into the installed EMAS.

Both main wheels broke the top surface of the EMAS bed as they entered it. A tire track for the nose gear was observed on top of the EMAS for the first 40 feet of travel into the EMAS bed. The top cover of the EMAS bed exhibited fractures under the nose wheel tire track, but did not appear to be broken through. After traveling 40 feet, the nose wheel broke through the top of the EMAS bed cover and entered the material below. Measurements taken of the ruts made in the EMAS by the landing gear of the incident airplane revealed that the EMAS had decelerated the airplane to a stop in approximately 144 feet.

Examination of the airplane revealed that the wing flaps were in the "LAND" position (40 degrees), the speed brakes were in the "EXTEND" position, and during the overrun the airplane had received minor damage. The nose landing gear tire and bottom of the nose landing gear trunnion had separated from the airplane, the left landing gear door had partially separated from its mounting location, numerous scrapes were present on the lower fuselage skins and nose gear doors, the battery hold down clamp wing nuts were loose and not safety wired, and the engines had ingested dirt, and dust.

Flight recorders

The airplane was equipped with a cockpit voice recorder (CVR) that records a minimum of the last 30 minutes of aircraft operation; this is accomplished by recording over the oldest audio data. When the CVR is deactivated or removed from the airplane, it retains only the most recent 30 minutes of CVR operation. This model CVR, the Fairchild GA-100, records 30 minutes of analog audio on a continuous loop tape in a four-channel format: one channel for each flight crew and one channel for the cockpit area microphone (CAM).

Examination of the CVR revealed that it had not sustained any heat or structural damage during the overun and the audio information was extracted from the recorder normally, without difficulty.

The recording consisted of four channels of poor quality audio information; however none of the audio was pertinent to the incident investigation. The audio was consistent with the CVR being inoperative prior to the event or being overwritten by subsequent events.

An internal inspection of the CVR revealed that the hour meter indicated beyond the 5,000 hour scale and corrosion was evident on the inside of the case. When power was applied to the CVR the tape mechanism would not turn.

The limited audio content was consistent with ground operation of the aircraft. The recording consisted of a few power cycles; brief periods of singing; and sounds similar to a door opening.

Tests and Research

Landing Distance Calculations

At the request of the NTSB, Cessna Aircraft Company calculated the landing distances for the incident airplane. Using a landing weight of 12,700 pounds, an elevation of sea level, a dry runway, and temperature of 30 degrees C, the following landing distances were obtained from data in the Aircraft

Flight Manual (AFM):

• 10 knot tailwind; 3,220 feet.
• No wind; 2,340 feet.
• 10 knot headwind 2,210 feet.

While the reported temperature prior to the incident was 27 degrees C, no extrapolation was done between the published values of 25 degrees C and 30 degrees C as the landing distance would only have decreased approximately 10 feet in a no wind condition.

These landing distances were based on the following criteria published in the AFM concerning landing distance and technique:

• Landing preceded by a steady approach down to the 50-foot height point with airspeed at Vref (the airspeed equal to the landing 50-foot height point speed of 1.3 times the stalling speed or minimum steady flight speed) in landing configuration (landing flaps and gear down).
• Thrust setting during approach was selected to control the rate of descent to approximately 800 to 1,000 feet per minute.
• Idle thrust was established at the 50-foot height point and throttles remained in that setting until the airplane had stopped.
• Rotation to a three-point attitude after touchdown was accomplished at a normal rate.
• Maximum pilot braking effort was initiated immediately on nose wheel contact and continued throughout the landing roll.
• The antiskid system was "ON".
• Speed brakes were not used (not required to meet the performance requirements).

Radar Data

Review of FAA air traffic control radar data revealed that the airplane was first acquired by radar at approximately 1136 edt as it climbed out of FLL. It then continued to climb and eventually reached a cruising altitude of 14,000 feet above mean sea level (msl). At approximately 1156 edt, the airplane began its initial descent into EYW. Groundspeed peaked at 325 knots in the descent. As the airplane passed through 10,000 feet msl, groundspeed was 302 knots. The airplane continued to descend and reached 1,600 feet msl at approximately 1208 edt. The airplane then entered a right downwind for runway 9 at EYW at a ground speed of 256 knots.

At 12:11:10.31, the airplane had descended to 1,000 feet msl, was still on the downwind leg of the traffic pattern, and had slowed to 169 knots.

