AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9169
Aircraft Registration	**ZS-SAR**	**Date of Accident**	27 April 2013	**Time of Accident**	±1440Z
Type of Aircraft	Cessna 152 (Aeroplane)		**Type of Operation**	Private Flight	
Pilot-in-command Licence Type	Private	**Age**	40	**Licence Valid**	Yes
Pilot-in-command Flying Experience	Total Flying Hours	173,0		Hours on Type	93,1
Last point of departure	Worcester aerodrome (FAWC), Western Cape province				
Next point of intended landing	Worcester aerodrome (FAWC), Western Cape province				
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)					
Farm Wittekop in the Worcester district (GPS position; 33°42.507' South 019°35.794' East)					
Meteorological Information	Surface wind; 260°/12kt gusting 23 kt, Temperature; 31°C, Visibility: + 10 km				
Number of people on board	1 + 0	**No. of people injured**	0	**No. of people killed**	1

Synopsis

The aircraft, a Cessna 152 with registration number ZS-SAR, was hired by a member of the Worcester Flying Club for a local private flight. The pilot had indicated to the flying club members that he intended to fly for approximately one hour. The aircraft took off from runway 33 at Worcester aerodrome (FAWC) at approximately 1420Z.

When the aircraft was overdue for landing by approximately one hour, the club members started getting concerned. They phoned the pilot on his cell phone, but without any response. They then started phoning farmers in the area as well as air traffic control (ATC) at Cape Town International aerodrome (FACT) to enquire whether the aircraft had been in radio communication with them, which was not the case. At around 1900Z that evening they received a call that the wreckage of the missing aircraft had been located on the farm Wittekop, which was located 9,2 nautical miles (nm) southeast of FAWC. The pilot was fatally injured in the accident.

Probable cause

The right-hand rudder cable was found to have failed. This most probably rendered the pilot without rudder authority to counteract the spin and recover from the manoeuvre.

IARC Date		Release Date	

AIRCRAFT ACCIDENT REPORT

Name of Owner	**:** Worcester Flying Club
Name of Operator	**:** Worcester Flying Club
Manufacturer	**:** Cessna Aircraft Company
Model	**:** 152
Nationality	**:** South African
Registration Marks	**:** ZS-SAR
Place	**:** Farm Wittekop, Worcester district
Date	**:** 27 April 2013
Time	**:** ±1440Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (1997) this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and **not to establish legal liability**.*

Disclaimer:

This report is produced without prejudice to the rights of the CAA, which are reserved.

1. FACTUAL INFORMATION

1.1 History of flight

1.1.1 The pilot, who was a member of the Worcester Flying Club, made a reservation with the flying club to hire and fly a Cessna 152, registration ZS-SAR, on Saturday afternoon, 27 April 2013. The pilot indicated that he planned to fly for approximately one hour.

1.1.2 According to an official of the flying club the aircraft had been refuelled to capacity the previous day, and following refuelling one flight had been conducted with the aircraft with a total duration of 55 minutes (0,9 of an hour). The fuel that remained in the aircraft prior to the flight was adequate for a 2½ hour flight. The pilot took off from Worcester aerodrome (FAWC), runway 33 at approximately 1420Z. The prevailing wind at the time was from the southwest at 7 knots, gusting up to 10 knots. At ±1440Z the wind speed increased to 12 knots, gusting up to 23 knots from the southwest.

1.1.3 When the aircraft did not return to the aerodrome after being overdue for approximately an hour, the club members started enquiring about the aircraft by phoning the pilot's cell number (without response) as well as people in the local community (farmers). They also called air traffic control (ATC) at Cape Town International aerodrome, as they thought the aircraft might have been in contact with the tower, which was not the case. At around 1900Z that evening they received a call that the wreckage of the missing aircraft had been located on the farm Wittekop, which was located approximately 9,2 nautical miles (nm) southeast of FAWC. The pilot was fatally injured in the accident.

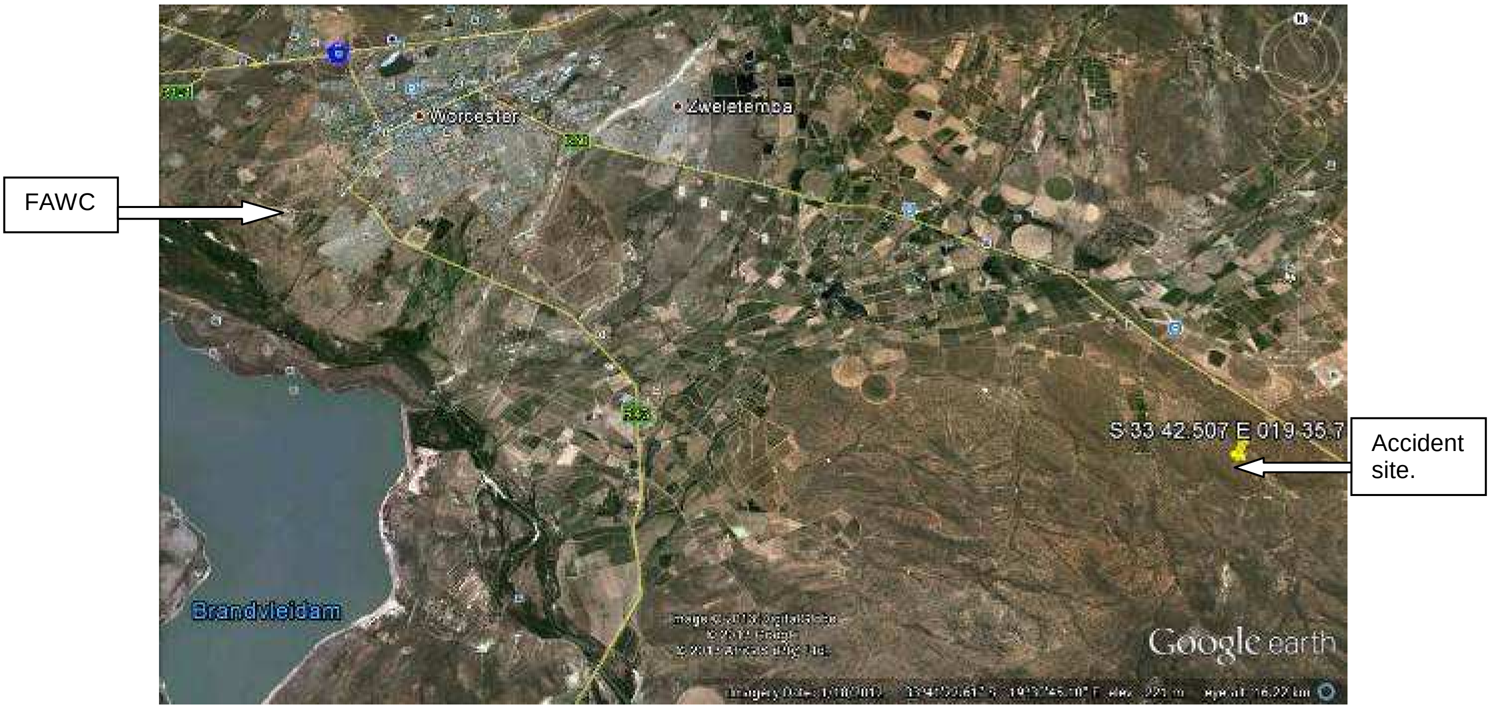


Figure 1. The Google earth map indicates the accident site in relation to the Worcester aerodrome (FAWC)

1.1.4 The aircraft was observed flying in the vicinity of the farm Wittekop by a farm worker on the afternoon of 27 April 2013. According to his observation the aircraft was flying in the direction of Worcester (north-westerly). It then commenced with a left turn, whereupon the attitude of the aircraft changed; it would appear to have pitched nose up. The aircraft then fell to the ground in a nose-down attitude. The farm worker immediately phoned the farm manager from his cell phone to notify him of the accident, but the manager did not answer his phone immediately. He made several attempts to call him without success. The farm manager phoned him back a few hours later. After he had explained to him what had happened, the farm manager drove to the farm, where he found the wreckage. He then informed the police and emergency services, which came to the accident scene. During an interview with the eye-witness, the investigating team tried to establish the height the aircraft was flying at when it commenced with the left-hand turn. It was, however, not possible to make an accurate assessment of the height the aircraft was at, but from what could be gathered the aircraft was most probably flying not higher than 1000 feet above ground level (AGL).

1.1.5 During the on-site investigation the team located the book *"The Air Pilot's Manual, 1 Flying Training",* by Trevor Thom, on the scene of the accident. The book had three subheadings highlighted by page markers, namely forced landings, precautionary landings and spins. The book was located on the right-hand side of the aircraft in close proximity to the right-hand door, which was found in the open position following ground impact.

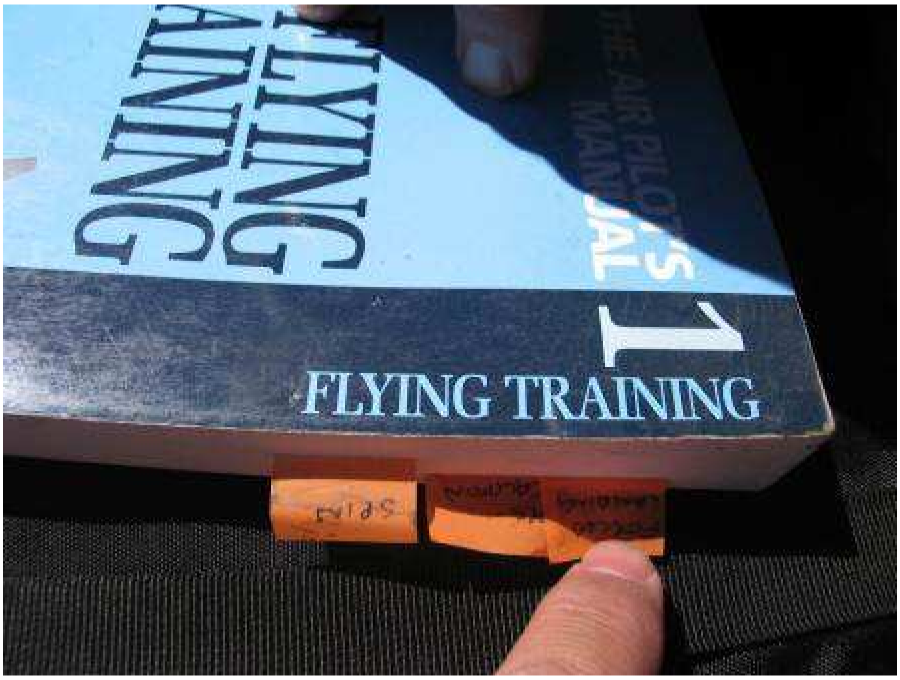


Figure 2. The flying training handbook that was found on the accident site

1.1.6 The accident occurred during daylight conditions at a geographical position that was determined to be 33°42.507' South 019°35.794' East at an elevation of 1 052 feet above mean sea level (AMSL).

1.2 Injuries to persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	1	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to aircraft

1.3.1 The aircraft was extensively damaged during the impact sequence.

Figure 3. The aircraft as it came to rest

1.4 Other damage

1.4.1 Minor damage was caused to vegetation.

1.5 Personnel Information

1.5.1 Pilot-in-command

Nationality	South African	Gender	Male	Age	40
Licence number	0270479157	Licence type	Private pilot		
Licence valid	Yes	Type endorsed	Yes		
Ratings	None				
Medical expiry date	31 December 2013				
Restrictions	None				
Previous accidents	None				

The pilot commenced with his flying training as a student pilot on 18 December 1999. An application for a student pilot licence was received by the regulating authority on 11 January 2000. On 13 February 2001 he submitted his application for a private pilot licence; this was after he had passed his practical flight test on 5 February 2001, accumulating 54,9 flying hours during this period. The pilot continued to keep his private pilot licence current. According to available evidence, his last aviation medical examination prior to the accident flight was on 21 November 2011 and his last initial skills test (for private pilot licence - form CA 61-03.4) on record was conducted on 16 May 2012. According to the pilot logbook, which was kept up to date, he had flown a further nine flights following the revalidation skills test flight on 16 May 2012 and had accumulated a further 8,3 flying hours over this period. His last flight prior to the accident flight was on 6 April 2013, during which he flew for 30 minutes (0,5 of an hour) on the Cessna 152, ZS-SAR.

Flying experience:

Total hours	173,0
Total past 90-days	2,4
Total on type past 90 days	0,5
Total on type	93,1

1.6 Aircraft information

1.6.1 The Cessna 152 is an American-designed and built two-seat, high-wing, fixed tricycle landing gear, general aviation aircraft used primarily for flight training and personal use.

The 152's airframe is an all-metal construction. It is primarily aluminum 2024-T3 alloy, although some components such as wing tips and fairings are made from glass-reinforced plastic. The fuselage is a semi-monocoque construction: it has vertical bulkheads and frames joined by longerons which run the length of the fuselage. The metal skin of the aircraft is riveted, which allows loads to be spread over the structure. The wings are of a strut-braced design and have a 1° dihedral angle. The tapered (outboard) portion of each wing has 1° of washout (the chord of the tip section has one degree lower angle of attack than the chord at the end of the constant-width section). This allows greater aileron effectiveness during a stall, although it is much less than the 3° used for Cessn a 172 wings. Cessna 152s produced between 1977 and 1982 were equipped with Lycoming O-235-L2C engines producing 110 hp (82 kW) at 2 550 rpm.

Figure 4. Cessna 152-type aircraft

Airframe:

Type	Cessna 152
Serial number	152-82591
Manufacturer	Cessna Aircraft Company
Year of manufacture	1979
Total airframe hours (at time of accident)	11 086,1
Last MPI (hours & date)	11 000,0 / 16 November 2012
Hours since last MPI	86,1
C of A (issue date)	29 April 2008
C of A (expiry date)	28 April 2013
C of R (issue date) (present owner)	30 July 2008
Operating category	Standard part 135

According to available documentation, read in conjunction with the tachometer reading at the time of the accident, the aircraft was airborne for approximately 15 minutes.

Engine:

Type	Lycoming O-235-L2C
Serial number	L-22456-15
Hours since new	11 086,1
Hours since overhaul	1 386,1

Propeller:

Type	McCauley 1A103/TCM6958
Serial number	SR 773762
Hours since new	11 086,1
Hours since overhaul	186,1

1.6.2 Weight and balance

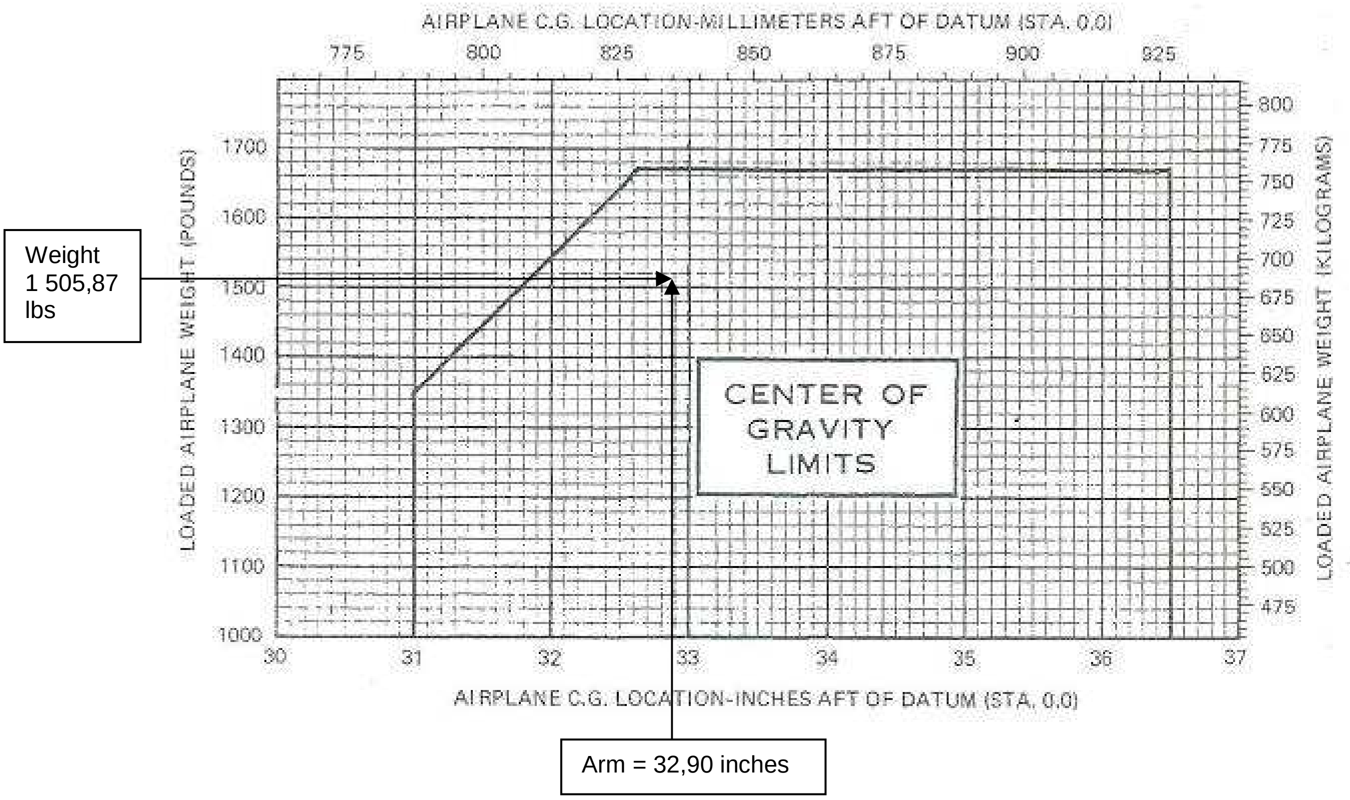
Approximately 52 litres of Avgas was drained from the aircraft fuel tanks at the accident site prior to recovery of the wreckage. Both fuel tanks remained intact during the impact sequence, although the left fuel tank became dislodged from its upper wing attachments. The aircraft was equipped with an "ON" and "OFF" fuel selector, which when in the "ON" position supplies fuel to the engine from both left and right tanks simultaneously under gravity.

