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A1. Factual information

A1.12 Information on the wreckage, impact and accident site

A1.12.1 Accident site

The accident site was located in the basin south-west of Piz Segnas, approximately 1.2 km from its summit and at an altitude of 2,480 m AMSL. The Martinsloch, a natural rock window in the Tschingelhörner range of mountain peaks, is located approximately 500 m west of the accident site. At this point, the Tschingelhörner peaks form the border between the cantons of Glarus in the north-west and Grisons in the south-east. The accident site falls within the municipality of Flims in the canton of Grisons (see annex [A1.1](#)).



Figure 1: Final position of the wreckage. Looking east towards the scene of the accident.

A1.12.2 Impact

All evidence at the scene of the accident indicates that the aircraft hit the ground in a vertical flight attitude with an almost vertical flight path. These findings were confirmed by video footage.

A1.12.3 Technical findings on the wreckage

A1.12.3.1 General

Section A1.12.3 describes findings that are illustrative examples of a much larger number of comparable findings on the wreckage. Not all findings made as part of this safety investigation are listed here.

At the scene of the accident, it became apparent that none of the structural components or control surfaces of the aircraft were missing. The wreckage was flown down into the valley, where it was cleaned, sorted according to its components and then subjected to separate detailed examinations.

A1.12.3.2 Findings on the fuselage

The forward fuselage including the cockpit was destroyed on impact. It was therefore not possible to perform an integral assessment of the mechanics of the control surfaces and the engines.

The fuselage, centre wing and tail, including empennage, were examined in detail. For this purpose, the connecting linkages of the control system and parts of the centre wing were cut out.

The layer of paint applied to prevent corrosion had flaked off or was missing, especially inside the fuselage and in places that are not visible on an intact aircraft.

Important structural parts had become corroded, i.e. those made of steel had rusted and those made of aluminium had partially oxidised to powder. The corrosion found was particularly pronounced in the non-visible inner area of hollow sections, in areas of contact between two layers of sheet metal and under the wooden cabin floor (see figures 2 to 8). Several places on the structure of the fuselage exhibited areas that had been repaired using self-fabricated components.

Parts of the fuselage structure were then examined in the laboratory (see annex [A1.16](#)).



Figure 2: Aft bottom fuselage including cabin floor – severely corroded hinges of the cargo door (1) and (3), as well as severely corroded fuselage structure (2), (3) and (4).

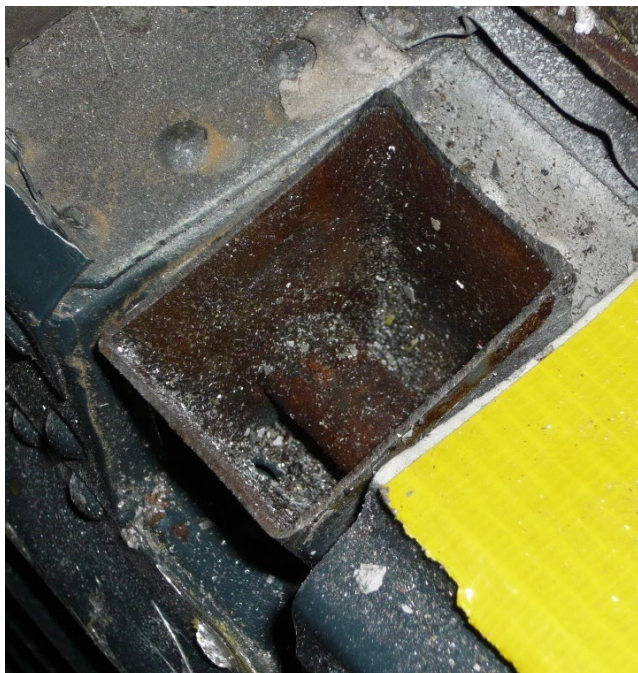


Figure 3: Close-up of figure 2 number (1) – severely corroded hinge of the cargo door on the right-hand side of the fuselage.



Figure 4: Close-up of figure 2 number (2) – severely corroded floor structure and bolts (red circle).