At 12:12:11:14, the airplane had descended to 500 feet, was on the base leg of the traffic pattern, and had slowed to 130 knots.

At 12:12:47.33, the airplane had descended 100 feet, was on final approach, had slowed to approximately 112 knots, and was approximately 1 mile from the runway threshold.

Video Study

Video recording obtained from a surveillance system installed at EYW, was provided to the NTSB Vehicle Recorder Division by the Monroe County Sheriff's Office. Images from the surveillance system were used to calculate the airplane's position and ground speed at several locations during the landing rollout.

Examination of the video revealed that it contained images captured from three separate cameras, all located on the north side of the air traffic control tower at EYW. The recordings covered the timespan from 12:13:00 to 12:14:44.

The images from each camera were examined for landmarks and references suitable for calculating the airplane's position as it traveled down the runway during the landing. A line-of-sight method was used for position calculations, using landmarks that were identifiable in both the surveillance images, and satellite imagery of the airport, using a geographical information system. This method was applied at 15 different locations of the airplane along the runway, and a 3-degree glide path reference was also superimposed along a profile view and perspective view leading from the aiming point markings back up the approach path.

Review of the last of the radar data points recorded and the images of the airplane on final indicated that the airplane was below the normal glide path.

Review of the images of the airplane while traveling along the runway, revealed that the airplane's wing flaps were down. The airplane however was too far from the cameras to determine the condition of the speed brakes (deployed or stowed).

Further review of the images also indicated that after touchdown, at approximately 1,935 feet from the threshold, the airplane had decelerated to about 80 knots.

At approximately 2,443 feet from the threshold, the airplane had decelerated to about 73 knots.

At approximately 3,769 feet from the threshold, the airplane had decelerated to about 63 knots, and was now within 1,000 feet of the end of the paved portion of the usable runway surface.

At approximately 4,456 feet from the threshold, the airplane had decelerated to about 57 knots.

The image of the airplane was then observed to continue to travel along the runway, then moments later leave the marked area of usable runway, travel across the pavement between the painted runway end line, and then travel into the EMAS bed.

Examination of the deceleration values determined by using time, distance, and velocity calculations presented in the video study, indicated that the deceleration was consistent with no effect from braking being present.

Checklists and Aircraft Flight Manuals

Review of the Cessna Citation Model 550 AFM revealed that on landing the throttles were to be brought to idle and the brakes applied. The landing checklist also cautioned that if during landing, a "HARD BRAKE PEDAL-NO BRAKING CONDITION" was encountered, to operate the emergency brake system. It also noted that to obtain maximum braking performance from the antiskid system, the pilot must apply continuous maximum effort (no modulation) to the brake pedals.

The Citation II Pilot's Abbreviated Checklist also contained emergency procedures for:

• Wheel Brake Failure - advising to "REMOVE FEET FROM BRAKE PEDALS" and to pull the emergency brake handle as required, cautioning that the antiskid system does not function during emergency braking, and that excessive pressure on the emergency brake handle could cause both wheel brakes to lock, resulting in blowout of both main tires, and to multiple the landing distance in the flight manual by 1.6.

• Antiskid Failure ("ANTISKID INOP LIGHT ON") – advising to check that the antiskid switch was "ON" and to reset the skid control circuit breaker. If the light remained "ON", the antiskid switch should then be switched "OFF" and to multiply the landing distance in the flight manual by 1.6. The checklist cautioned that differential power braking was available. However, since the antiskid was inoperative, excessive pressure on the brake pedals may cause wheel brakes to lock, resulting in tire blowout and to be prepared to use the emergency brake system.

Examination of the cockpit revealed however that, neither of these documents was in the cockpit. Instead a single page, double sided SimCom laminated checklist titled "Normal Procedures" was found. No emergency procedures were printed on the checklist. The bottom of the check list stated, "For Training Purposes Only." A box in the back of the cabin however did contain a copy of the Aircraft Flight Manual (AFM) and a Cessna Aircraft Company checklist. It was discovered though that the checklist was for the incorrect model of airplane and the AFM with a decal showing the airplane's serial number on the front, did not contain the current manual revisions. The manual also contained a weight and balance sheet dated 02-17-09. No other current weight and balance, checklist, or AFM was discovered onboard.

