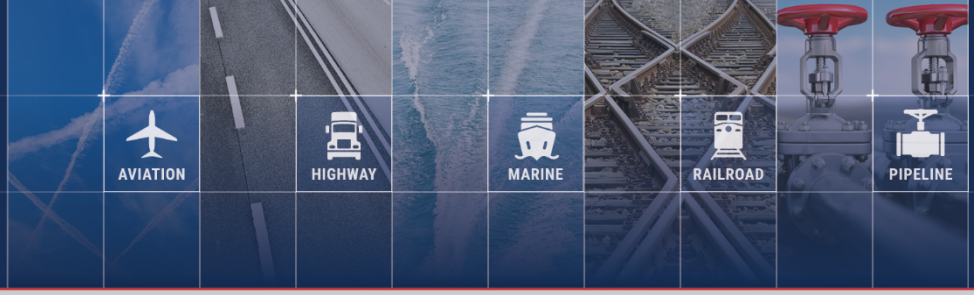

Aviation Investigation Final Report

Location:	Midlothian, Texas	**Accident Number:**	CEN10FA291
Date & Time:	June 2, 2010, 14:00 Local	**Registration:**	N515MK
Aircraft:	Bell 222	**Aircraft Damage:**	Substantial
Defining Event:	Part(s) separation from AC	**Injuries:**	2 Fatal
Flight Conducted Under:	Part 91: General aviation - Other work use		

Analysis

The helicopter was on a postmaintenance flight when it experienced an in-flight breakup about 8 minutes after departure, collided with the ground, and exploded into flames. Several witnesses reported seeing the tail boom, main rotor hub, main rotor blades, and other debris separate from the helicopter. One witness heard a "loud crack" sound. A postaccident examination revealed that the helicopter's swashplate A-side drive pin had failed in flight, which resulted in the helicopter's in-flight breakup and uncontrolled descent. The separated head of the drive pin remained in the interior of the swashplate. The fractured drive pin hole exhibited mechanical damage, with the markings of increased amplitude and spacing progressing outward, which suggests that the fractured drive pin oscillated and then ejected from its hole.

The fracture surface of the swashplate A-side drive pin displayed brittle cleavage-like fractures interspersed with intergranular separations and small regions of ductile dimples, consistent with hydrogen embrittlement. The B-side drive pin, on the opposite side, was found intact. Both drive pins met engineering drawing requirements for material, hardness, heat treatment and plating. However, there were no engineering standards for hydrogen content. During tests of two pins intentionally charged with hydrogen, one pin fractured under static load, and the fracture topography was consistent with the fracture topography on the failed A-side pin from the accident helicopter. Based on the fracture topography, it is likely that the swashplate A-side drive pin fractured as a result of hydrogen embrittlement. Investigators were unable to conclusively determine the source of the hydrogen. No other material discrepancies of the drive pin were found. Metallurgical examination revealed that fractures through the mast, B-side pitch link bolt and actuator attachments were consistent with overstress separations.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: The fracture of a swashplate drive pin as a result of hydrogen embrittlement due to an unknown source, which resulted in an in-flight breakup of the main rotor system during cruise flight.

Findings

Aircraft	Main rotor mast/swashplate - Failure
Aircraft	Main rotor mast/swashplate - Not specified
Not determined	(general) - Unknown/Not determined

Factual Information

History of Flight

Enroute-cruise	Part(s) separation from AC (Defining event)
Enroute-cruise	Aircraft structural failure
Uncontrolled descent	Collision with terr/obj (non-CFIT)
Post-impact	Fire/smoke (post-impact)

This report was modified on 1/25/2012 and on 4/23/2012. Please see the docket for this accident to view the original report.

HISTORY OF FLIGHT

On June 2, 2010, at 1400 central daylight time, a Bell 222U, N515MK, registered to and operated by CareFlite, Grand Prairie, Texas, collided with the ground following an in-flight break-up near Midlothian, Texas. The post maintenance flight was operated under the provisions of 14 Code of Federal Regulations Part 91. Visual meteorological conditions (VMC) prevailed and a company flight plan was filed. The airline transport pilot and mechanic were killed. The helicopter sustained substantial damage. The flight departed from Grand Prairie Municipal Airport (GPM) Grand Prairie, Texas, at 1352, about 8 minutes before the accident.