Item	Weight (lbs)	Arm (inches)	Moment (lbs x inch)
Aircraft empty weight	1 203,71	30,66	36 905,00
*Pilot (93 kg)	205,00	39,00	7 995,00
Baggage (*pilot flying bag, 7 kg)	15,00	90,00	1 350,00
Fuel (main left - 26 litres)	41,08	40,00	1 643,20
Fuel (main right - 26 litres)	41,08	40,00	1 643,20
Weight	**1 505,87**	**32,90**	**49 536,40**

The maximum certified take-off weight for the aircraft according to the POH, Section 2, Limitations was 1 670 pounds (757 kg).

*NOTE: The weight of the pilot used for the calculation above was obtained from the post-mortem report. The pilot's flying bag, which was positioned in the aft baggage area, contained documentation, maps, a small first aid kit, a space blanket and associated flying-related equipment. The aircraft empty weight was obtained from the last weighing report, which was carried out on 26 March 2013 (weight and balance data, page 82 in the airframe logbook).

The aircraft was flown within the centre of gravity (CG) limits as stipulated in the CG graph below, which was obtained from the POH, Section 6, p 6-12.



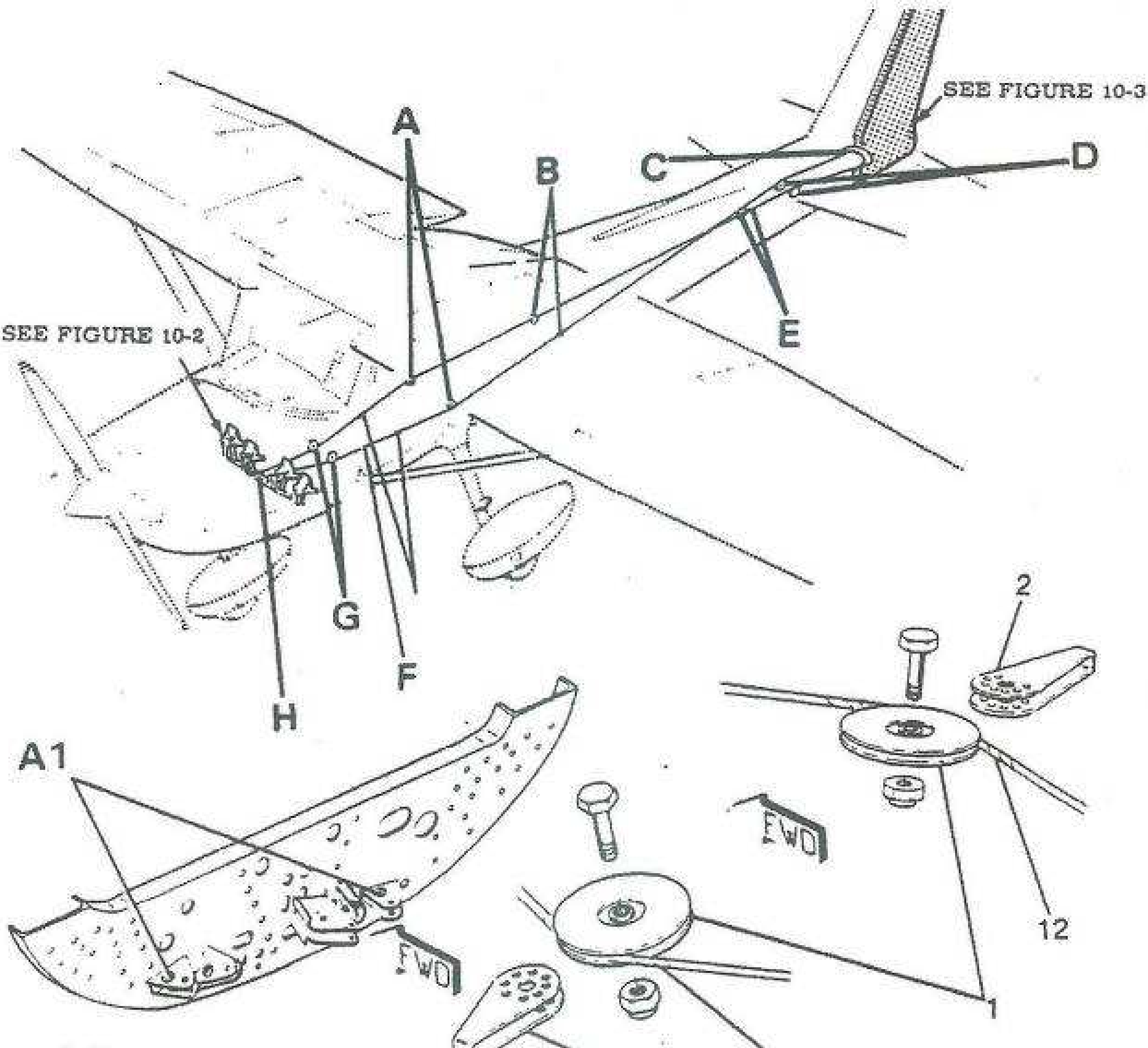
1.6.3 Rudder Control System

Source: Cessna 152 Service Manual

Description: *"Rudder control is maintained through use of conventional rudder pedals which also control nose wheel steering. The system is comprised of the rudder pedals, cables and pulley, all of which link the pedals to the rudder and nose wheel steering."*

The illustration on the next page, figure 5(a), provides the reader with some insight into the layout of the rudder control system on the Cessna 152 type aircraft.

MODEL 152 SERIES SERVICE MANUAL



1. Pulley
2. Cable Guard
3. Fairlead
4. Rudder Cable
5. Clevis
6. Bushing
7. Bellcrank
8. Stop Screw
9. Clip
10. Rudder Bar
11. Left Cable
12. Right Cable
13. Turnbuckle

CAUTION

Maintain specified control cable tension.

CABLE TENSION:
REFER TO RIGGING PARAGRAPH IN THIS SECTION.
SEE FIGURE 1-1 FOR TRAVEL.

Figure 10-1. Rudder Control System (Sheet 1 of 3)

Figure 5(a). Rudder control system

MODEL 152 SERIES SERVICE MANUAL

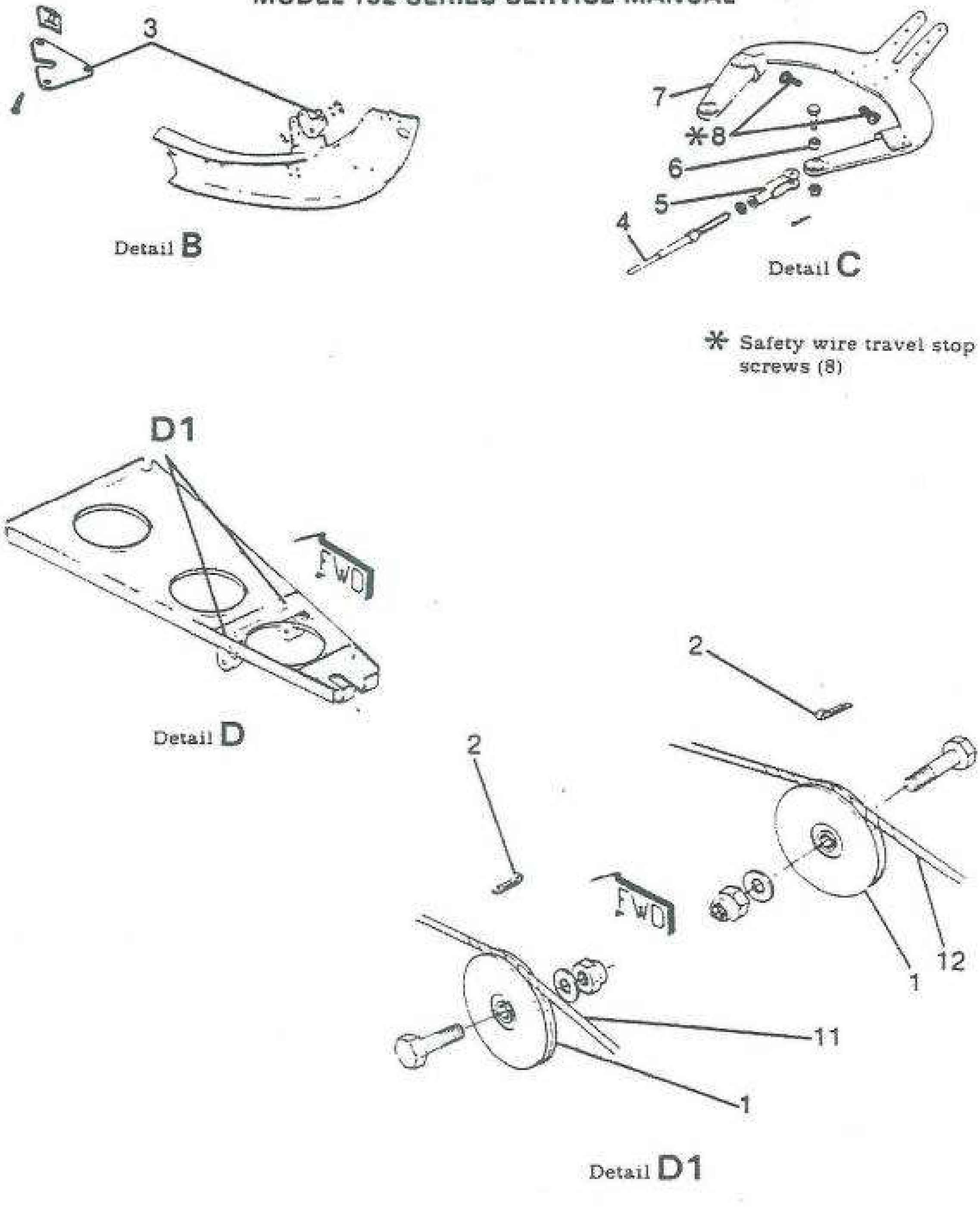


Figure 10-1. Rudder Control System (Sheet 2 of 3)

Figure 5(b). Rudder control system

MODEL 152 SERIES SERVICE MANUAL

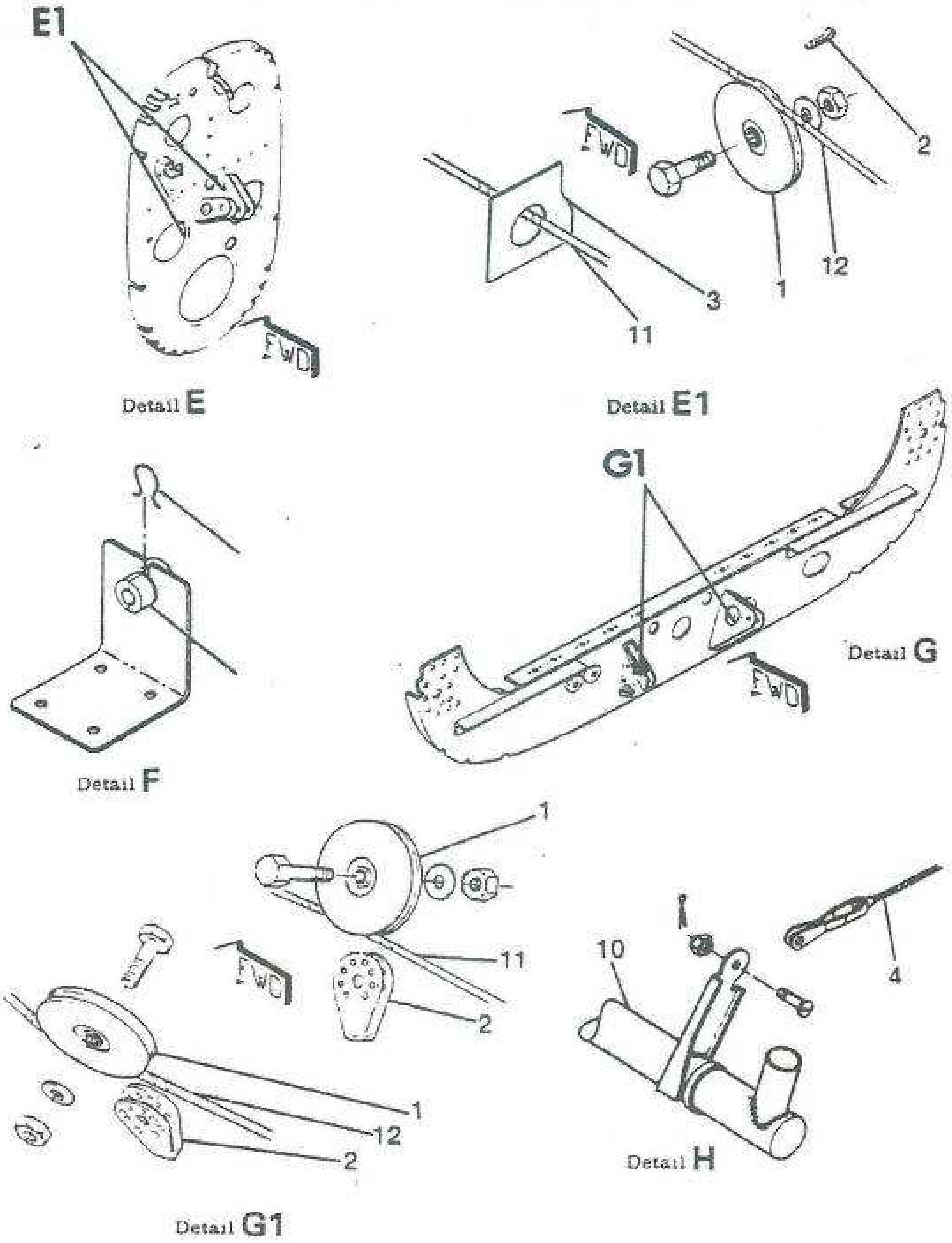


Figure 10-1. Rudder Control System (Sheet 3 of 3)

Figure 5(c). Rudder control system

1.6.4 Cessna Rudder Stop Service Kit

According to the airframe logbook, page 85, the Cessna rudder stop service kit with reference SEB01-1 was installed on the aircraft by an aircraft maintenance organisation (AMO) in South Africa on 10 March 2008.

1.6.5 The Cessna Aircraft Company Model 152 Service Manual

The service manual states that the rudder cables (Expanded Maintenance Inspection) "*Are to be examined after the first 100 hours of operation. The inspection to be repeated every 600 hours of operation or 12 months, whichever occurs first, after the initial inspection has been accomplished".*

"Rudder. 1. Check rudder travel and cable tension. 2. Check rudder cable system, control cables and pulleys, in accordance with the flight cable inspection procedures in Section 2A-20-01, Expanded Maintenance, Control Cables."

The rudder inspection service manual requirement as well as the cable inspection procedure as contained in Section 2A-20-01 can be found attached to this report as Annexure B.

1.6.6 Aircraft maintenance inspections

The aircraft was imported into South Africa in early 2008. According to the airframe logbook the aircraft was subjected to fourteen mandatory periodic inspections (MPIs) since it was registered on the South African register, which amounted to 1 300 airframe hours. The last maintenance inspection that was carried out on the aircraft prior to the accident flight was certified on 16 November 2012. The supporting documentation with reference to the maintenance inspection was obtained from the AMO. Under both subheadings 'Airframe' and 'Control systems' (Document: Cessna 152 Service Manual, Revision 1, dated 2 October 1995) the relevant tasks with reference to cables were signed off.

The table on the next page presents a summary of the fourteen MPI inspections certified on the aircraft.

Date of inspection	Airframe hours	Maintenance facility
10 March 2008	9 700.0	Approved AMO

13 November 2008	9 800.0	Approved AMO
11 February 2009	9 900.0	Approved AMO
15 April 2009	10 000.0	Approved AMO
5 July 2009	10 100.0	Approved AMO
24 September 2009	10 200.0	Approved AMO
1 April 2010	10 300.0	Approved AMO
12 August 2010	10 400.0	Approved AMO
7 December 2010	10 500.0	Approved AMO
28 January 2011	10 600.0	Approved AMO
2 June 2011	10 700.0	Approved AMO
25 October 2011	10 800.0	Approved AMO
18 May 2012	10 900.0	Approved AMO
16 November 2012	11 000.0	Approved AMO

1.6.7 Rudder cable inspection interval requirements

The rudder cables on these aircraft are *'on condition'* items, which means they have no defined service life prescribed by the aircraft manufacturer and are replaced following assessment of the condition of the cables during maintenance inspections.

The inspections on these cables need to be conducted every 600 hours or 12 months, whichever occurs first. That would mean the cables are to be inspected every 6th 100-hour periodic inspection, or once every 12 months if the aircraft hours do not add up to 600 hours during a 12-month period. According to the maintenance inspection table in paragraph 1.6.6, the cables were required to be inspected once every 12 months, as the aircraft flying hours never added up to the 600 hours within a 12 month period. The 12-month items are usually inspected at a mandatory periodic inspection closer to the 12-month date. (Inspection interval requirements as per Cessna Service Manual are contained in Annexure B attached to this report, subheading 24).