Landing Gear Manual Extension

The manual extension system was actuated by the red "AUX GEAR CONTROL" T-handle located under the PIC's instrument panel. The handle was pulled and rotated clockwise to lock. This action mechanically disengaged the landing gear uplocks, allowing the landing gear to free-fall to the down and locked position and also unlocked the red, collar-type, blow down knob. Yawing the airplane could be required to achieve green light indications and the pneumatic system would be used to assure positive locking of all three gear actuators. Pulling the red, collar-type knob on the T-handle shaft mechanically ported the emergency air bottle into the extend side of all three landing gear actuators. The gear was then driven to the down and locked position and norma1 indications would appear in the cockpit providing the gear handle was down. After actuation of the pneumatic system, the knob would be left in the extended position.

Examination of the auxiliary gear control revealed that the T-handle was in the deploy position however, the knob was stowed.

Wheel Brakes

Toe-actuated multiple disc brakes were installed on the main gear wheels. Braking could be accomplished by either of two independent systems: the power brake hydraulic system or the back-up pneumatic system. Normal braking could be applied from either cockpit seat. The emergency brake control was installed under the PIC's instrument panel only.

Fluid was supplied from a reservoir mounted on the right forward side of the forward pressure bulkhead. Sight gauges on the reservoir allowed for visual inspection of the brake fluid quantity during external inspection (preflight). An electric motor, hydraulic pump, check valve, relief valve, and filter were combined in one modular assembly. A bleed-off valve discharged stored fluid back into the reservoir so the accumulator precharge could be checked.

Four brake master cylinders, one for each of the PIC's and SIC's pedals were paired in series. When the pedals were depressed, fluid was forced from the outlet ports of the master cylinders into the respective brake signal inlet ports of the power brake assembly. The amount of pressure going to the brakes would be proportional to the amount of pressure exerted from the outlet side of the master cylinder brake pedals. With the brakes released, a check valve was held open, which would allow fluid to move freely in either direction.

Anti-Skid and Power Brake Systems

The anti-skid system provided power assisted braking with skid protection. It was designed to provide maximum braking efficiency on all runway surfaces. The system consisted of two wheel speed generators, power brake relay/anti-skid valve, control box, oversize reservoir, accumulator, an electrically driven hydraulic pump, filter, pressure and control switches and two indicator lights. System operation was conventional with power braking available at all speeds while anti-skid protection was available at speeds above approximately 12 knots.

The anti-skid protection feature was designed to operate with maximum pilot brake applied pressure. The wheel speed generator was bolted in the main gear axle with the drive shaft connected through a drive cap to the main wheel. As the wheel turned, the generator generated a 36 Hz signal for each wheel revolution that was sent to the control module as a variable frequency. The control module would accept the output of the left and right wheel speed generators and convert these signals to a DC voltage that was directly proportional to wheel speed. The voltage from the left and right wheels was averaged to provide a composite or reference voltage. Any significant variation between either wheel speed voltage and the reference voltage would produce an error signal that would activates the power brake and anti-skid valve which controlled the amount of braking being applied against each wheel. At touchdown, the generator voltage would reach maximum as soon as the wheel spun up. As long as no skid occurred, the generator voltage would follow wheel speed and the reference voltage would follow the voltage of the generator. When excessive deceleration of a wheel occurred, generator voltage would suddenly drop. An error signal would then be generated which would energize the servo valve segment of the power brake and antiskid valve. The servo valve controlled the movement of spools within the main body of the power brake and anti-skid valve which modulated the braking effort being applied by the pilot as required to maintain generator voltage and reference voltage within the skid limits, preventing the skid condition. When the airplane speed would drop below approximately 12 knots, the anti-skid function would disengage.

To insure proper braking, it was necessary for the pilot to apply maximum effort to the brake pedals throughout the braking run. When the system anticipated a skid and released the applied brake pressure, any attempt by the pilot to modulate braking could result in an interruption of the applied brake signal and could increase stopping distance significantly.

Hydraulic power for the anti-skid system was provided by an electrically driven hydraulic pump located in the left nose of the airplane. An accumulator was installed in the system to maintain system pressure when the pump was not running. The pump was controlled by a pressure switch that opened when the pressure approached 1300 PSI and closed when the system pressure approached 900 PSI.