During interviews with the National Transportation Safety Board (NTSB) investigator-in-charge (IIC), several witnesses consistently reported seeing the tail boom, main rotor hub, main rotor blades, and other debris separate from the helicopter. Another witness heard a "loud crack" sound. The helicopter subsequently collided with the ground and exploded into flames.

Review of radar data confirmed N515MK departed GPM at 1352:03. The helicopter proceeded southbound until the last radar target was recorded at 1359:49. The last six radar hits recorded from 1359:26 to 1359:49 indicated an average altitude of 1,300 feet mean sea level (msl), at an average ground speed of 115 knots, and an average ground track of 178 degrees.

PERSONNEL INFORMATION

The certificated airline transport pilot, age 44, held an airline transport pilot certificate, with a rating for rotorcraft-helicopter, issued on November 10, 2004. In addition, he held a commercial pilot certificate, with ratings for airplane single-engine land, airplane multiengine land and instrument airplane, issued on November 10, 2004. The pilot also held a flight instructor certificate, with ratings for rotorcraft-helicopter and instrument-helicopter, issued on July 18, 2009, and a ground instructor certificate, with ratings for advanced and instrument, issued on November 10, 2004.

He was issued a second-class airman medical certificate on January 21, 2010, with no limitations. The pilot's logbook was not recovered for examination. Based on the pilot's airman medical certification application, company crewmember records and other documents, his total flight experience was estimated at 6,500 hours with at least 5,300 hours in helicopters, and an estimated 346 hours in Bell 222 helicopters. The pilot's last Part 135 competency check in the Bell 222U was completed on July 29, 2009. He completed a Part 135 competency check and flights review in an Augusta A-109E on April 23, 2010. The pilot had flown 19.6 hours in the last 90 days of which 9.8 hours were in the Bell 222U. He had flown 3.2 hours in the last 30 days.

The mechanic, age 23, held a mechanic certificate with ratings for airframe and powerplant, issued on September 26, 2006. In addition, he held a private pilot certificate, with a rating for rotorcraft-helicopter, issued on April 19, 2006. The mechanic's pilot logbook was not recovered. The mechanic held a first-class airman medical certificate that was issued April 13, 2007, with no limitations.

AIRCRAFT INFORMATION

The Bell 222U was a 5-place twin engine helicopter, serial number 47515, and was equipped with high skid landing gear. The pilot's station was located in the right cockpit seat and the co-pilot's station in the left cockpit seat. Flight controls were not installed in the co-pilot station. A medical interior was installed in the main cabin with seats for three passengers and a stretcher for one patient. Two Honeywell LTS-101-750-1, 680-shaft horsepower engines powered the helicopter.

The helicopter had been previously maintained on the manufacturer's inspection program was in the process of being added to the operator's Approved Airworthiness Inspection Program (AAIP). According to the Pilot/Operator Aircraft Accident Report (NTSB Form 6120.1) submitted by the operator, the helicopter had an estimated total time in service of 9,925.1 flight hours. A review of the maintenance logbooks indicated that the last recorded inspection of the engines and airframe was a 600-hour inspection which had been completed on May 27, 2010, at 9,924.0 hours.

Prior to the accident, the swashplate and lever assembly (p/n 222-010-400-127, s/n EA136) was removed from N515MK. The swashplate and lever assembly (p/n 222-010-400-127, s/n EA0052), previously installed on N142CF, was reinstalled on N515MK at 9,925.0 total time air frame hours. As of the accident date, the recently installed assembly had approximately 49.9 hours remaining until overhaul.

The outer ring assembly, (p/n 222-010-403-005, s/n AR-16) had accumulated 4,069.6 hours since new and 2,450.1 hours since overhaul. The drive pins, (p/n 230-010-402-103, s/n A-5 and s/n A-17), were installed in the outer ring assembly during an overhaul on December 23, 1999.