Figure 5: Close-up of figure 2 number (3) – rotten wooden floor (zone marked in yellow), severely corroded hinge of the cargo door (red circle) and severe corrosion on the fuselage structure (powdery, whitish patches of aluminium oxide).



Figure 6: Close-up of figure 2 number (4) – severely corroded floor structure with fracture (red circle).



Figure 7: Close-up of figure 5 – severely corroded hinge of the cargo door (red circle).



Figure 8: Severely corroded bolt for mounting a seat rail.

A1.12.3.3 Findings on the wing

Parts of the wing wreckage consisting of the centre wing and the two outer wings were sorted, laid out and collated. The components were then visually inspected and, if marked for more detailed assessment, examined further in the laboratory.

All parts of the wing had originally been given a coat of paint to prevent corrosion. There was no evidence to suggest that this coat had been renewed or restored after the aircraft had been manufactured. In many places, the surface protection was no longer intact or was missing altogether.

Many of the spar tubes examined showed signs of contact wear. This was particularly pronounced where the panelling was riveted to the spar tube.

Some of the sheet steel joints and many of the steel rivets were rusty (see figures 9 and 10).

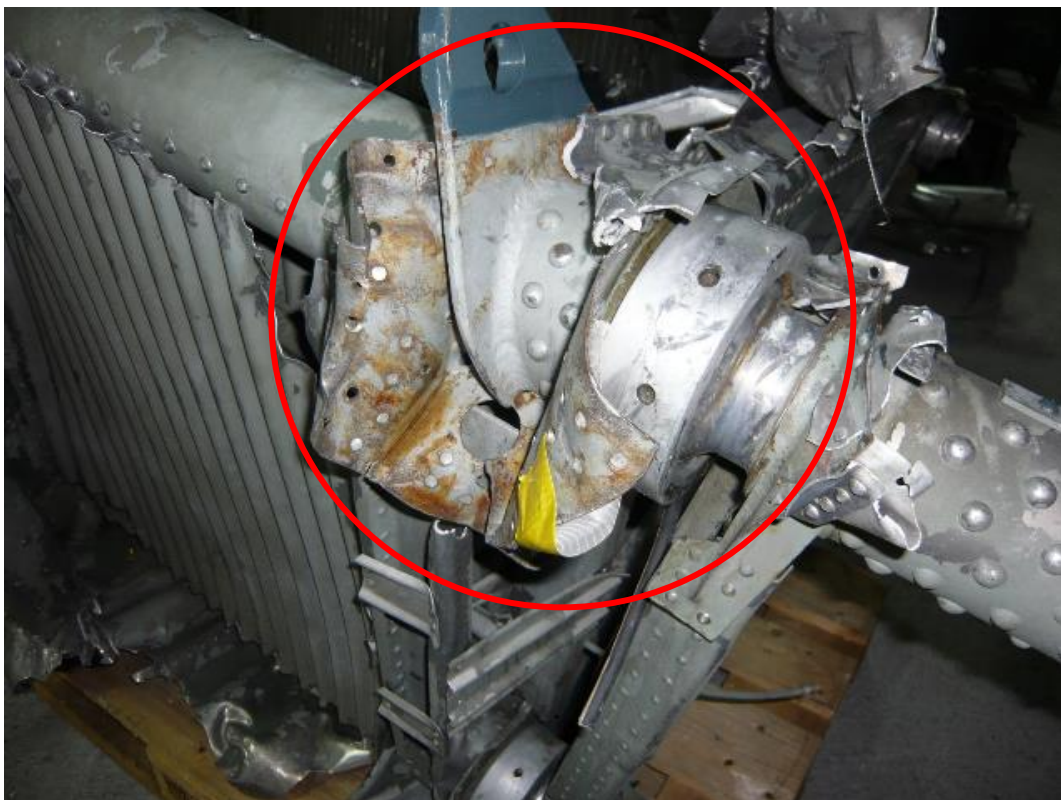


Figure 9: Corrosion over the entire area connecting the outer wing to the centre wing (red circle).



Figure 10: Corrosion in an area connecting the outer wing to the centre wing.