A switch on the instrument panel allowed the pilot to select anti-skid "ON" or "OFF". When the switch was in the ON position, the anti-skid function was operational. With the control switch in the OFF position, the "ANTI-SKID INOP" light would illuminate on the annunciator panel and the pilot would have power braking available, without the anti-skid function. If the power system failed, application of braking signal force would move shuttle valves in the power brake and anti-skid valve connecting the pilot and copilot master brake cylinders directly to the wheel brakes and manual braking would be available. The anti-skid control module also incorporated test circuitry which continually monitored the anti-skid system. If a fault was detected, the "ANTI-SKID INOP" light would illuminate on the annunciator panel. If hydraulic pressure in the power system dropped below 750 PSI, the "PWR BRK PRESS LO" light would illuminate.

Examination of the anti-skid and power brake systems revealed that the anti-skid control switch was in the "on" position, and that there was no evidence of flat spots or skidding on either main gear tire. The wire harness to the right wheel anti-skid transducer exhibited impact damage and had broken at the axle. The main landing gear dust caps appeared to be properly safetied and attached to the anti-skid transducers. The brake accumulator pressure needle was between empty and the precharge line. The brake fluid reservoir showed full fluid in both windows. When aircraft power was activated the brake pump could be heard running, the brake accumulator pressure needle entered the green arc, and fluid was removed from the brake reservoir. When the brake pedals were pushed the brake motor activated. The left tire was jacked clear of the ground and could not be rotated when the brakes were applied. The left anti-skid transducer released its brake when a skid was induced using a drill motor.

Parking Brake

The parking brake was a part of the normal brake system and employed controllable check valves that could prevent the return of fluid after the brakes had been set. The Parking brake was set by depressing the toe brakes and pulling out the black parking brake control handle located under the lower left side of the PIC's instrument panel.

With the pedals depressed and the parking brake control handle pulled, the system would maintain pressure on the wheel brakes. With the handle off, the check valves would be open and fluid could move freely in either direction.

The parking brake valve assembly also had two thermal relief valves which would open at approximately 1,000 psi to protect the brake system from being damaged by excess pressure resulting from expanding fluid.

Post incident, during an attempt to tow the airplane out of the EMAS bed, the airplane would not move. Examination of the parking brake handle revealed that it was in the "ON" position.

A review of the system revealed that if the parking brake handle had been actuated during the landing roll it would not have had significant effect as it does not apply pressure on its own and only traps pressure with the parking brake valve after brake application. Closure of the parking brake valve prior to landing would also not cause brake pressure to be applied. However, following parking brake valve closure, any brake pressure provided to the brakes by the hydraulic system would be trapped at the brakes even after the hydraulic brake system stopped directing pressure to each wheel brake.

Further review of the system also revealed that the parking brake valve was located in the system between the antiskid and the wheel brakes which indicated that if the parking brake was holding pressure during the landing or landing roll, the antiskid system would be unable to release it. However, examination of the main landing gear revealed no evidence of flat spotting or skidding of the tires.

Emergency Braking

In the event of normal hydraulic braking system failure, a pneumatic system was available. The pneumatic pressure required was contained in the emergency air bottle (emergency braking/landing gear blow down bottle) and was controlled by a lever with red knob located to the left of the "AUX GEAR CONTROL" T-handle. Pulling the lever aft would apply equal pressure to both main landing gear brake assemblies. Releasing the back pressure on the lever and allowing it to move forward would relieve the pressure. The air pressure to the brakes could be modulated to provide any braking rate desired, but differential braking and anti-skid would not be available. The emergency air bottle, when fully charged, contained sufficient pressure for ten or more full brake applications. For the most efficient use of the system, the pilot would apply sufficient air pressure to the brakes to obtain the desired deceleration rate. Then would maintain that pressure until airplane was stopped. When the handle was released, residual air pressure from the brakes would be exhausted overboard. Normal braking should not be applied while using the pneumatic brakes. Depressing the pedals would reposition the shuttle valves in the brake lines open, allowing high pressure air from the brake housing to enter the brake hydraulic reservoir and possibly rupture it. Adequate emergency braking for most conditions would be available from a properly serviced air bottle, even if the landing gear had been extended pneumatically.