1.6.8 Rudder cable visual inspection

A very short section of the rudder cable and clevis can be visually inspected by the pilot during his/her pre-flight inspection; this is where the cable protrudes from the fuselage on the side and is attached to the rudder bell crank as can be seen in figure 6. These aircraft are fitted with two maintenance inspection panels, one on either side of the fuselage, also shown in figure 6; these panels are removed during maintenance inspections, as shown in figure 7. Once the panels have been removed, maintenance personnel can access/inspect these cables and the pulleys, which are mounted and routed within the aft fuselage and attached to the bell crank on the rudder control surface.

Figure 6. A view of the inspection panel as well as the rudder cable and attachment bracket

Figure 7. On the photo the inspection panel is removed and the rudder cable disconnected (maintenance)

The photo in figure 8 was taken of the rudder cables and pulleys positioned inside the fuselage after the inspection panel as referred to in figure 6 was removed.

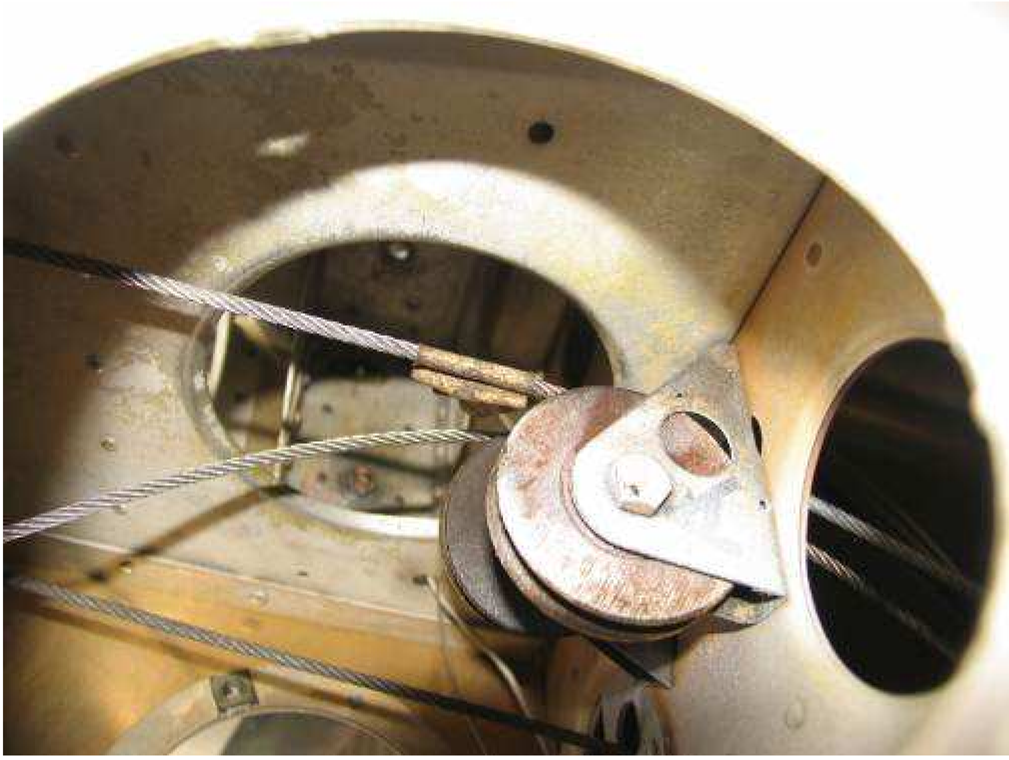


Figure 8. Photo of the rudder cables and pulleys taken through the inspection panel (maintenance in progress)

1.6.9 Wreckage inspection

During the on-site investigation it was found that the aft section of the right-hand rudder cable had failed. Both the right as well as the left-hand rudder cables were removed for metallurgical examination.

Following recovery of the wreckage the aft section of the fuselage was cut open in order to inspect the area as well as the pulleys (see figure 9). The primary objective was to ensure that the pulleys were properly aligned, free of any sharp edges and not frozen. The pulleys were found to be properly aligned, free of any sharp edges and could easily be turned by hand, nor did they display any evidence of excessive wear or lubrication. The surrounding structure was also inspected and no evidence could be found that any part of it might have caused the cable to be exposed to excessive mechanical wear during operation apart from the pulleys. The pulley shown in figure 9 as section B and also in figure 11 is the last pulley that supports the right-hand rudder cable before it protrudes from the fuselage and is visible from the outside as can be seen in figure 6.

Figure 9. The aft section of the fuselage cut open in order to inspect the rudder cable pulleys

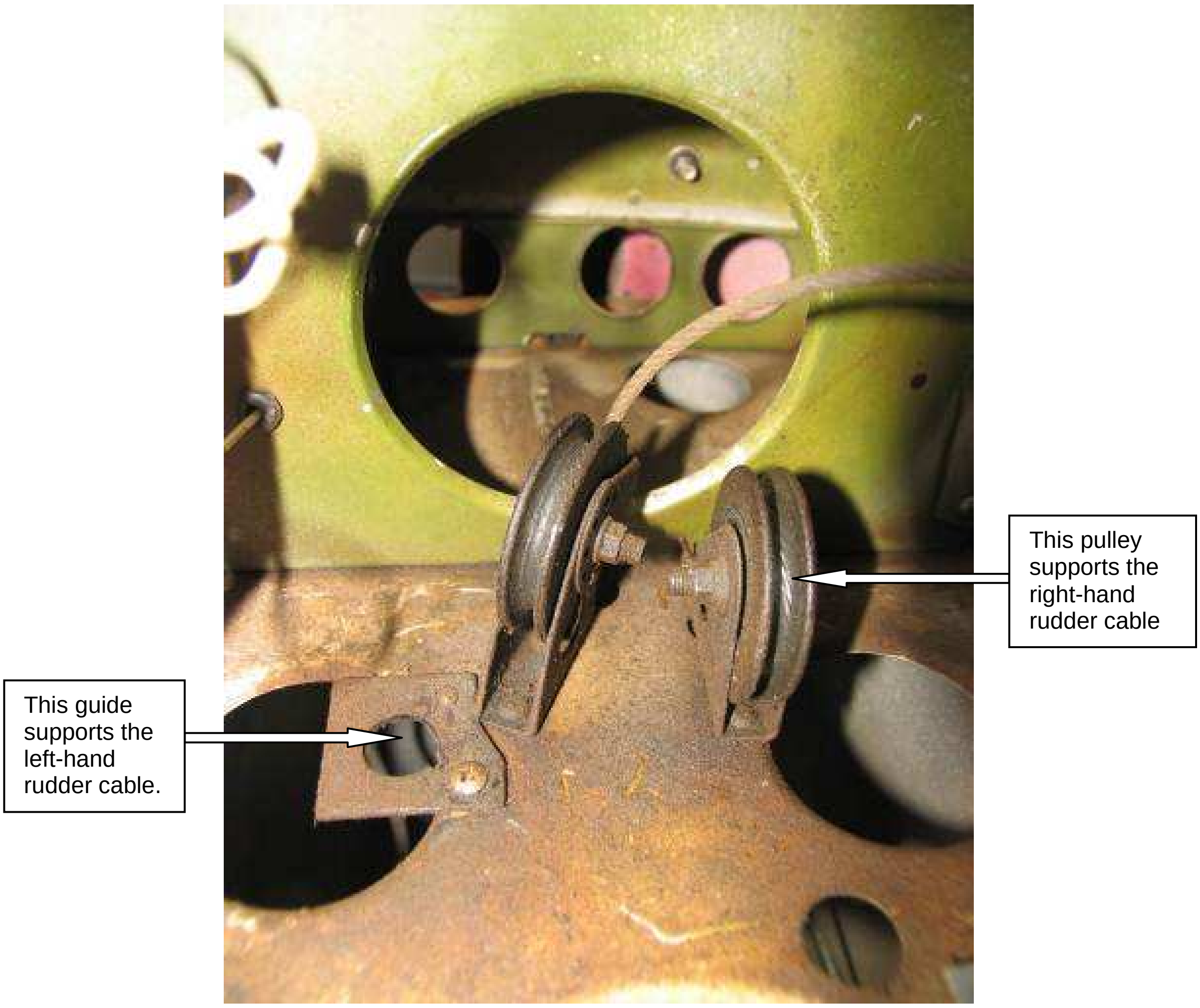


Figure 10. A close-up view of the pulley (Section A) that supports the right-hand rudder cable

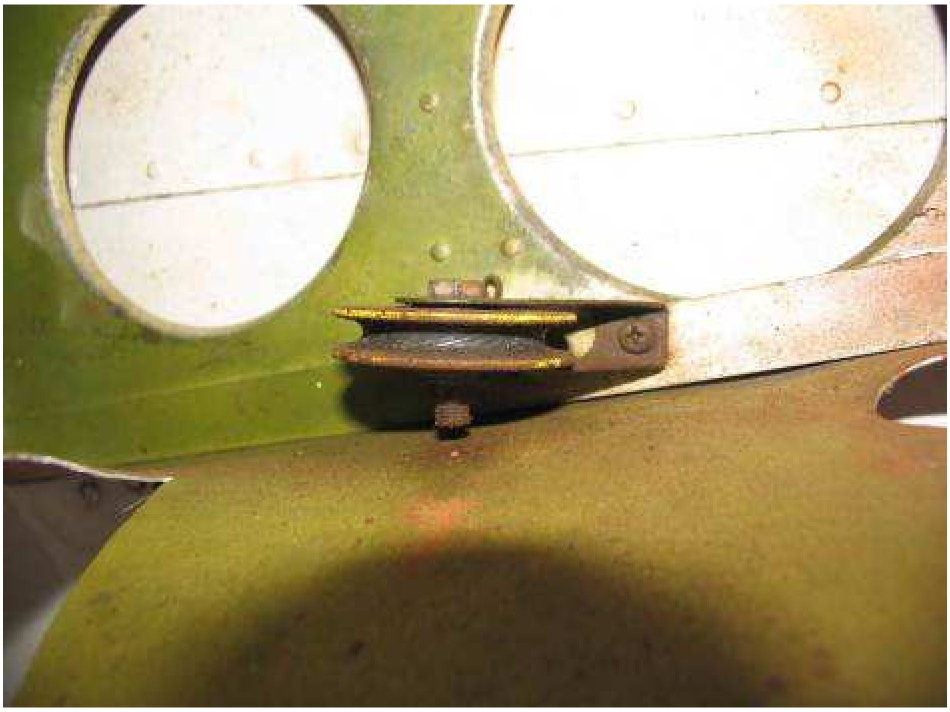


Figure 11. A close-up view of the pulley (Section B) that supports the right-hand rudder cable

1.7 Meteorological information

1.7.1 An official weather report was obtained from the South Africa Weather Services (SAWS) for this accident. The data entered in the column below was taken on the day of the accident at 1440Z, which was the weather data for the area closest to the possible time of the accident.

Wind direction	260°	Wind speed	12 gusting 23 knots	Visibility	+ 10 km
Temperature	31℃	Cloud cover	Nil	Cloud base	Nil
Dew point	4℃				

1.8 Aids to navigation

1.8.1 The aircraft was equipped with standard navigational equipment that was approved by the regulator.

1.9 Communication

1.9.1 The aircraft was flying outside controlled airspace below the terminal control area (TMA) when the accident occurred. The VHF frequency in use in the area was 124.40 MHz. No radio communication pertinent to the accident was recorded.

1.10 Aerodrome information

1.10.1 The accident did not occur at an aerodrome. The closest licensed aerodrome to the accident site was FAWC, which was located 9,2 nm to the northwest.

1.11 Flight recorders

1.11. The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was it required to be installed on this aircraft type according to the regulations.

1.12 Wreckage and impact information

1.12.1 The accident site was located 9,2 nm east-southeast of FAWC on the farm Wittekop. The wreckage was confined to a small area and was consistent with a low velocity and a high rate of descent. The only ground markings visible were located approximately 4 m in front of the main wreckage and were caused by the nose landing gear, which broke off during the impact sequence.

The aircraft battery was found at the ground impact location as well as the nose wheel and nose landing gear strut assembly. The impact heading was 315°M. The impact sequence was associated with an aircraft that was in a left spin during ground impact, with damage to the left wing as well as the wing strut, which was found to have bent approximately mid-span along the strut. The right wing strut was undamaged. The cockpit area was substantially deformed, especially in the area of the rudder pedals as well as the roof structure. The right front door was found in the open position. The flaps were found to be in the retracted position (up). Flight control continuity was ascertained for the ailerons and elevators.

The horizontal stabiliser on the right side displayed some deflection upwards approximately mid-span along the surface; very little damage was visible to the left horizontal stabiliser. The vertical stabiliser, including the rudder, was found to be deflected towards the right, when looking at the wreckage from the aft position. The right rudder cable was found to have fractured approximately 27 centimetres from the attachment to the aft rudder bracket. The left rudder cable remained intact. Both rudder cables were removed from the wreckage for further examination.

Figure 12. The aircraft as it came to rest

Figure 13. Aft view of the aircraft

One of the propeller blades displayed signs of impact damage, with the blade tip being bent backwards; the other blade as well as the spinner revealed no signs of rotational scoring, as can be seen in figure 14 below. Cockpit examination revealed that the carburettor heat selector lever was in, the throttle was in (maximum power selected), and the mixture lever was about 1 cm out (very close to full rich).

Figure 14. A view of the propeller and front section of the aircraft.

1.13 Medical and pathological information

1.13.1 The medico-legal autopsy was carried out on the deceased on 29 April 2013, two days after the accident. The cause of death was attributed to *multiple injuries*, including head and chest injuries.

1.13.2 A blood specimen of the deceased was submitted for toxicological analysis. At the time this report was concluded the toxicological results were not available yet. Should the results have any bearing on the outcome of the report, the evidence will be included in the report and the report will be revised accordingly.

1.13.3 No medical factor that could have affected the pilot's ability to fly the aircraft was detected during the medico-legal autopsy.

1.14 Fire

1.14.1 There was no pre- or post-impact fire.

1.15 Survival aspects

1.15.1 The accident was associated with high kinetic impact forces above that of human tolerance, which rendered this accident not survivable.

1.16 Tests and research

1.16.1 The engine, a Lycoming O-235-L2C, serial No. L-22456-15, was removed from the wreckage. The engine sustained impact damage and it was not possible to conduct an engine bench test run. A teardown inspection was conducted on 30 April 2013 at an aircraft maintenance organisation (AMO). The engine did not reveal any mechanical defects that could have contributed to or have caused the engine to fail. The evidence displayed was associated with normal engine operation.

Figure 15. A view of the engine taken during the on-site investigation.

1.16.2 During the on-site investigation the right-hand rudder cable was found to have failed approximately 27 centimetres (10 inches) from the aft rudder bracket attachment (also referred to as the clevis). Both the right-hand as well as the left-hand cable assemblies 0400107-49 and -50 were removed from the wreckage and were forwarded to the Federal Aviation Administration (FAA) in the United States of America for metallurgical analysis at an approved facility. Figure 16 on the next page displays the aft section of the failed right-hand rudder cable as well as the left-hand cable that was installed on the aircraft at the time of the accident flight. A detailed metallurgical report can be found attached to this report as Annexure A. The report concludes that: *"The cable likely broke due to wear. No evidence of fatigue was noted. On all but the centre strand, the majority of the wires were worn less than 50% of the original diameter. The centre strand of the wires exhibited tensile fracture over the majority of the wires".*

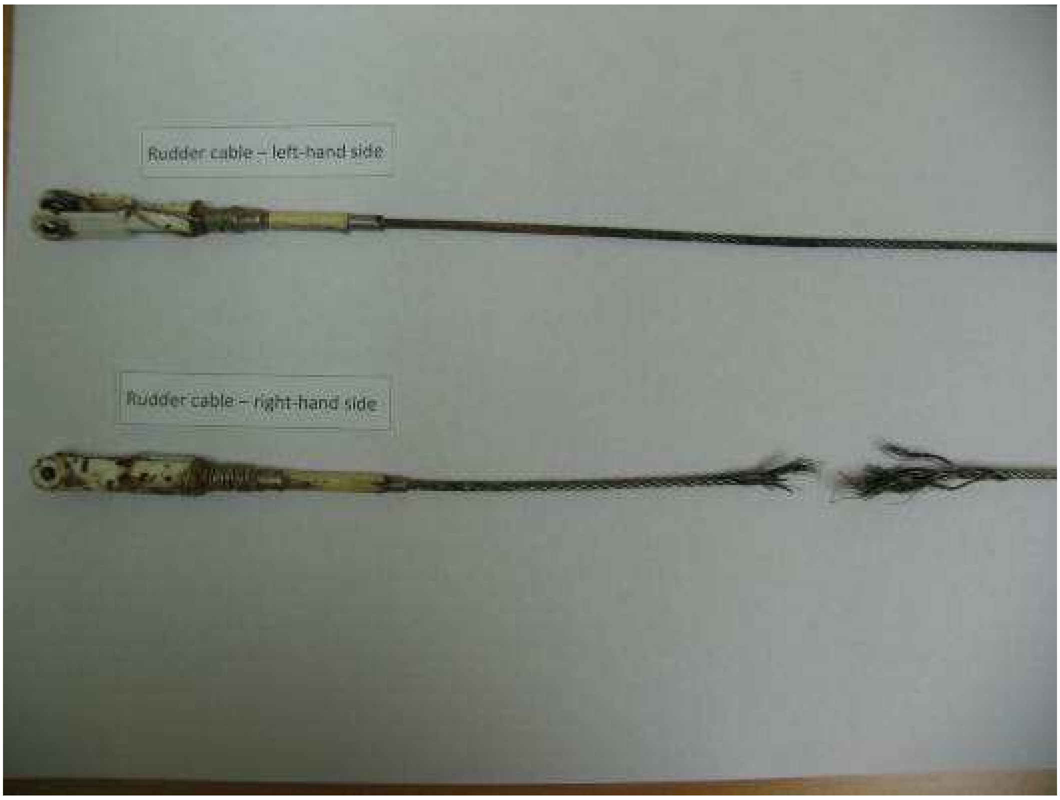


Figure 16. A view of the aft section of the two rudder cables.