Examination found broken rivets exhibiting corroded fractured surfaces and rivets that were already loose before the accident (see annex [A1.16](#)) as well as rivet holes with missing rivets.

The results of the borescope inspection conducted in February 2017 confirmed that rivets were broken or missing (see annex [A1.6](#)).

Many of the areas of contact between joined and riveted components had become corroded. The corrosion was particularly pronounced at points of contact between different, unfavourable material pairings and in places that lacked corrosion protection.

Components subjected to high loads and stress were found to have been repaired (see figure 11). This included sheet aluminium parts that had been attached using blind rivets and sheet-metal screws.



Figure 11: Repairs carried out in the centre wing, apparent by the greenish-yellow structural parts and the golden yellow connecting elements.

The visual assessment of the spar tubes identified cracks, which were then examined in the laboratory to assess whether the damage existed prior to impact (see annex [A1.16](#)).

An area featuring fractures was found near the engine frame on the lower spar tube of spar I on the left outer wing (see figures 12 and 13). These fractures were examined from a metallurgical point of view (see annex [A1.16](#)).



Figure 12: Lower spar tube of spar I on the left outer wing. The arrow points to the area of the spar tube with fractures. The outer diameter of the spar tube is 90 mm.



Figure 13: Close-up of the inside of the spar tube where fractures were found.

A1.12.3.4 Findings on the empennage

A1.12.3.4.1 Elevator, horizontal stabiliser and horizontal-stabiliser support strut

The elevator was still attached to the horizontal stabiliser following the accident.

The connecting flanges of the elevator's actuating element were assembled using nuts, bolts and washers. Nylon locknuts had been fitted instead of castellated nuts with locking pins. The thread of the bolts was too short for the use of locknuts (see figure 14).

On the inside of the horizontal stabiliser, the anti-corrosion paint had partially flaked off (see figure 15).

On the inside of the left elevator, the anti-corrosion paint had flaked off extensively (see figure 16).

In general, the components were severely corroded. Corrosion was also present under some rivet heads.



Figure 14: Right-side elevator with connecting flange of its actuating element, which was mounted using a nylon locknut on a thread that was too short for this purpose (red circle).



Figure 15: Inside of the horizontal stabiliser – areas where the anti-corrosion paint had partially flaked off.



Figure 16: Flaked off anti-corrosion paint on the inside of the left elevator.

A1.12.3.4.2 Rudder and vertical stabiliser

The rudder is connected to the vertical stabiliser by two brackets and additionally attached to the end of the fuselage.

Inside the rudder and vertical stabiliser, the anti-corrosion paint had flaked off in many places and the sheet metal had become corroded (see figures 17 and 18). The bolts at the joints had been secured using nylon locknuts, but the bolt threads were too short to use this kind of nut. Moreover, they were not tightened properly and could be loosened by hand.

A hardened piece of water hose had been used as a stop buffer for the rudder. Some of the rivets were loose. Blind rivets had also been used. This indicates that repairs had been carried out, as such rivets were not yet in use when the aeroplane had been manufactured.



Figure 17: Inside of the rudder – head of the bolt for attaching the central hinge; lack of anti-corrosion paint; corrosion on sheet metal, rivets and bolt (label text reads central hinge).



Figure 18: Flaked off anti-corrosion paint on the inside of the rudder.

A1.12.3.4.3 Ailerons and flaps

The left and right ailerons as well as the two flaps were each connected to the wing by four brackets. Some of these connections were torn off during impact. All joints were visually inspected and some were disassembled.

The right-hand flap was not identical to the left-hand flap (see annex [A1.6](#)).

Individual joints of the aileron connections as well as joints of the flaps exhibited wear and play, and some of the hinge pins were corroded. The majority of the castellated nuts used to secure the bolts had locking pins that were too small for the size of the nut. In addition, the locking pins were improperly fitted. The threads and locknuts of the adjustable ends of the push-pull rods used to operate the ailerons, flaps and flap trim tabs had been partially painted over. This suggests that no adjustments were made to these components after the aircraft had been repainted.

A1.12.3.5 Findings on the controls

A1.12.3.5.1 Elevator, rudder and aileron controls

The connecting linkages for the controls were removed from the wreckage and visually inspected. The control elements in the cockpit were severely damaged in the accident. It was therefore not possible to assess the condition of these parts.