Pneumatics

An air bottle was located on the right side of the forward pressure bulkhead to provide for emergency extension of the landing gear and/or emergency braking. The bottle was considered to have been properly serviced when it contained 1800-2050 pounds per square inch (PSI) and was required to be checked during the exterior inspection (preflight) by observing if the indicator needle on the "Brake and Gear Pneumatic Pressure Gauge" was in the "GREEN ARC". A relief valve on the bottle would rupture at 4000 PSI if the bottle became over pressurized. The bottle had outlets to the vent line. The gear auxiliary extension line and the brake air pressure line. The landing gear auxiliary extension line was normally connected to the vent line.

When the collar-type knob on the "AUX GEAR CONTROL" T-handle shaft was pulled, a valve was repositioned to direct air from the bottle through the auxiliary extension lines to the extend side of the landing gear-actuators.

Emergency braking was controlled through a manually operated, three-way pressure regulating valve. Air from the bottle was connected directly to the inlet port of the valve by the brake air pressure line. The outlet port was connected to the brakes and was normally vented to an exhaust line. When the emergency brakes were applied, the vent would close, the inlet port would open and high pressure air would be applied to the brakes. Releasing the emergency brake handle would open the vent relieving pressure. This allowed modulation of the system to obtain the desired braking force. Each time the handle was cycled some air pressure would be vented overboard, reducing the emergency bottle supply.

Examination of the emergency braking/landing gear blow down nitrogen bottle revealed that it was empty. No indication of leakage was discovered and the witness wire on the landing gear blow down cable at the nitrogen bottle was intact.

Additional Information

Post incident Sale and Inspection

After the incident the airplane was sold as salvage by the insurance carrier. Examination by the new owner also revealed no evidence of any anomalies which would have precluded normal operation of the brakes, and the airplane was successfully flown on a ferry permit from EYW to the operator's facility in Vermont.

RSA Improvement Program

In 2000, the FAA developed an RSA improvement program to improve runways that did not meet FAA design standards. When the program began, only 30 percent of RSAs met full FAA design standards and 55 percent met 90 percent of the FAA design standards.

Many airports were developed on land with limited space making it difficult to improve RSAs to meet changing standards. As a result the FAA implemented a number of RSA improvement options including construction and expansion of RSAs, Modifications or relocations of runways, removal of objects that were not fixed by function, implementation of declared distances, and installations of EMAS beds (such as the one on the end of runway 9 at EYW), the purpose of which was to stop an aircraft overrun with no human injury and minimal aircraft damage (usually none). The loss of energy required to crush the EMAS material slows the aircraft. An EMAS is similar in concept to a runaway truck ramp made of gravel or sand. It is intended to stop aircraft that have overshot a runway when there is an insufficient free space for a standard RSA.

To date, EMAS has a 100 percent success rate. At the time of this report, EMAS is installed at 66 runway ends at 45 airports in the United States, with additional EMAS installations planned through 2015.

Contrasting Overrun

On October 31, 2011(three days prior to the incident involving N938D), A Gulfstream G150, N480JJ overran runway 27 during landing at EYW (ERA12FA056). During the approach in night visual meteorological conditions, after losing sight of the runway once, and going around, the flight crew continued the approach, even though the PIC stated that he thought they were going to land long. The PIC stated that the main landing gear touched down near the 1,000-foot marker of the 4,901-foot-long runway, about the Vref of 120 knots. The PIC stated that he then applied the brakes but thought they were not working; he had not yet activated the thrust reversers. He alerted the SIC who also depressed the brake pedals with no apparent results. The PIC suggested a go-around, but the SIC responded that it was too late. The airplane subsequently traveled off the end of the runway, and in contrast to the overrun of runway 9, where N938D received minor damage after traveling into the EMAS bed, and being brought to a stop, N480J received substantial damage, one passenger was seriously injured, and three passengers received minor injuries when it struck a gravel berm, and came to rest about 816 feet beyond the end of the runway.

Originally only 100 feet of safety area was present off the end of runway 27, which led into a salt pond and embankment.

In May 2011, as part of the RSA improvement program, a 600-ft unpaved safety area was added off the end of runway 27 to provide a more expansive safety buffer.

On August 16, 2013, the FAA and Monroe County Board of Commissioners entered into a grant agreement for airport improvements at EYW which included improvements to the runway 27 safety area (EMAS-Phase 1).

Administrative Information

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