1.17 Organisational and management information

1.17.1 The pilot was a member of the Worcester Flying Club and had made a reservation with the club to hire and fly the aircraft with the intention to conduct a private flight of the area. The pilot had signed the flight authorisation sheet prior to the flight. According to a representative from the flying club, the fuel that remained in the aircraft allowed for a flight of approximately 2½ hours and the pilot had indicated that he would be flying for approximately one hour.

1.17.2 The last maintenance that was carried out on the aircraft prior to the accident flight was performed by an aircraft maintenance organisation (AMO) that was in possession of a valid AMO approval certificate that was issued by the regulating authority.

1.18 Additional information

1.18.1 Pilot's Operating Handbook (POH)

Recovery procedure from a spin as stipulated in the Cessna 152, POH, Section 3, Emergency Procedures, should be as follows:

"1. Place ailerons in neutral position.

2. Retard throttle to idle position.

*3. Apply and **hold** full rudder opposite to the direction of the rotation.*

*4. Just **after** the rudder reaches the stop, move the control wheel **briskly** forward far enough to break the stall. Full down elevator may be required at aft centre of gravity loadings to assure optimum recoveries.*

*5. **Hold** these control inputs until rotation stops. Premature relaxation of the control inputs may extend the recovery.*

6. As rotation stops, neutralize rudder, and make a smooth recovery from the resulting dive.

NOTE: If disorientation precludes a visual determination of the direction of rotation, the symbolic airplane in the turn coordinator may be referred to for this information.

NOTE: Variation in basic airplane rigging or in weight and balance due to installed equipment or cockpit occupancy can cause differences in behaviour, particularly in extended spins. These differences are normal and will result in variations in the spin characteristics and in the recovery lengths for spins of more than 3 turns. However, the above recovery procedure should always be used and will result in the most expeditious recovery from any spin".

1.18.2 In section 3 of the POH, page 3.2 it states *"that during prolonged spins, the aircraft engine may stop. Spin recovery is, however, not adversely affected by engine stoppage."*

1.18.3 The aerodynamics of a spin

Annexure C explains the aerodynamics of a spin.

1.19 Useful or effective investigation techniques

1.19.1 Not applicable.

2. ANALYSIS

2.1 Pilot (Man)

The pilot was the holder of a valid private pilot licence. He commenced with his flying training as a student pilot on 18 December 1999 and at the time of the accident flight had accumulated a total of 173,0 flying hours (this comprises training hours (flying with a flight instructor) as well as solo flying hours). The pilot maintained his private pilot licence throughout the years, and his last flight prior to the accident flight was conducted on 6 April 2013 in the same aircraft.

The book *"The Air Pilot's Manual - 1 Flying Training"* was located on the accident scene (see figure 2, page 4 of this report). The possibility cannot be excluded that the pilot intended to practise the three different flight manoeuvres highlighted by page markers in the book. From the accident scene it was evident that the book was not in his flying bag at the time, as the bag remained intact in the aft cabin area and all compartments were closed. The book was most probably lying next to the pilot on the right front seat during the flight. It should be noted that the accident occurred approximately 15 minutes after take-off (this information is based on the tachometer reading when compared with the last flight folio entry as found at the accident scene).

From the eyewitness account it was very difficult to determine whether the pilot had initiated the spin manoeuvre or whether it was unintentional. Following an assessment of the wreckage, it could be ascertained that the aircraft was indeed in a spin when it impacted the ground. For an aircraft to enter a spin, certain flight criteria must be met, which indicate that the pilot most probably induced the manoeuvre. Whether his intention was to enter a fully developed spin or to recover following the incipient phase could not be determined, however. The aircraft impacted the ground while still in a spin. No medical factor that could have affected the pilot's ability to fly the aircraft was detected during the medico-legal autopsy.

2.2 Aircraft (Machine)

The aircraft was manufactured in 1979 and was imported into South Africa from the United States of America in March 2008. The airframe hours entered into the South African logbook indicates that the aircraft had accumulated 9 700 hours since new when it arrived in South Africa. Over the period March 2008 until November 2011, fourteen (14) mandatory periodic inspections were carried out on the aircraft in South Africa prior to the accident flight, which constitute a further 1 300 airframe hours. An additional 86,1 hours were flown with the aircraft after the last MPI was certified until the accident flight.

The aircraft was subjected to the required maintenance inspections since it was imported into South Africa and all the inspections were conducted under the auspices of an approved aircraft maintenance organisation. The aircraft was in possession of a valid certificate of airworthiness at the time of the accident flight.

The rudder cables installed on this aircraft were *'on condition'* items, which means they have no defined service life prescribed by the aircraft manufacturer and are replaced following assessment of the condition of the cables during maintenance inspections. The Cessna 152 Service Manual, read in conjunction with the expanded maintenance procedure 2A-20-01 (Control Cables) attached to this report as Annexure B, provides clear guidelines to maintenance personnel on how to inspect these cables during every prescribed maintenance inspection. The expanded maintenance procedure provides maintenance personnel with the required information on when these cables need to be replaced should any discrepancy be detected that could impair/jeopardise the integrity of such cables. This is of paramount importance with reference to flight control cables.

According to available maintenance records these inspections where complied with by the AMO during routine maintenance. No documented evidence could be obtained that either of the rudder cables were replaced after the aircraft was imported into South Africa in 2008.

The metallurgical report indicates that the right-hand rudder cable had failed due to mechanical wear, which progressed over an undetermined period of time. The left-hand cable also displayed evidence of wear, but the wear had not reached such an advanced state as the right-hand cable, which failed in operation. A breaking strength test was performed on the left-hand cable and it failed in the area where the wear was present, which was well below the 2 000 pounds engineering limit.

2.3 Mission

The aircraft was hired from the flying club by the pilot with the intention to conduct a private flight. The possibility that the pilot could have opted to practise certain flying manoeuvres as marked in the book that was found on site, namely *"The Air Pilot's Manual, 1 Flying Training,* by Trevor Thom, which include spins, forced landings and precautionary landings, cannot be excluded. In order for the aircraft to enter into a spin the pilot had to initiate such a manoeuvre by entering a condition of stalled flight (high angle of attack), whereby a wing drop is essential to enter a spin; this may occur by itself or (more likely) be induced by the pilot yawing the aircraft. Ground impact markings and wreckage deformation indicate that the aircraft was in a spin when it collided with the ground. The intention of the pilot might not have been to enter a fully developed spin, but to recover following the incipient phase. However, the incipient phase also requires the pilot to apply sufficient rudder to prevent further yaw.

2.4 Environment

Fine weather conditions prevailed at the time of the flight and were not considered to have had a bearing on the accident. The pilot was familiar with the area, as he had flown there on many previous occasions, having been a member of the Worcester Flying Club since 2002.

2.5 Conclusion

The examination of the wreckage suggested that the aircraft impacted the ground with very little forward velocity, but with a substantial vertical component associated with a high rate of descent (illustrated by the compression of the wreckage). The wreckage showed slightly more damage on the left wing than the right wing; the deformation of the fuselage (especially the nose section) displayed a clear twist towards the left, which was indicative of an aircraft that had entered a spin to the left.

The fact that the propeller and spinner displayed very little signs of rotation on impact could be an indication that the engine had stopped prior to the aircraft impacting the ground. The POH of the aircraft states that prolonged spinning could cause engine stoppage, but that this should not adversely affect spin recovery.

In view of the handbook found in the cockpit area with the exercise in spin recovery highlighted, the pilot may have been practising this exercise. It is unlikely that the aircraft had entered a turn to the left and subsequently a spiral dive due to the failure of the right-hand rudder cable.
It could, however, not be determined at what stage during the flight the cable failed. An essential part of the recovery technique from a spin is that the pilot should check throttle close and apply full opposite rudder. Taking into consideration that the cable was found to be in a state of wear, the cable most probably failed when the pilot applied full opposite rudder, which in this case would have been right rudder, in

order to recover from the spin manoeuvre. Following the failure of the cable the pilot had no rudder authority to counteract the yaw rate and the aircraft continued to spin towards the left until it impacted the ground.

3. CONCLUSION

3.1 Findings

3.1.1 The pilot was the holder of a valid private pilot licence and had the aircraft type endorsed on his licence.

3.1.2 The pilot was the holder of a valid aviation medical certificate that was issued by a CAA-approved medical examiner.

3.1.3 No medical factor that could have affected the pilot's ability to fly the aircraft was detected during the medico-legal autopsy.

3.1.4 The aircraft was in possession of a valid certificate of airworthiness at the time of the accident flight.

3.1.5 The aircraft had accumulated a further 86,1 flying hours since the last MPI inspection prior to the accident flight was certified on the aircraft, dated 16 November 2012.

3.1.6 The aircraft weight and balance and centre of gravity (CG) were found to be within the prescribed limits as stipulated in Section 6 of the POH.

3.1.7 During the on-site investigation it was found that the right-hand rudder cable had failed. The failure mode was attributed to mechanical wear. The wear occurred over an undetermined period of time.

3.1.8 Wear damage on the right-hand cable at other locations suggested extended operational exposure.

3.1.9 Although to a lesser degree, the left-hand rudder cable revealed similar damage. During a strength test that was conducted on the cable it failed in the area where wear was present.

3.1.10 Fine weather conditions prevailed at the time of the flight; the wind was from the west at 12 knots gusting 23 knots, with clear sky conditions.

3.2 Probable cause:

3.2.1 The right-hand rudder cable was found to have failed, this most probably rendered the pilot without rudder authority to counteract the spin and recover from the manoeuvre.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended to the Director of Civil Aviation that the Airworthiness division issue an Urgent Safety Advisory Notice to all Cessna 150/152 owners to ensure rudder cable integrity is not compromised in any way. A detailed inspection of the rudder cables (from the front to the back) should be conducted by an approved aircraft maintenance organisation. Such an inspection should be documented in the aircraft airframe logbook and should not be limited to a once-off inspection.

This safety recommendation was issued in the interest of aviation safety.

5. APPENDICES

5.1 Annexure A (Metallurgical report on rudder cables)
5.2 Annexure B (Cessna 152 Service Manual and expanded maintenance procedure)
5.3 Annexure C (The aerodynamics of a spin)

ANNEXURE A

M&P
Metals Nonmetals NDE R&D

Cessna
A Textron Company

REPORT TITLE:	Examination of a Rudder Cable 0400107-50 from A/C 152-82591		
REPORT #:	13-359-167	**DATE:**	08/9/2013
TO:	Steven Miller	**FROM:**	J. Graham-Rateliff
cc:			
Approved by:	Bret Vogel	**Checked by:**	L. Isliefson

Subject Information

P/N:	0400107-50	**Model:**	152
Part description:	RH Rudder Cable	**Flight hours:**	unknown
A/C:	**152-82591**		

Summary

Cessna Air Safety Group and a FAA Representative requested an examination of portions of the right (R) and left (L) rudder control cable assemblies 0400107-49, and -50 from A/C 152-82591 to M&P from an incident in South Africa. M&P was asked to determine if the cable separated due to wear or fatigue, if the damaged areas contained aluminum or pulley material, and to determine the breaking strength of the cable of both undamaged and damaged cable. Based on the examination of the parts, the following conclusions can be made:

1. The cable likely broke due to wear. No evidence of fatigue was noted. On all but the center strand, the majority of the wires were worn to less than 50% of the original diameter. The center strand of wires exhibited tensile fracture over the majority of the wires.

2. Energy-dispersive spectroscopy (EDS) identified some minor amount of aluminum present in the cable debris. The debris also included white fibers, which could be seen optically. The source of these materials cannot be determined.

3. The breaking strength of an undamaged portion of the cable exceeded the CSAM026 requirement of 2000 pounds, and the breaking strength of a portion of cable with localized wear on the outer strands of approximately 50%, was 1529 pounds.

Background

Cessna Air Safety Group and a FAA Representative brought portions of the right (R) and left (L) rudder control cable assemblies 0400107-49, and -50 from A/C 152-82591 to M&P for examination following an incident in South Africa. Figure 1 shows the rudder control system. The -50 (R) cable was separated into two pieces. The -49 (L) cable portion had been cut for removal from the system. See Figure 2. The engineering drawing required the cable assembly to be made from 1/8 inch diameter, 7x19 carbon steel cable per MIL-W-83420, with a MS20664C4 ball end and a MS21259-4RH terminal, and fabricated per CSAM026. M&P was requested to determine if the cable separated due to wear or fatigue, if the damaged areas contained aluminum or pulley material, and to determine the breaking strength of the cable of both undamaged and damaged cable.

Results of Examination

The cables were examined visually and two locations on each cable showed visible debris coating the cable, and evidence of wear at approximately 10 inches from the end of the clevis, or approximately 8 inches from the end of the MS21259-4 terminal, and at approximately 23 inches from the end of the clevis, or approximately 21 inches from the end of the MS21259-4 terminal. The Right cable was separated at approximately 10 inches from the end of the clevis, and one strand was broken at approximately 23 inches from the end of the clevis. The Left cable exhibited shiny wire surfaces in a localized area on the cable. See Figures 3 thru 5.

The -50 Right cable was examined at the break. The 19 broken wires of each of the 7 strands were examined in detail, see Figures 6 thru 12. On all but the center strand, the majority of the wires were worn to less than 50% of the original diameter. Only the center strand of wires exhibited tensile fracture over the majority of the wires. Figure 13 shows a closer view of the broken strand on the -50 Right cable at approximately 23 inches, where wear is evident on the broken wires. Figure 14 shows the shiny areas on the -49 Left cable at approximately 10 inches and 23 inches. Upon closer examination, the wire surfaces are worn to the point where they appear flat.

The -50 Right cable portion (ref. Figure 4) was soaked in Methyl Propyl Ketone (MPK) to remove the oil and debris from the cable. The solution was filtered, washed with MPK to remove the oil, and dried. The debris was examined optically and was found to consist of red and white fibers, large particulate, fine grey particulate, and a few shiny particles. Samples were taken to perform Energy Dispersive Spectroscopy (EDS) (Figure 15). The EDS spectrum shows elements of silicon, iron, zinc, oxygen, carbon, aluminum, magnesium, potassium, and sulfur present in the debris (Figure 16.)

A 2 foot section of undamaged cable was removed from the Left (-49) cable and terminals were swaged on the ends per CSAM026. The cable was pulled in tension to the point of breaking per CSAM016. Also, a section of the Left cable that contained the worn areas was likewise tested to the point of breaking. The cable broke within the area that corresponded to the worn area at approximately 23 inches (ref: Figure14). Figure 17 shows the broken cable. The breaking strength results are listed in Table 1. A semi-quantitative chemical analysis was performed on the cable to check the material chemistry against the specification. The results indicate the cable is carbon steel. See Figure 19.

Discussion of Results

FAA Advisory Circular 43.13-1B provides a graphic that characterizes wear on cable through the wear pattern of the outer wires. As the outer wires wear, the edges of the worn area on individual wires eventually blend. When this occurs, the wear is at approximately 50% of the thickness of the individual outer wires. See Figure 19. Based on this graphic, the individual outer wires in wear areas, as shown in Figures 13 and 14, have worn to at least 50% of their diameter. Although accumulated debris on the cable can act as an abrasive on the wires as the cable moves over a pulley, the relative motion between the wire surfaces also produces wear over time. The breaking strength of the undamaged cable met the requirement of 2000 pounds per CSAM026, but the worn portion of the cable broke below requirement at 1529 pounds.

With a majority of the wires showing wear to the point of fracture on 6 of 7 strands, it is likely that the cable broke due to wear. No evidence of fatigue was noted. The debris found coating the cable appeared to contain some large particulate and fibers. The red fibers are likely a color tracer filament common to a specific cable manufacturer. The white fibers are from an unknown source, however, the cable pulleys (S378-3) are made from phenolic, which is required by MIL-DTL-7034 to be fiber reinforced. Much of the large particulate resembles sand and dirt. A few shiny particles were evident. The EDS spectrum showed a significant amount of silicon, which indicates sand and other organic material, as does the carbon, oxygen, and potassium. The presence of iron and zinc are expected as wear debris from the cable, which is zinc coated. Aluminum was detected in the debris but the source is not known.