A review of manufacturing records provided by Bell Helicopter Textron show they built 17 drive pins of p/n 230-010-402. Fifteen were non-stepped straight pins (p/n 230-010-402-101) and two were stepped pins (p/n 230-010-402-103), s/n A-5 and A-17. All 17 of the drive pins built were hardened in furnace number 72212-03. The s/n A-5 drive pin was the only part aged in furnace number 72101-15.

The maintenance manual requires an inspection of the drive pins, (p/n 230-010-402-103), every 300 hours. The last inspection was conducted at 2,346.4 hours. The drive pins had accumulated about 5.9 flight hours of operation since that inspection had been completed.

A records review revealed none of the rotor system components had any history of being involved in a previous accident.

METEOROLOGICAL INFORMATION

At 1353, the automated surface observing system (ASOS) at Arlington Municipal Airport (GKY), Arlington, Texas, about 11 miles north northwest of the accident site. reported the wind from 200 degrees at 8 knots, gusting to 14 knots, visibility 10 statute miles, sky clear, temperature 33 degrees Celsius, dew point 19 degrees Celsius, and an altimeter setting of 29.77 inches of Mercury.
At 1350, the ASOS at GPM, about 13 miles north of the accident site, reported the wind from 210 degrees at 10 knots, visibility 10 statute miles, few clouds at 5,000 feet, temperature 34 degrees Celsius, dew point 18 degrees Celsius, and an altimeter setting of 29.79 inches of Mercury.

COMMUNICATIONS

At 1349 N515MK called the FAA contract air traffic control tower at GPM and requested to depart the Care Flite ramp southbound to Joe Pool Lake. The tower approved the departure and issued N515MK the altimeter setting. N515MK acknowledged and departed. There were no further recorded conversations between N515MK and the tower.

WRECKAGE AND IMPACT INFORMATION

The wreckage was located in a field about 13 miles south of GPM at an estimated surface elevation of 650 feet msl. The fuselage was oriented on a 044-degree heading, covered in soot and partially consumed by thermal damage. The other portions of the wreckage did not exhibit fire damage. The separated tail boom was found approximately 550 feet northeast from the main fuselage and 340 feet northeast from the main rotor. The main rotor was found approximately 220 feet northeast from the fuselage. The fractured and separated main rotor mast section was found about 80 feet east of the main fuselage.

Pieces of wreckage found northeast of the main fuselage included fuselage skin from a sponson, a patient backboard, sections of tail boom skin exhibiting tail rotor blade strikes, and

push-out window sections. The most distant debris was located about 1,500 feet north-northeast of the main fuselage and included several pieces of main rotor blade skin and small fuselage paint chips.

The main rotor system was found mostly intact. There was no evidence that large pieces departed from the main rotor, although some blade skin and honeycomb had departed the rotor blades. One main rotor blade exhibited trailing edge damage just inboard of the outboard trim tab, consistent with striking a hard object. A severed mesquite tree and bent steel rebar exhibited evidence of contact where the main rotor came to rest. The other main rotor blade exhibited abrasions and gouges on its bottom surface, exhibiting signatures consistent with contact with a hard object. Further examination revealed a separated tail rotor hanger bearing section fit the size and shape of a gouge on the bottom main rotor blade skin surface. For identification and differentiation purposes, the main rotor blades were labeled "A" and "B".

The A side pitch change link had intact connections at both top and bottom but was bent near the center of the link. The B side pitch change link was connected to the walking beam on its bottom end, but the bolt was fractured at the upper connection to the pitch change horn.

The rotating outer ring swashplate was found with the A side drive pin fractured and separated. The separated head of the side A drive pin remained in the interior of the swashplate. The entire shank and attaching hardware from side A were not found. The side B drive pin on the opposite side was found intact and installed in the rotating swashplate.