Material Evaluation

Table 1

Sample ID	Breaking Strength Pounds (LBS)
-49 Left cable undamaged	2133
-49 Left cable 28 inch section from end of clevis - damaged	1529
Engineering Requirement	2000 LBS. per CSAM026

Notes:

1. Ref. CMF Lab Request # TL-319

MODEL 152 SERIES SERVICE MANUAL

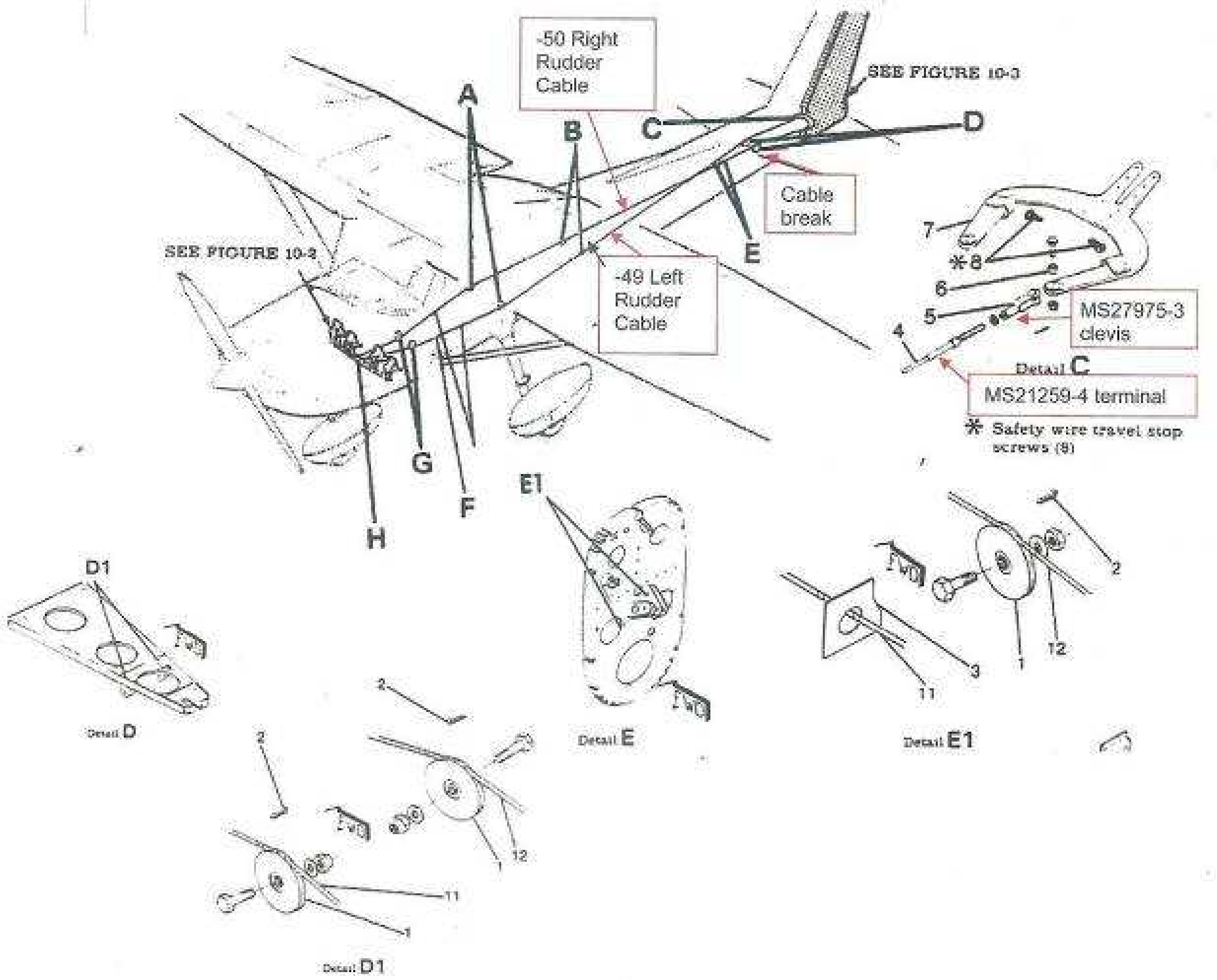


Figure 1 - Figure showing an overview of the rudder control system from 152 Series Service Manual and figures showing details from the Illustrated Parts Catalog. The -49 and -50 cables are labeled, as well as the approximate location of the cable break.

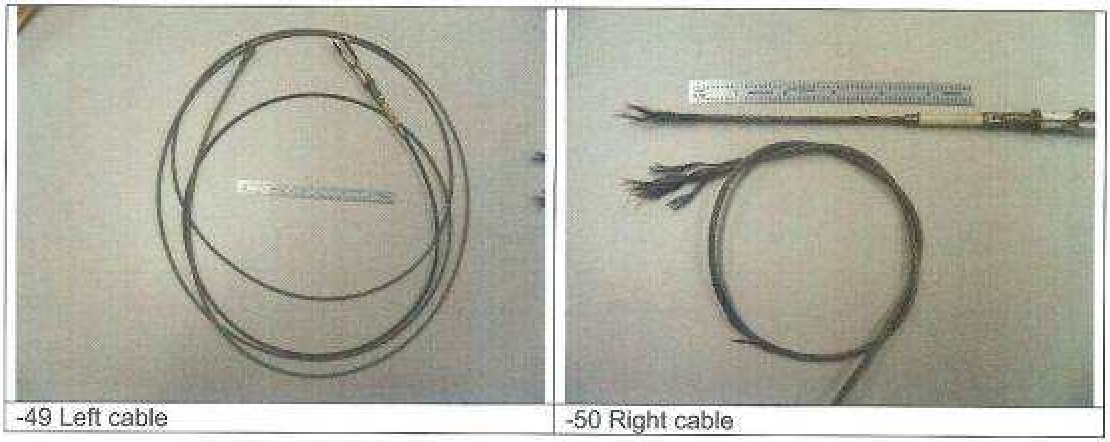


Figure 2 – Photos of cables as-received.

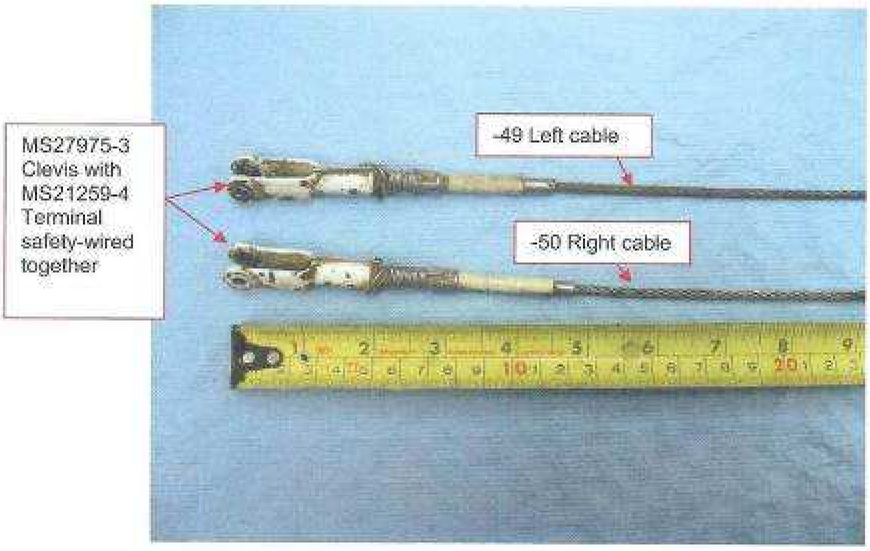
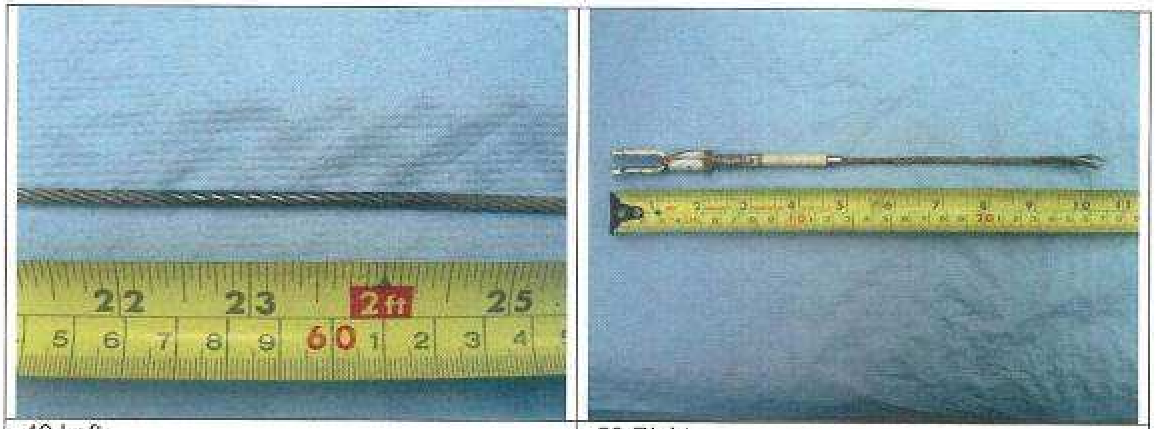
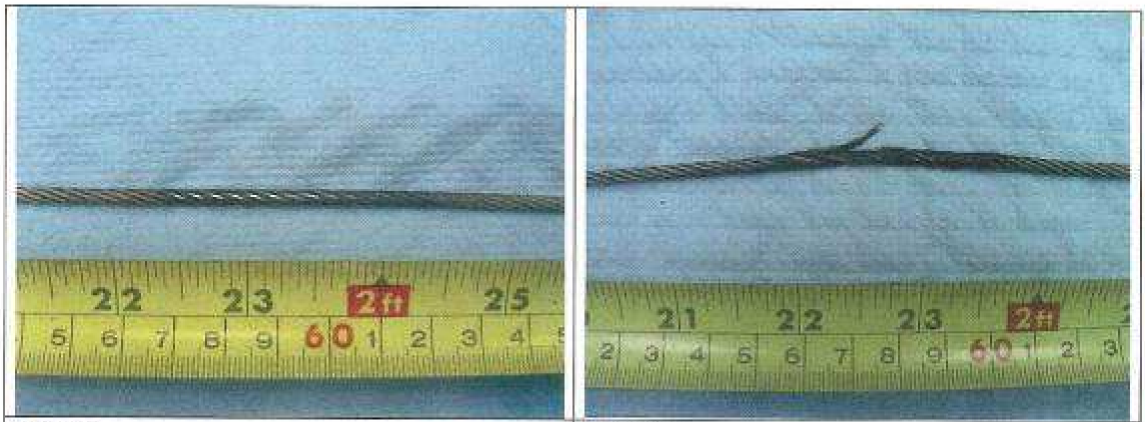


Figure 3 – Photo of cable terminals with clevis safety wired to it, showing condition. This is the aft end which attaches to the rudder horn.



-49 Left	-50 Right

Figure 4 – Photo of cables at approximately 10 inches from end of clevis (ref. Figure 3 approx. 8" from end of MS21259-4 terminal) showing wear on the -49 cable and cable separation of the -50 cable.



-49 Left	-50 Right

Figure 5 – Photo of cables at approximately 23 inches from the end of clevis (approx. 21" from end of MS21259-4 terminal showing wear on the -49 cable and a broken strand on the -50 cable.

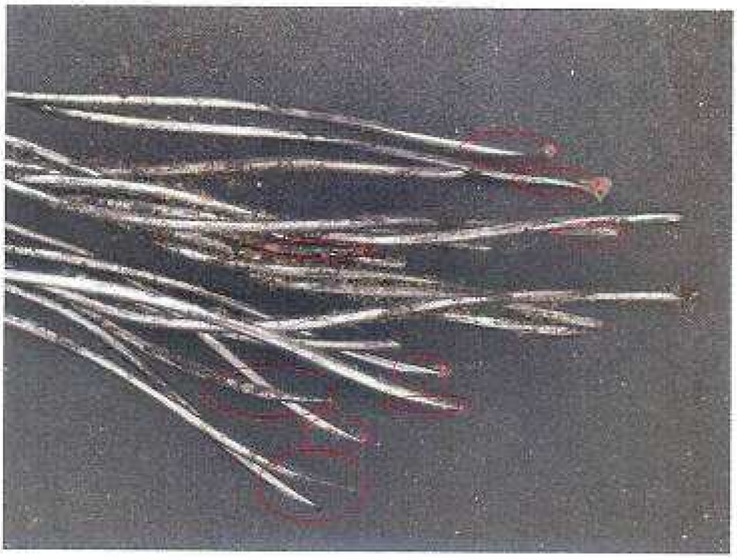


Figure 6 – Photo of Strand 1 from -50 Right cable (ref. Figure 4) showing the individual wires. Note many of the wires are flat-sided and thinned at the tip (red ovals), typical of fracture due to wear. Magnification approximately 10x.

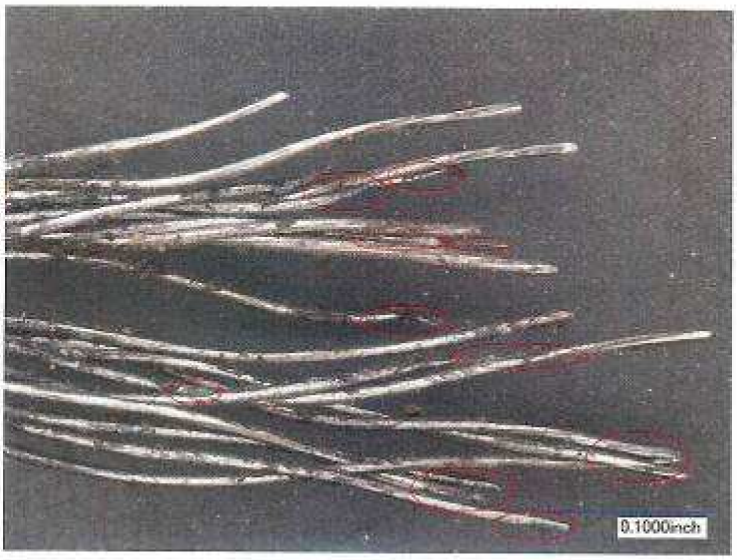
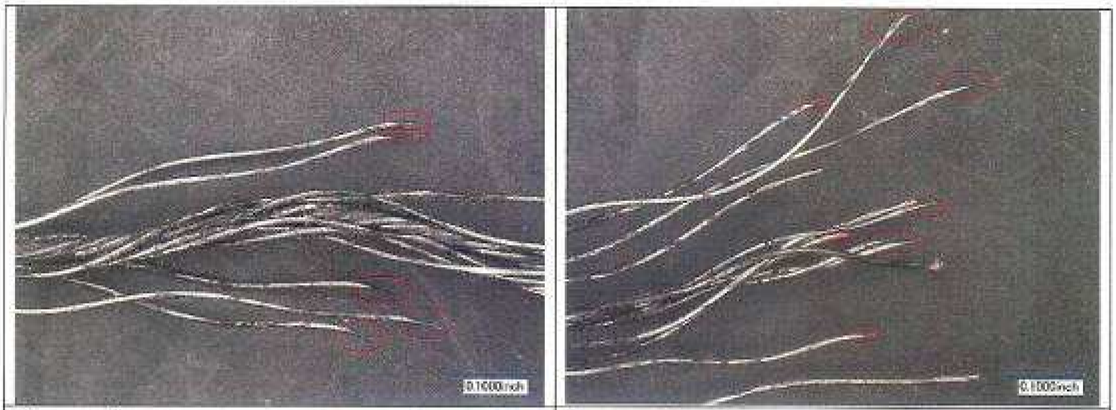


Figure 7– Photo of Strand 2 showing the individual wires. Note many of the wires are flat-sided and thinned at the tip (red ovals), typical of fracture due to wear. Magnification approximately 10x.



5 worn wires	8 worn wires

Figure 8– Photo of Strand 3 showing the individual wires. Note many of the wires are flat-sided and thinned at the tip (red ovals), typical of fracture due to wear. Magnification approximately 5x.

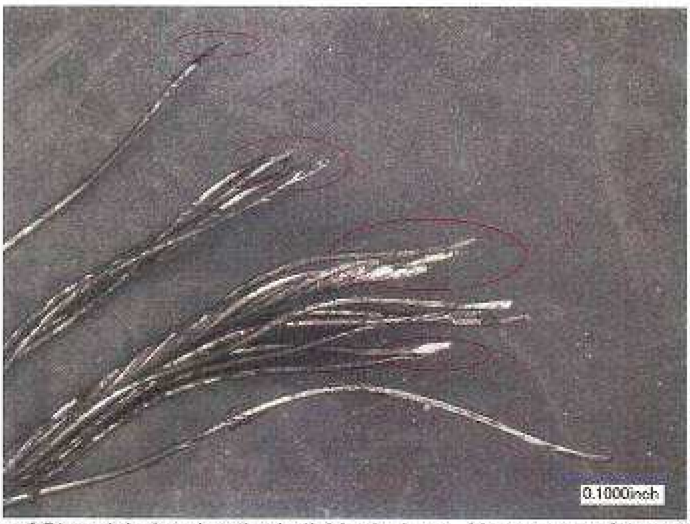


Figure 9 - Photo of Strand 4 showing the individual wires. Note many of the wires are flat-sided and thinned at the tip. Magnification approximately 7x.

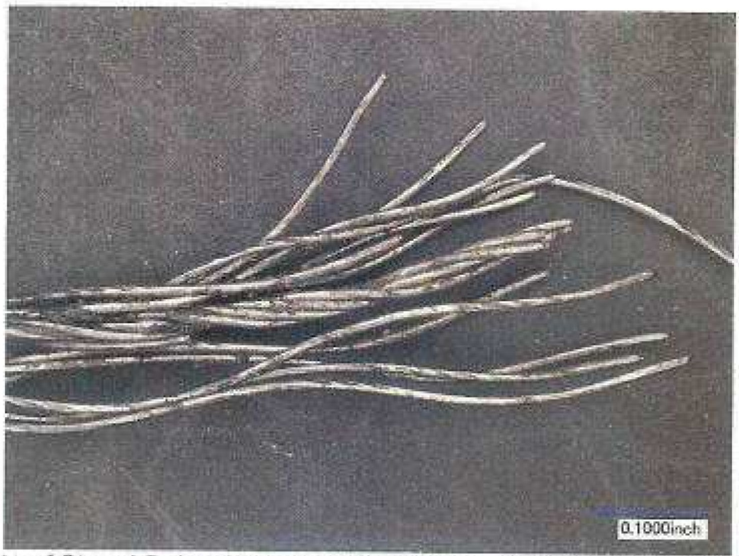


Figure 10 - Photo of Strand 5 showing the individual wires. All wires show shear-mode tensile fracture with some necking observed. This was the center strand of the cable. Magnification approximately 7x.

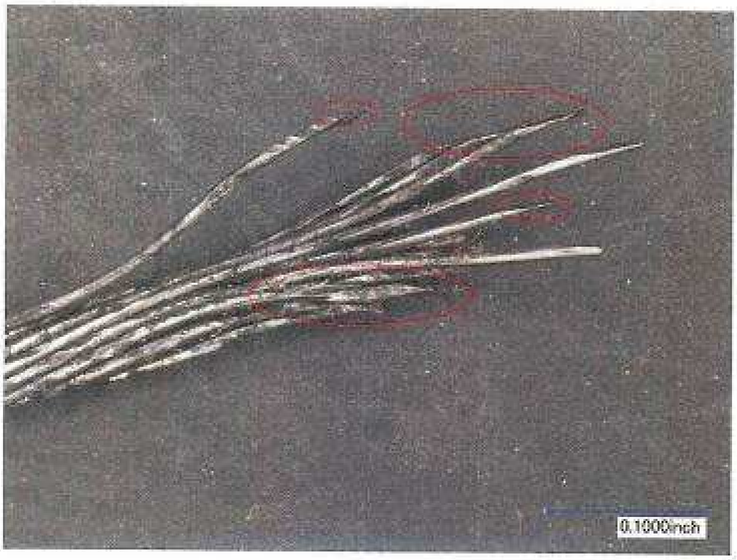


Figure 11 – Photo of Strand 6 showing the individual wires. Note wires are flat-sided and thinned at the tip (red ovals), typical of fracture due to wear. Magnification approximately 10x.

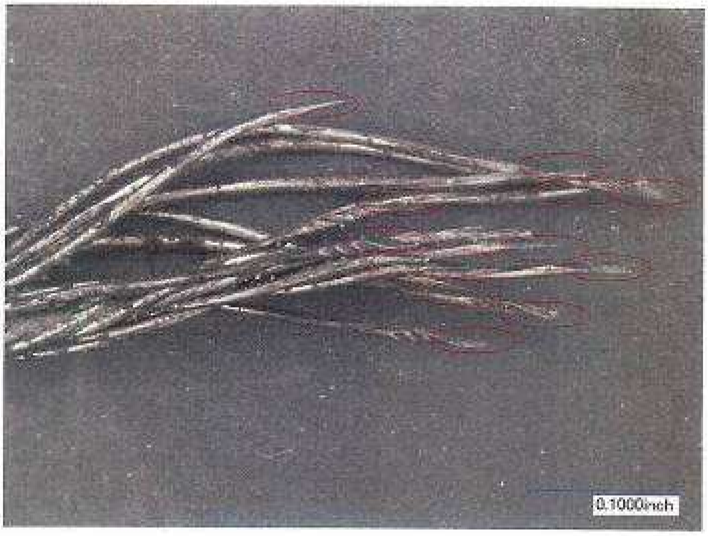


Figure 12 - Photo of Strand 7 showing the individual wires. Note nearly all wires are flat-sided and thinned at the tip (red ovals), typical of fracture due to wear. Magnification approximately 10x.

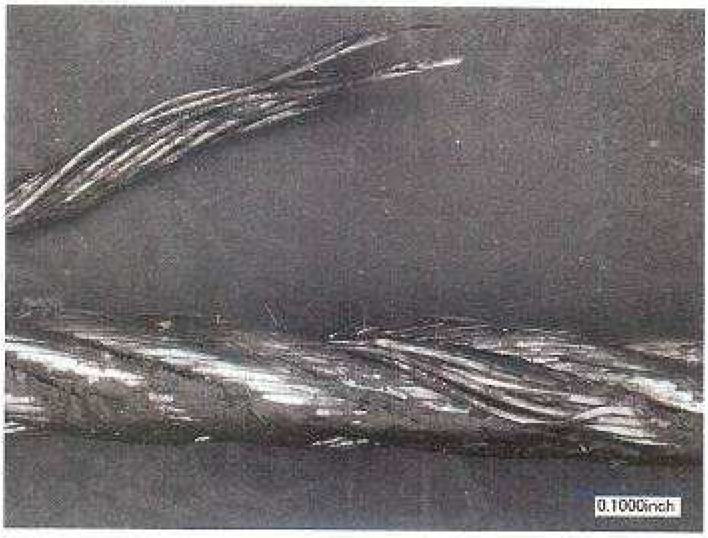
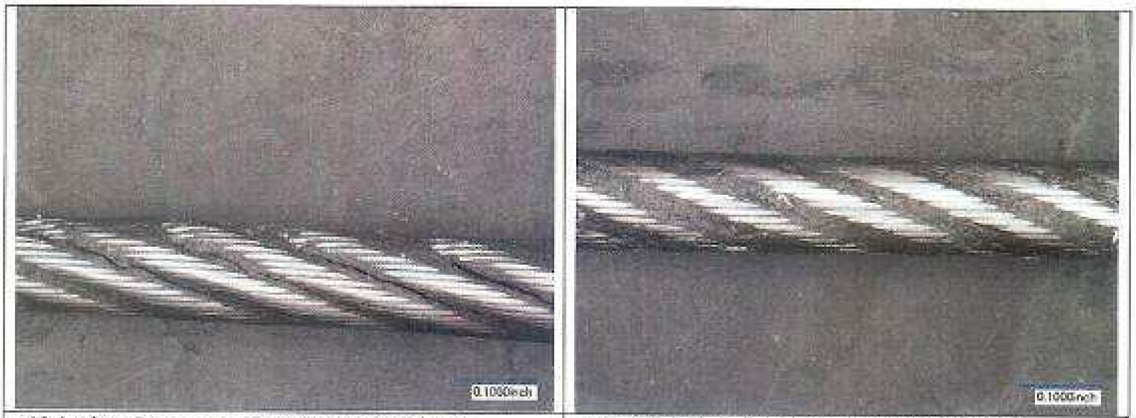


Figure 13 – Photo at slightly higher magnification of the Right cable (ref. Figure 5) showing the degree of wear at approximately 23" from the clevis and thinning of the broken wires. Magnification approximately 7x.



-49 Left cable wear @ approx.10 inches	-49 left cable wear @ approx.23 inches

Figure 14 – Photos under magnification of the Left cable showing wear at approximately 10 inches and 23 inches. The outer surfaces of the wires are worn flat. Magnification approximately 5x.

Figure 15 – Photo of the filtrate from the -50 broken cable. The red fibers are a color tracer filament common to a specific cable manufacturer. The white fibers are from an unknown source, however, the cable pulleys (S378-3) are made from phenolic, which is typically fiber reinforced. Much of the large particulate resembles sand and dirt. A few shiny particles are evident. Magnification of debris approximately 15x.

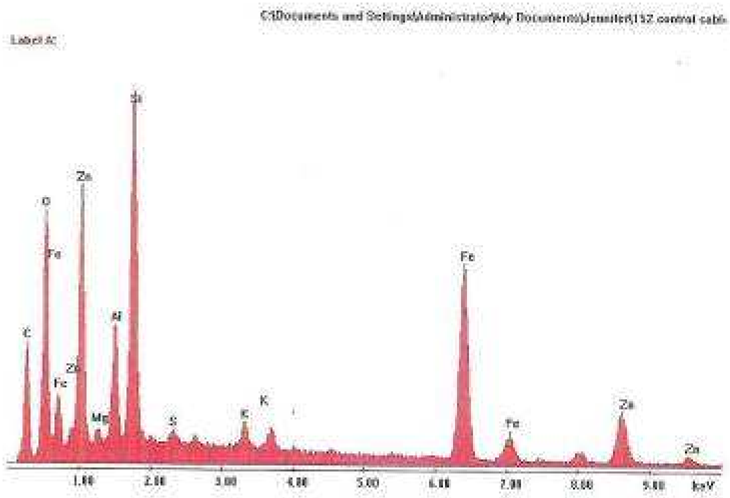


Figure 16 - The EDS spectrum shows elements of silicon (Si), iron (Fe), zinc (Zn), oxygen (O), carbon (C), aluminum (Al), magnesium (Mg), potassium (K), and sulfur (S) present in the debris.

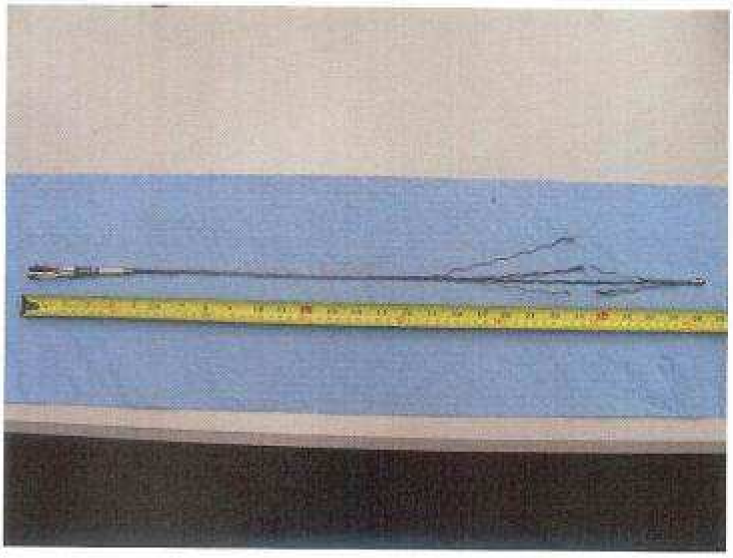


Figure 17 – Photo of the section of Left cable containing worn areas tested to the point of breaking. The cable broke within the area that corresponded to the worn area at approximately 23 inches.

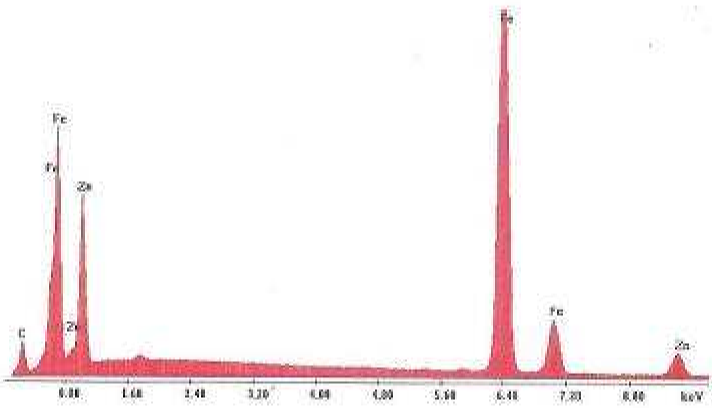


Figure 18 - EDS spectrum of wire, showing this to be a carbon steel cable. The zinc (Zn) peaks are due to the plating on the wires and are not part of the material chemistry.

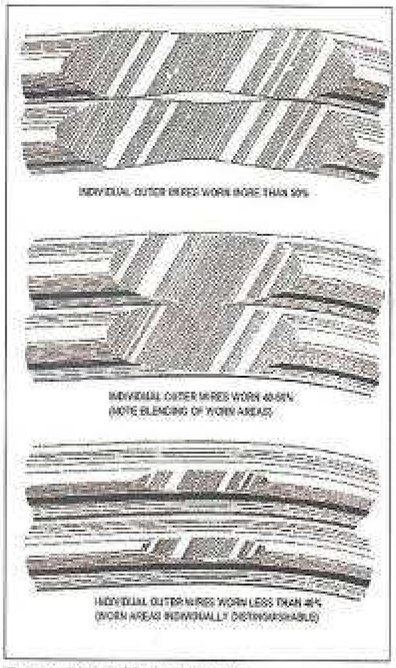


FIGURE 7-17. Cable wear patterns.

Figure 19 – Reference graphic excerpted from AC43.13-1B, Figure 7-17, which shows cable wear patterns.

REVISION STATUS	TASK	INTERVAL	OPERATION	ZONE
	Areas of the cabin structure. Make sure you inspect these areas: 1. Cabin door forward and aft frames. 2. Window frames with emphasis at stringers and channel assemblies from aft of door frame to aft bulkhead. 3. Seat attachment structure. 4. Aft Cabin Bulkhead. NOTE: Corrosion Prevention and Control Program Inspection item (baseline interval, refer to Section 2A-30-00 for additional inspection information).	Every 60 months	6	210
	Flaps. 1. Check flap travel cable tension, and travel time. 2. Check flap cable system, control cables, and pulleys, in accordance with the flight cable inspection procedures in Section 2A-20-01, Expanded Maintenance, Control Cables.	Initial: 100 hours; repeat: every 600 hours or 12 months	24	210, 510, 610
	Aileron. 1. Check aileron travel and cable tension. 2. Check aileron cable system, control cables, and pulleys, in accordance with the flight cable inspection procedures in Section 2A-20-01, Expanded Maintenance, Control Cables.	Initial: 100 hours; repeat: every 600 hours or 12 months	24	210, 510, 520, 610, 620
	Elevator. 1. Check elevator travel and cable tension. 2. Check elevator cable system, control cables, and pulleys, in accordance with the flight cable inspection procedures in Section 2A-20-01, Expanded Maintenance, Control Cables.	Initial: 100 hours; repeat: every 600 hours or 12 months	24	210, 310, 340, 330
	Elevator Trim. 1. Check elevator trim travel and cable tension. 2. Check elevator trim cable system, control cables, and pulleys, in accordance with the flight cable inspection procedures in Section 2A-20-01, Expanded Maintenance, Control Cables.	Initial: 100 hours; repeat: every 600 hours or 12 months	24	210, 310, 340, 330
	Rudder. 1. Check rudder travel and cable tension. 2. Check rudder cable system, control cables, and pulleys, in accordance with the flight cable inspection procedures in Section 2A-20-01, Expanded Maintenance, Control Cables.	Initial: 100 hours; repeat: every 600 hours or 12 months	24	210, 310, 320
	Wing structure internal. Make sure you inspect these areas: 1. Main spar upper and lower carry-thru fittings, 2. Main spar upper and lower caps, 3. Main spar web. NOTE: Corrosion Prevention and Control Program Inspection item (baseline interval, refer to Section 2A-30-00 for additional inspection information).	Every 12 months	2	510, 520, 610, 620
	Wing structure internal. Make sure you inspect these areas: 1. Wing front spar and lower spar caps. 2. Upper and lower wing attach spar fittings. 3. Wing lower skins. NOTE: Corrosion Prevention and Control Program Inspection item (baseline interval, refer to Section 2A-30-00 for additional inspection information).	Every 60 months	6	510, 520, 610, 620

Operation	Details
20 -	Supplemental Inspection Document items that are to be examined after the first 10,000 hours of operation or 20 years, whichever occurs first. The inspection is to be repeated every 2,000 hours of operation or 4 years, whichever occurs first, after the initial inspection has been accomplished.
21 -	Supplemental Inspection Document items that are to be examined after the first 3 years. The inspection is to be repeated every 3 years after the initial inspection has been accomplished, for airplanes operating in a severe corrosion environment.
22 -	Supplemental Inspection Document items that are to be examined after the first 100 hours of operation or 1 year, whichever occurs first. The inspection is to be repeated every 100 hours or 1 year whichever occurs first, after the initial inspection has been accomplished.
23 -	Supplemental Inspection Document items that are to be examined after the first 2,000 hours of operation or 4 years, whichever occurs first. The inspection is to be repeated every 2,000 hours or 4 years, whichever occurs first, after the initial inspection has been accomplished.
24 -	Expanded Maintenance Inspection items that are to be examined after the first 100 hours of operation. The inspection is to be repeated every 600 hours of operation or 12 months, whichever occurs first, after the initial inspection has been accomplished.

EXPANDED MAINTENANCE

1. **Control Cables**

A. The chromium nickel steel wire is helically twisted into strands and the strands laid about other strands forming the flexible steel cable. The diameter of the cable is determined by the number of wires and the number of strands in the cable.

(1) Construction of Cables

(a) Cable diameter, 1/32 inch, 3 by 7 construction - Cable of this construction shall consist of three strands of seven wires each. There shall be no core in this construction. The cable shall have a length of lay of not more than eight times nor less than five times the nominal cable diameter.

(b) Cable diameter, 1/16 inch and 3/32 inch, 7 by 7 construction - Cable of this construction shall consist of six strands of seven wires each, laid around a core strand of seven wires. The cable shall have a length of lay of not more than eight times nor less than six times the nominal cable diameter.