The separated tail boom assembly was found in an upright orientation and flattened on its bottom surface. It exhibited fractures of the tail boom skin and longerons approximately 4 inches aft of the fuselage attachment structure. The left end plate on the horizontal stabilizer exhibited a main rotor blade strike near its bottom surface. The strike was to the inboard face on the bottom of the end plate in an outboard direction. The tail boom also exhibited strikes to the left side of the aft tail boom area, which matched damage to the tips of both tail rotor blades. The tail rotor hub and blade assembly remained connected to the tail boom assembly. Both tail rotor pitch change links were bent near the center of the links.

The main transmission remained connected with the main fuselage and was covered with soot. The transmission outer case exhibited several holes in it, consistent with impact fractures. The right aft transmission mount was fractured, but the other three mounts were intact. Free rotation was observed through the intact tail rotor gearbox assembly.
The main rotor mast was fractured and separated near the top of the mast and just above the transmission top case. The appearance of the fractured surface at the top of the mast was consistent with a hard contact with the main rotor yoke.

The swashplate and lever assembly, swashplate drive assembly, main rotor hub assembly and mast section were forwarded to Bell Helicopter Engineering Laboratories for initial examination under the supervision of an NTSB investigator. The main rotor system components: including the swashplate and lever assembly, swashplate drive assembly, main

rotor hub assembly, ring assembly-rotating, main rotor controls, pin-outer ring, swashplate, main rotor controls, and main rotor pitch link assembly were forwarded to the NTSB Materials Laboratory for further analysis.

Control continuity in the main fuselage area for the main rotor cyclic, collective, and tail rotor controls could not be verified. Melted remnants of aluminum control tubes were observed in several locations surrounding the main fuselage.

Tail rotor control continuity was confirmed in the tail boom section from the forward tail boom fracture to the tail rotor hub and blade assembly.

The left engine remained in the wreckage and was fire damaged. The engine data plate was not recovered. The engine was removed from the wreckage and examined at a salvage yard. The accessory gearbox, inlet housing and all engine accessories manufactured from aluminum and magnesium were consumed by fire. The power section of the engine was not disassembled. The external surfaces of the engine contained ash and debris. The plenum sustained damage on the lower right side. The remains of the exhaust pipe were removed. The power turbine wheel was free to rotate with corresponding rotation of the power turbine shaft through the power pinion gear. The power turbine rotor was intact and no rotational scoring was present on the turbine tip shroud surface. Rotational scoring was present on the aft side of the power turbine disk rim and the aft surface of the power turbine blade platforms and attachment fir trees.

The axial compressor rotor was intact and no damage was present on the leading edges of the compressor blades. The gas generator group was rotated with resistance due to rubbing between the rotating and static parts of the group. The remainder of the power section was not disassembled.

The accessory and reduction gearbox gears were collected from the wreckage and examined. The gear teeth were intact and were able to provide power on all three gears, including the power pinion, torque meter idler gear, and the power output gear. All remaining gears from the accessory reduction gearbox were examined and the gear teeth were intact.

The right engine remained in the wreckage and was fire damaged. The engine data plate was not recovered. The engine was removed from the wreckage and examined at a salvage yard. The accessory gearbox, inlet housing and all engine accessories manufactured from aluminum and magnesium were consumed by fire. The fuel pump, fuel control unit, and the power turbine governor were consumed by fire. The power section of the engine was not disassembled. The external surfaces of the engine contained ash and debris. The plenum sustained damage around the majority of the circumference. The remains of the exhaust pipe were removed. The power turbine wheel would not rotate. One turbine blade was missing a piece 1/4 inch in radius from the trailing edge tip corner. The remainder of the turbine blades was intact. Rotational scoring was present near the trailing edges on the suction aft side of the blades.

The axial compressor rotor was intact and no damage was noted on the leading edges of the blades. The gas generator would not rotate. The remainder of the power section was not disassembled.
The accessory and reduction gearbox gears were collected from the wreckage and examined. The gear teeth were intact and were able to provide power on all three gears, including the power pinion, torque meter idler gear, and the power output gear. All remaining gears from the accessory reduction gearbox were examined and the gear teeth were intact.