(c) Cable diameter, 1/8 inch through 3/8 inch, 7 by 19 construction - Cable of this construction shall consist of six strands laid around a core strand. The wire composing the seven individual strands shall be laid around a central wire in two layers. The single core strand shall consist of a layer of 6 wires laid around the central wire in a right direction and a layer of 12 wires laid around the 7 wire strand in a right direction. The 6 outer strands of the cable shall consist of a layer of 6 wires laid around the central wire in a left direction and a layer of 12 wires laid around the 7 wire strand in a left direction.

(d) Lubrication - A pressure type friction preventative compound, having noncorrosive properties, is applied during construction as follows:

- Friction preventative compound is continuously applied to each wire as it is formed into a strand so that each wire is completely coated.
- Friction preventative compound is continuously applied to each strand as it is formed into a cable so that each strand is completely coated.

(e) Definitions - The following definitions pertain to flexible steel cable:

- Wire - Each individual cylindrical steel rod or thread shall be designated as a wire.
- Strand - Each group of wires helically twisted or laid together shall be designated as a strand.
- Cable - A group of strands helically twisted or laid about a central core shall be designated as a cable. The strands and the core shall act as a unit.
- Diameter - The diameter of cable is the diameter of the circumscribing circle.
- Wire Center - The center of all strands shall be an individual wire and shall be designated as a wire center.
- Strand Core - A strand core shall consist of a single straight strand made of preformed wires, similar to the other strands comprising the cable in arrangement and number of wires.
- Preformed Type - Cable consisting of wires and strands shaped, prior to fabrication of the cable, to conform to the form or curvature which they take in the finished cable, shall be designated as preformed types.
- Lay or Twist - The helical form taken by the wires in the strand and by the strands in the cable is characterized as the lay or twist of the strand or cable respectively. In a right lay, the wires or strands are in the same direction as the thread on a right screw and for a left lay, they are in the opposite direction.
- Pitch (or length of lay) - The distances, parallel to the axis of the strand or cable, in which a wire or strand makes one complete turn about the axis, is designated as the pitch (or length of lay) of the strand or cable respectively.

B. Inspection of Cable System

NOTE: For tools and equipment used in checking and rigging, refer to the appropriate sections of the Model 152 Service Manual.

(1) Routing
  (a) Examine cable runs for incorrect routing, fraying and twisting. Look for interference with adjacent structure, equipment, wiring, plumbing and other controls.
  (b) Check cable movement for binding and full travel. Observe cables for slack when moving the corresponding controls.

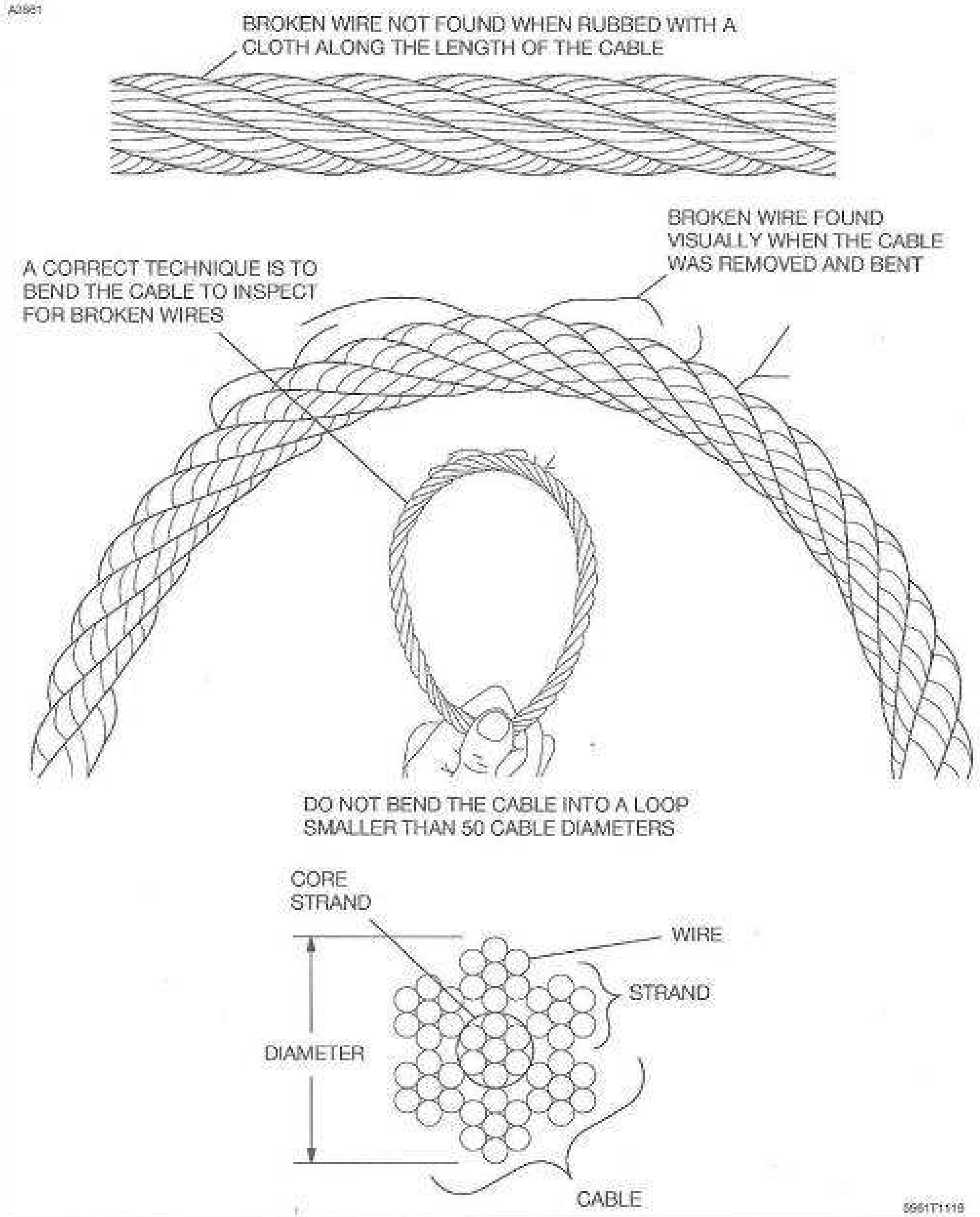
(2) Cable Fittings
  (a) Check swaged fitting reference marks for an indication of cable slippage within the fitting. Inspect the fitting for distortion, cracks and broken wires at the fitting.
  (b) Check turnbuckles for proper thread exposure. Also, check turnbuckle locking clip or safety wire.

(3) Inspection of Control Cable.
  (a) The control cable assemblies are subjected to a variety of environmental conditions and forms of deterioration that ultimately may be easy to recognize as wire/strand breakage or the not-so-readily visible types of corrosion and/or distortion. The following data will aid in detecting an unserviceable cable condition:
  (b) Broken Wire
    1 Examine cables for broken wires by passing a cloth along the length of the cable. This will detect broken wires, if the cloth snags on the cable. Critical areas for wire breakage are those sections of the cable which pass through fairleads, across rub blocks and around pulleys. If no snags are found, then no further inspection is required. If snags are found or broken wires are suspected, then a more detailed inspection is necessary, which requires that the cable be bent in a loop to confirm the broken wires. Refer to Figure 1 for an example. Loosen or remove the cable to allow it to be bent in a loop as shown. Refer to Table 1 for bend diameter criteria. While rotating cable, inspect the bent area for broken wires.

Table 1. Loop and Coil Diameter Criteria

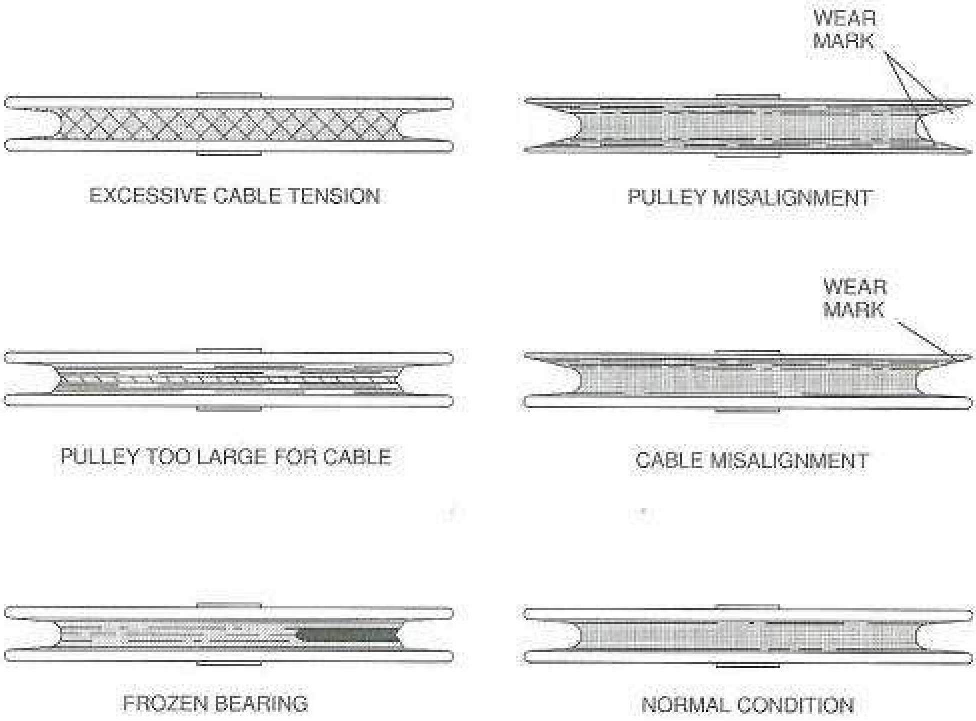
Cable Diameter	Smallest Allowable Loop Diameter (Loop Test)	Smallest Allowable Inside Diameter of Coil (Cable Storage)
1/32 Inch	1.6 Inch	4.7 Inch
1/16 Inch	3.2 Inch	9.4 Inch
3/32 Inch	4.7 Inch	14.1 Inch
1/8 Inch	6.3 Inch	18.8 Inch
5/32 Inch	7.9 Inch	23.5 Inch
3/16 Inch	9.4 Inch	28.2 Inch

    2 Wire breakage criteria for the cables in the flap, aileron, rudder and elevator systems are as follows:
      a Individual broken wires are acceptable in primary and secondary control cables at random locations when there are no more than three broken wires in any given 10-inch (0.254 m) cable length.
    3 Corrosion
      a Carefully examine any cable for corrosion that has a broken wire in a section not in contact with wear producing airframe components, such as pulleys, fairleads, rub blocks etc. It may be necessary to remove and bend the cable to properly inspect it for internal strand corrosion, as this condition is usually not evident



Cable Broken Wires and Pulley Wear Patterns
Figure 1 (Sheet 1)

A2867



Cable Broken Wires and Pulley Wear Patterns
Figure 1 (Sheet 2)

on the outer surface of the cable. Replace cable if internal corrosion is found. For description of control cable corrosion, refer to Section 2A-30-01, paragraph 4(C), Steel Control Cables.

b Areas conducive to cable corrosion are below the refreshment center, in the wheel well and in the tailcone. Also, if a cable has been wiped clean of its corrosion preventative lubricant and metal-brightened, the cable must be examined closely for corrosion.

(4) Pulleys

(a) Inspection of Pulleys

1 Inspect pulleys for roughness, sharp edges and presence of foreign material embedded in the grooves. Examine pulley bushings or bearings to ensure smooth rotation, freedom from flat spots and foreign material.

2 Periodically rotate pulleys, which turn through a small arc, to provide a new bearing surface for the cable.

3 Check pulley alignment. Check pulley brackets and guards for damage, alignment and security. Various failures of the cable system may be detected by analyzing pulley conditions. Refer to Figure 1 for pulley wear patterns; these include such discrepancies as too much tension, misalignment, pulley bearing problems and size mismatch between cable and pulley.

(5) Cable Storage

(a) Cable assemblies shall be stored straight or in a coil. When stored in coil form, the coil inside diameter shall not be less than 150 times the cable diameter or bent in a radius of not less than 75 times the cable diameter. Refer to Table 1 for coil diameter criteria. Coils shall not be flattened, twisted or folded during storage. Storage requirements shall apply until the cable is installed in its normal position in the airplane. If only a part of the cable is installed in an assembly, cable storage requirements apply to the uninstalled portion of the cable.

(6) Flight Control Cable Inspection

(a) General Information

WARNING: If the flight control cable system(s) are removed, disconnected or cable section(s) are replaced, make sure that all rigging, travel checks, cable tensions and control surface checks are done in accordance with the procedures in the appropriate section for the affected flight control system.

NOTE: Flight control cable inspections are normally performed without removing or disconnecting any part of the flight control system. However, it may be necessary to derig or remove the cable to get access to the entire cable.

(b) Cable Inspection Procedure

1 Each flight control cable must be visually inspected along its entire length for evidence of broken wires, corrosion, fraying or other damage. Visual inspection may be via direct sight, mirror and flashlight or borescope.

2 Visually check for proper routing along entire length of cable. Make sure that cables, pulleys, attaching sectors and bell cranks are free and clear of structure and other components

NOTE: Some systems use rub blocks, it is permissible for control cables to rub against these blocks.

3 Each flight control cable will be physically inspected, by passing a cloth along the entire cable. Pay particular attention at all pulley, fairlead, bulkhead seal locations and other locations where the cable may be subject to chafing or wear.

NOTE: It may be necessary to have a second person move the flight control system being inspected to ensure that the entire cable run in an affected area is checked.

4 Any flight control cable which snags the cloth due to broken wires is to be slackened (if not previously slackened) and a loop test performed to identify number and location of individual broken wires (refer to Inspection of Control Cable). Wire breakage criteria is as follows for all cable systems:
   a Individual broken wires,are acceptable in any cable provided that no more than three individual wires are broken in any given ten-inch (0.254 m) cable length. If number of individual broken wires cannot be determined, cable is to be rejected. Any amount of cable or wire wear is acceptable, provided the individual broken wire criteria is met.
   b Reject any cable if corrosion is found which appears to have penetrated into interior of cable. If extent of corrosion cannot be determined, cable is to be rejected.

5 Inspect all cable termination fittings (clevises, turnbuckles, anchors, swagged balls etc.) for security of installation, proper hardware and evidence of damage.
   a All turnbuckles are required to be secured. Safety wire or prefabricated clips are acceptable.

6 Inspect cable pulleys.
   a Inspect all pulleys for security of installation, evidence of damage and freedom of rotation.
   b Pulleys which do not rotate with normal cable movement due to internal bearing failure are to be rejected.
   c Pulleys with grooving etc., due to normal in-service use, are deemed serviceable, as long as overall function is not impaired.

7 Restore cable system as required following cable teardown (if performed).
   a Tension tasks and other tasks specific to individual systems are described under applicable individual tasks.
   b Any flight control cable system which has been torn down requires a flight control rigging check prior to release of airplane for flight.

The aerodynamics of a spin

Source: www.copanational.org/PilotsPrimer (Canadian Owners and Pilots Association)

"If pilots were to get together and rank the most dangerous situations they could encounter over the course of a flight, stall/spin incidents would be near the top.

While stall/spin accidents are not as frequent as other types of accidents, they are in general more deadly. The statistics show that although stall/spin encounters make up only 8% of all general aviation accidents, they account for 25% of the accidents involving serious or fatal injuries. Therefore, general knowledge of spins is stressed throughout pilot training and reiterated in aviation publications.

However, a deeper understanding of spins is commonly lacking among the majority of the pilot population. Hopefully this article will shed light on some of the basic aerodynamic principles that govern the behaviour of aircraft before, during, and after a spin is encountered.

To understand the aerodynamics of a spin, it is important to first understand how lift and drag behave at high angles of attack. This includes not only an understanding of what happens to lift and drag near stall, but also where the stall occurs along the span of the wing.

It is convention to say that a stall occurs when the aircraft exceeds its critical angle of attack. Aerodynamically speaking, this means that at the critical angle of attack, separated flow dominates the airflow over the wing resulting in a decrease in lift and an increase in drag. The location along the wingspan where the stall begins depends on many factors including the wing planform and any stall control device installed on the wing.

Typically, a wing is designed to stall from root to tip, resulting in more effective aileron control during stall. This is important in understanding the effect of aileron input during spin recovery, and will be discussed a little later in the article.

The generally accepted definition of a spin is an aggravated stall that results in autorotation. This is an accurate and concise definition, but it does not explain or provide good understanding to the underlying cause and persistence of a spin.

The aerodynamics of a spin are very complicated, and for ease of understanding the aerodynamics of each phase of a spin should be analyzed separately. The phases of a spin are: entry, incipient, and fully developed.

The entry phase begins with the aggravated stall and ends when the aircraft departs controlled flight. The incipient phase occurs between the departure from controlled flight and the point when the forces acting on the aircraft equilibrate. The fully developed phase is characterized by equilibrium between the aerodynamic and inertial forces.

The entry phase of a spin is characterized by an aggravated stall, causing the aircraft to depart controlled flight. A stall can become aggravated in two ways: a prolonged slip (or more importantly a skid) or a sudden yawing motion at the time of stall.

To answer the question why a prolonged slip aggravates a stall you must first understand that as an airplane slows down, its natural roll damping decreases. This means that the inherent stability of the airplane to keep wings level decreases with airspeed, which makes it much harder to keep wings level in a slip or skid.

Eventually it will result in a rolling motion in the direction of the prolonged slip or skid.

This rolling motion induces a higher angle of attack on the downward wing, resulting in an aggravated stall situation where the downward wing is more stalled than the upward wing. A sudden yawing motion at the time of stall causes the outside wing to travel faster than the inside wing.

This creates more lift on the outside wing compared to the inside wing, which results in rolling motion toward the inside wing and causes the inside wing to be at a higher angle of attack than the outside wing. In either case the airplane enters a state of aggravated stall where one wing is stalled more than the other.

The wing that is more stalled creates more drag and less lift than the less stalled wing, and this imbalance of forces pulls the aircraft away from controlled flight in the direction of the more stalled wing.

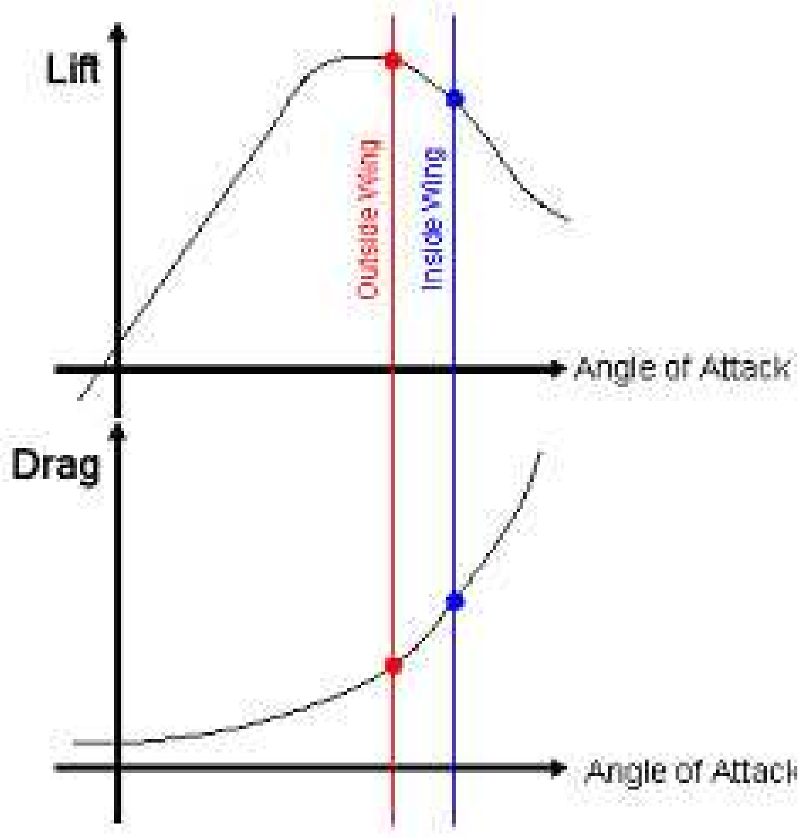


Figure 1 shows the behaviour of lift and drag during the entry phase.

The incipient phase of a spin is characterized by a continued imbalance of lift and drag that continues to pull the aircraft into the spin. In general, the incipient phase lasts for approximately two rotations, during which the rotation rate of the spin increases.

The increase in rotation rate causes the outside wing to increase its velocity, which corresponds to a lower angle of attack. This deepens the aggravated stall, causing a greater imbalance of forces that increases the rotation rate until the spin reaches equilibrium (Figure 2 shows the imbalance of forces on the aircraft during the incipient phase).

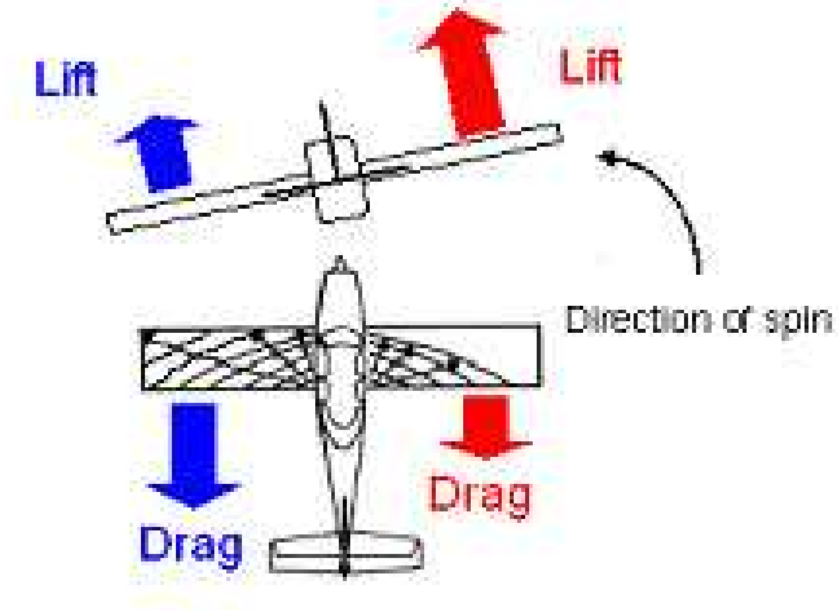


Figure 2. Forces on aircraft during incipient phase.

The fully developed phase of a spin is characterized by an equilibrium between the aerodynamic and inertial forces on the aircraft. Once the aircraft reaches this state it will remain in a fully developed spin until action is taken to recover.

There are four categories of fully developed spins: steep, moderately steep, moderately flat, and flat (Table 1 shows the distinctions between the categories). Spin recovery procedures are necessary to remove the aircraft from its spin equilibrium and return it to normal flight. It is important to understand that different aircraft have different spin characteristics and therefore spin recovery procedures are unique to each aircraft.

This makes it critical to know the procedures in your aircraft's operating handbook for the proper recovery. A general spin recovery procedure taught during primary flight training is known by the acronym "PARE", which states Power to idle, Ailerons neutral, Rudder opposite to rotation, and Elevator forward.

Most spin recovery procedures, even though different, incorporate all of these elements, albeit sometimes in a different order. Understanding the reason behind each of these steps can give insight into the specific spin recovery procedure and complicated spin aerodynamics of your aircraft.

The effect of power on the dynamics of a spin depends on the orientation of the spin (left or right), and also the configuration of the aircraft. The first effect of power on a spin is the torque effect. Torque affects a spin because of the equal and opposite reaction of the airplane to the rotation of the propeller.

For a propeller that rotates clockwise when viewed by the pilot, torque acts to tighten a left spin and flatten a right spin. The second effect of power is the gyroscopic effect. For a propeller that rotates clockwise as viewed by the pilot, a gyroscopic force acts to raise the nose in a left spin and lower the nose in a right spin.

The last effect of power is a thrust line effect, where the thrust line is a line parallel to the longitudinal axis of the airplane along which the thrust acts. If this line is below the centre of gravity (CG) of the aircraft, power results in a flatter spin. The opposite is the case if the thrust line is above the centre of gravity.

The effect of ailerons on the dynamics of a spin are probably the most complicated to explain as well as understand. Going back to the second paragraph, it was said that the vast majority of aircraft are designed so that their wings stall at the root before the tip. This is incredibly important to understand because it implies that the wing tip of the outside wing (less stalled wing) might not be completely stalled. This means that the outside aileron is still effective whereas the inside aileron is not.

To show the full effect of ailerons on spin behaviour, cases of both pro-spin and anti-spin aileron, need to be analyzed for situations with both wing tips stalled and for only one wing tip stalled.

If both wing tips are stalled, pro-spin aileron acts to level the wings and slow down the spin rate, whereas anti-spin aileron acts to steepen the wings and increase the spin rate. If only one wing tip is stalled, pro-spin aileron acts to steepen the wings and slow down the spin rate, and anti-spin aileron levels the wings and increases the spin rate (Figure 3 shows the effect of pro-spin aileron and Figure 4 shows the effect of anti-spin aileron).

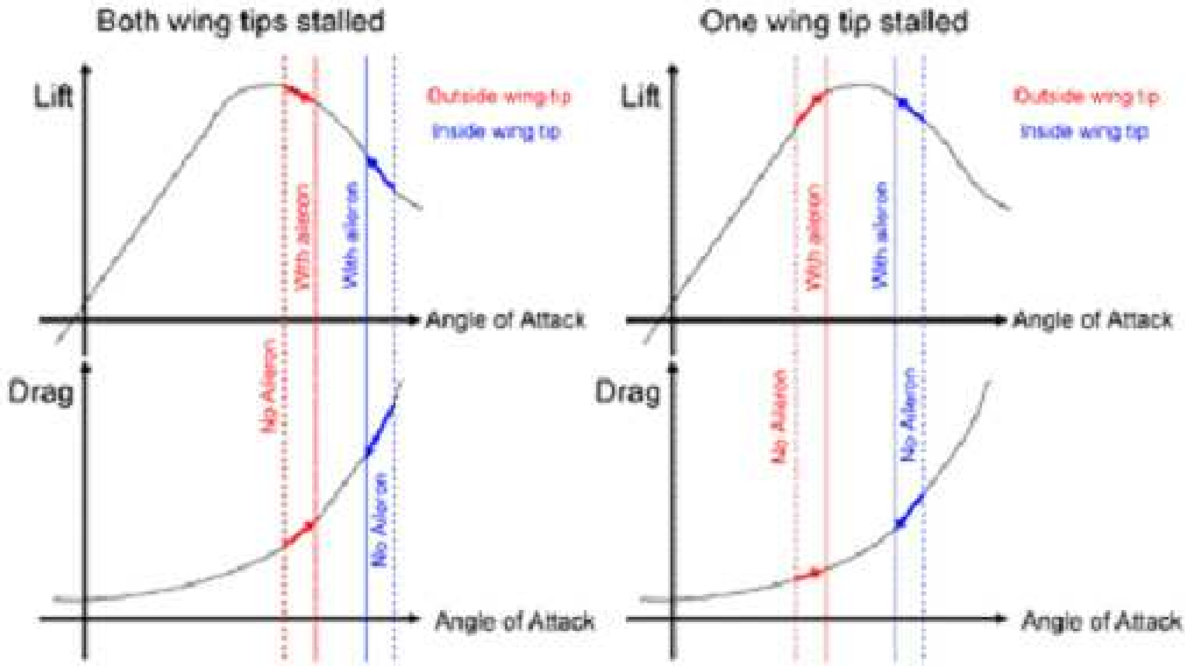


Figure 3. Effect of pro-spin aileron.

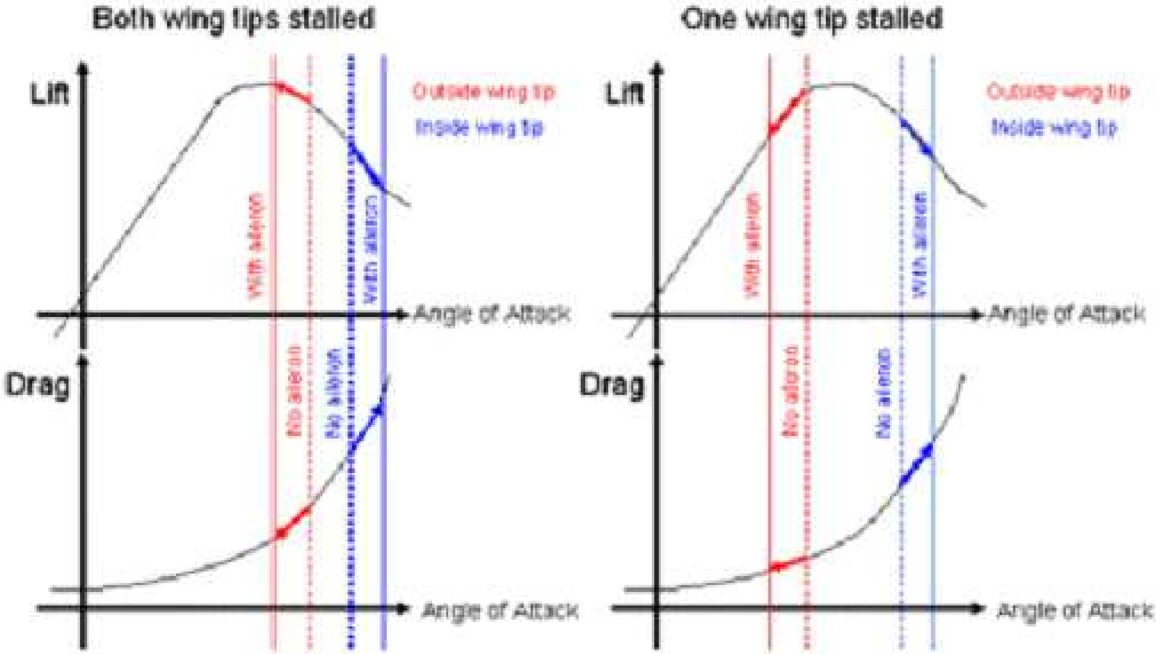


Figure 4. Effect of anti-spin aileron.

From a practical standpoint it is hard to know if one or both of your wing tips are stalled during a spin. Therefore, the best course of action during recovery is to keep the ailerons neutral because you do not know if aileron application will help or hurt recovery.

The last two steps of the general spin recovery procedure are relatively straightforward to understand. The rudder opposite rotation is used to stop the rotation of the spin, and the elevator forward step is to break the stall (decrease the angle of attack) so that the aircraft can be returned to normal flight.

Understanding the aerodynamics behind spins helps the pilot better understand how his or her airplane flies. Of course the critical point in all this is that the aircraft must be stalled in order to spin. No stall, no spin!

As a result, it's important to be proficient at stall recovery so that the spin condition is never reached. Especially at low altitude, successful spin recovery may be difficult if not impossible in many aircraft.

Many pilots also find it educational to seek out spin training so that if a spin is inadvertently encountered they will know what to expect and also how to make an effective recovery. If you haven't had spin training, consider seeking some instruction in this area. The life you save by having spin recognition and recovery skills may be your own!"

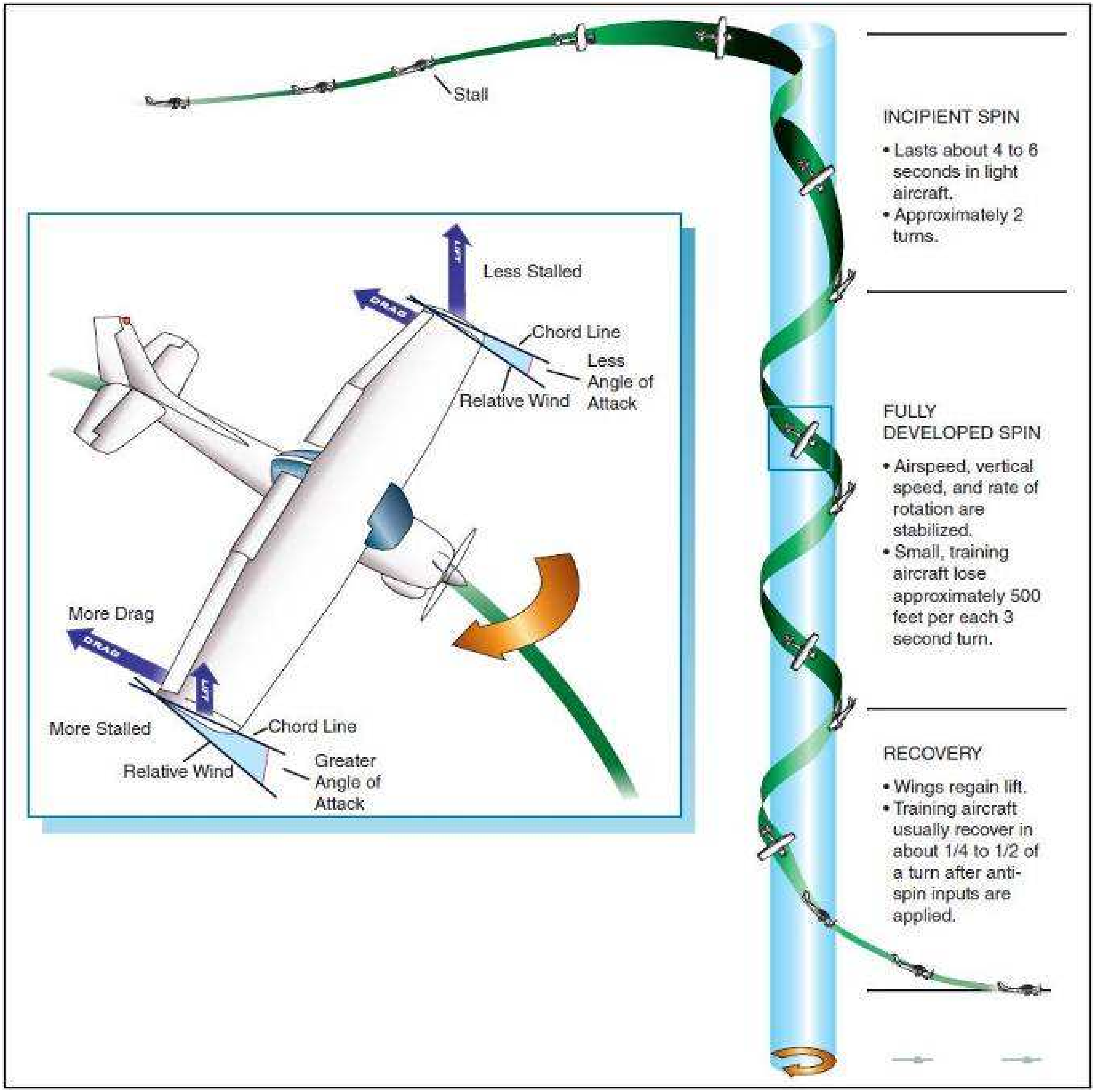


Illustration of an aerodynamic spin displaying the three phases.