MEDICAL AND PATHOLOGICAL INFORMATION

The Southwestern Institute of Forensic Sciences, Dallas, Texas, conducted an autopsy on the pilot on June 3, 2010. The cause of death was blunt force and thermal injuries. The Bioaeronautical Research Science Laboratory, FAA, Oklahoma City, Oklahoma performed postmortem toxicology of specimens from the pilot. No testing for carbon monoxide or cyanide was performed. No ethanol was detected in the liver. Acetone, 2 (mg/dl, mg/hg) was detected in the liver. Ethanol, 31 (mg/dl, mg/hg) was detected in the kidney, 17 (mg/dl, mg/hg) was detected in the muscle, and 15 (mg/dl, mg/hg) was detected in the brain. N-Propanol 1 (mg/dl, mg/hg) was detected in the kidney.

The Southwestern Institute of Forensic Sciences, Dallas, Texas, conducted an autopsy on the mechanic on June 3, 2010. The cause of death was multiple blunt force injuries. The Bioaeronautical Research Science Laboratory, FAA, Oklahoma City, Oklahoma performed postmortem toxicology of specimens from the mechanic. No carbon monoxide or cyanide was detected in the blood. No ethanol was detected in the urine. Naproxen was detected in the urine.

TESTS AND RESEARCH

Metallurgical examination revealed that fractures through the mast, B side pitch link bolt and actuator attachments were consistent with overstress separations.

The A side pin fracture surface was viewed in a scanning electron microscope (SEM). High magnification examinations of the fracture surface found predominately brittle cleavage-like fracture interspersed with intergranular separations and small regions of ductile dimples.
As a comparison, a new pin was provided by Bell and a bending overstress fracture was induced at a mechanically reduced section. The resulting fracture displayed bulk yielding and deformation adjacent to the fracture and a 100 percent ductile dimpled fractured surface when viewed at high magnification.

Maintenance records established that the outer ring assembly (p/n 222-010-403-5, s/n AR-16) had been repaired by Bell in December 1999, with the original (p/n 230-010-402-101) constant diameter pins replaced by (p/n 230-010-402-103) stepped pins, which have a larger diameter shank in the areas that mate with the rotating ring. The repair documents indicated that the pin holes in the outer ring were enlarged, then shot-penned and honed to a final diameter of

0.6430 inch for the A side and 0.6432 inch for the B side. The actual diameters of the pins were not recorded on the repair documents. However, after removal from the outer ring the enlarged shank diameter on the B side pin was measured at several locations with the diameter ranging from 0.6443 inch to 0.6448 inch and averaged 0.6446 inch. Those dimensions were within the specifications of the engineering drawing.

Using the recorded diameters of the outer ring holes and the drawing dimensions for the pins the interference fit would have been between 0.0020 inch and 0.0016 inch for the A side and between 0.0018 inch and 0.0014 inch for the B side. With the measured diameter of the B side pin (0.6446 inch) and the repair recorded hole dimension (0.6432 inch), the interference fit calculated as 0.00145 inch. Those dimensions were within the specifications of the engineering drawing. The drive pins were determined to meet the engineering drawings requirements for material and finish. The material of both pins was confirmed as AerMet 100 by handheld x-ray fluorescence spectrometer and by an optical emission spectrometer. Hardness measurements in the washer face of the A pin recorded values of 50.4 and 51.9 HRC. Tests in several locations on the B side pin averaged 51.1 HRC. SEM viewing of the cadmium plating revealed a scaly surface texture consistent with vacuum deposited cadmium. Energy dispersive x-ray spectra acquired during SEM examination confirmed the plating as cadmium. A radial metallographic section through the head of the A side pin revealed a fine tempered martensite microstructure consistent with the alloy and heat treatment.

Bell reported that manufacturing records indicated that drive pin A-5 was manufactured in December, 1998 as a finished lot of one part. Initially pin A-6 was also part of the manufacturing lot, but was scrapped during production for unknown reasons.

The atomic hydrogen content was measured in two samples removed from both the A and B side pins. Samples from the fractured pin A-5 (A side) contained 8.7 and 9.3 parts per million (ppm) hydrogen and samples from pin A-17 (B-side) contained 4.6 and 4.5 ppm hydrogen.

To explore the influences of hydrogen on the fracture behavior of the pin material, two tests were conducted by Bell at the direction of the NTSB Materials Laboratory. For the test, the cadmium layer was removed from two new drive pins and each was reheat treated at the same austenitizing conditions, but aged at 850 degrees F and 900 degrees F. Both parts were then pickled for 60 seconds, then electrolytically plated with a heavy layer of cadmium, but not baked. Each test pin was then inserted through aluminum blocks and using the proper nuts torqued to 125 ft-lbs of lubricated torque. The test pins remained loaded for 7 days, at which time the nuts were removed for inspection. With little applied loosening torque, the 850-degree F aged pin fractured through the first engaged thread. The 900-degree F aged pin remained intact. SEM examinations of the fracture surfaces reveal a brittle cleavage-like fracture over the vast majority of the surface. Some intergranular separation and small isolated patches of ductile dimples were also noted. Hydrogen content was measured on both pins and determined to be 2.0 ppm for both.

The bore of the A-side pin hole had skewed longitudinal scrape marks and a series of

circumferential impressions over much of the bore. The A side bore markings were consistent with the gradual extraction of the shank portion of the pin. The spacing of the marks was indicative of the relative outward movement of the pin fragment with each force reversal with gradual increasing displacement.

Pilot Information

Certificate:	Airline transport	**Age:**	44,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	
Instrument Rating(s):	Airplane; Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	Helicopter; Instrument helicopter	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	January 21, 2010
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	April 22, 2010
Flight Time:	(Estimated) 6500 hours (Total, all aircraft), 346 hours (Total, this make and model), 4800 hours (Pilot In Command, all aircraft), 19 hours (Last 90 days, all aircraft), 3 hours (Last 30 days, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Bell	**Registration:**	N515MK
Model/Series:	222 U	**Aircraft Category:**	Helicopter
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	47515
Landing Gear Type:	N/A; Skid	**Seats:**	5
Date/Type of Last Inspection:	May 27, 2010 AAIP	**Certified Max Gross Wt.:**	8250 lbs
Time Since Last Inspection:	1 Hrs	**Engines:**	2 Turbo shaft
Airframe Total Time:	9925 Hrs at time of accident	**Engine Manufacturer:**	LYCOMING
ELT:	C91A installed, not activated	**Engine Model/Series:**	LTS101
Registered Owner:	CareFlite	**Rated Power:**	680 Horsepower
Operator:	CareFlite	**Operating Certificate(s) Held:**	On-demand air taxi (135)
Operator Does Business As:		**Operator Designator Code:**	NXTA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KGKY,628 ft msl	**Distance from Accident Site:**	11 Nautical Miles
Observation Time:	13:53 Local	**Direction from Accident Site:**	338°
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	8 knots / 14 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	200°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.77 inches Hg	**Temperature/Dew Point:**	33°C / 19°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Grand Prairie, TX (GPM)	**Type of Flight Plan Filed:**	Company VFR
Destination:	Grand Prairie, TX (GPM)	**Type of Clearance:**	None
Departure Time:	13:52 Local	**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	Both in-flight and on-ground
Ground Injuries:	N/A	**Aircraft Explosion:**	Both in-flight and on-ground
Total Injuries:	2 Fatal	**Latitude, Longitude:**	32.45861,-97.038887(est)

Administrative Information

Investigator In Charge (IIC):	Latson, Thomas
Additional Participating Persons:	John Loomis; FAA Dallas FSDO; Irving, TX Andre Turenne; Transport Safety Board - Canada; Gatineau, Quebec Mark Stuntzner; Bell Helicopter - Textron; Fort Worth, TX James E Allen; Honewell Aerospace; Phoenix, AZ J. David Carr; CareFlite; Grand Prairie, TX
Original Publish Date:	April 4, 2012
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=76203