All examined connecting linkages used in controlling the aircraft were in working order but in poor condition. Many elements exhibited corrosion, and rivets were loose or missing. The protective coat of paint had flaked off almost all parts, and the corrosion protection was therefore insufficient (see figure 19). The control cables were old: their production method is consistent with the time when the aircraft was manufactured (see figure 20).

Replaced locking pins had not been fitted properly. In some cases, nylon locknuts had been used instead of the castellated nuts with locking-pin retention from the aircraft's original design. The rubber stop buffers for limiting the control travel had hardened due to their age.

The adjustable ends of the push-pull rods to control the left and right ailerons were completely screwed in. This raises doubts about the ability to use the correct setting for the ailerons as the range was exhausted on one side.

The oil shock absorber for the auxiliary-wing (ailerons and flaps) adjustment safety device had no oil. The following was written on the oil shock absorber in felt-tip pen: "*last inspection 1981*".

The hooks of the springs for the auxiliary-wing adjustment safety device were heavily worn and were at risk of breaking (see figure 21).

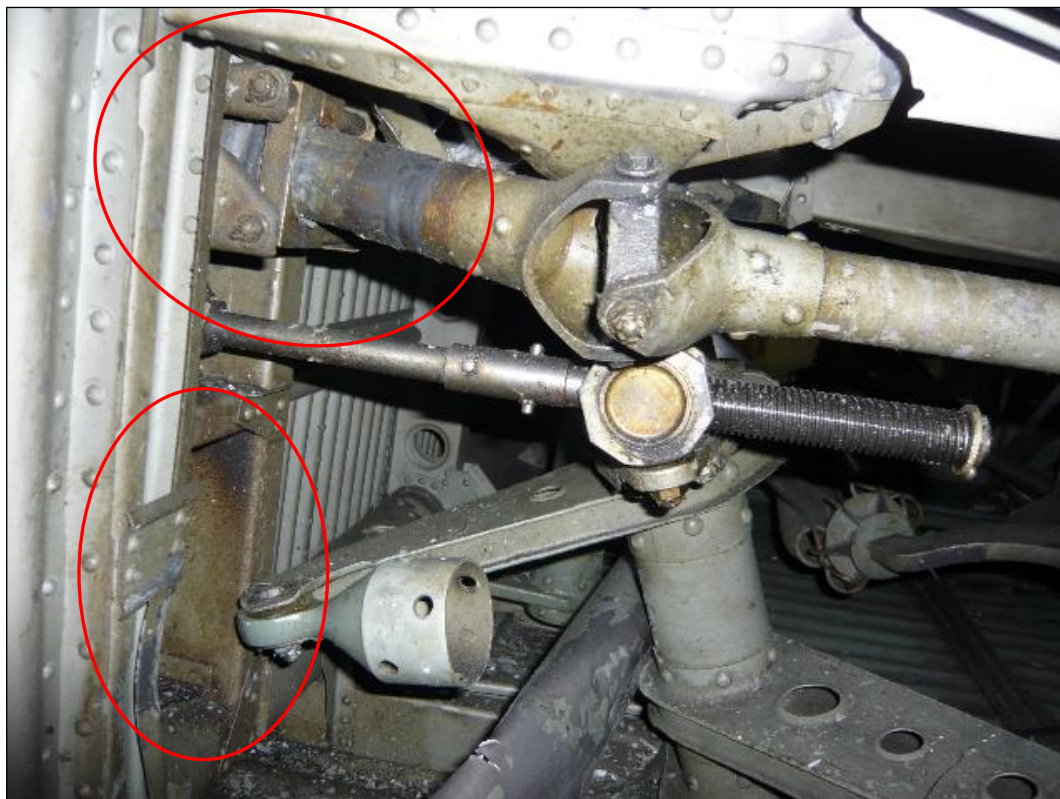


Figure 19: Corrosion (circled in red) in the centre wing and the control elements.



Figure 20: Old control cables, whose production method was consistent with the time when the aircraft was manufactured.

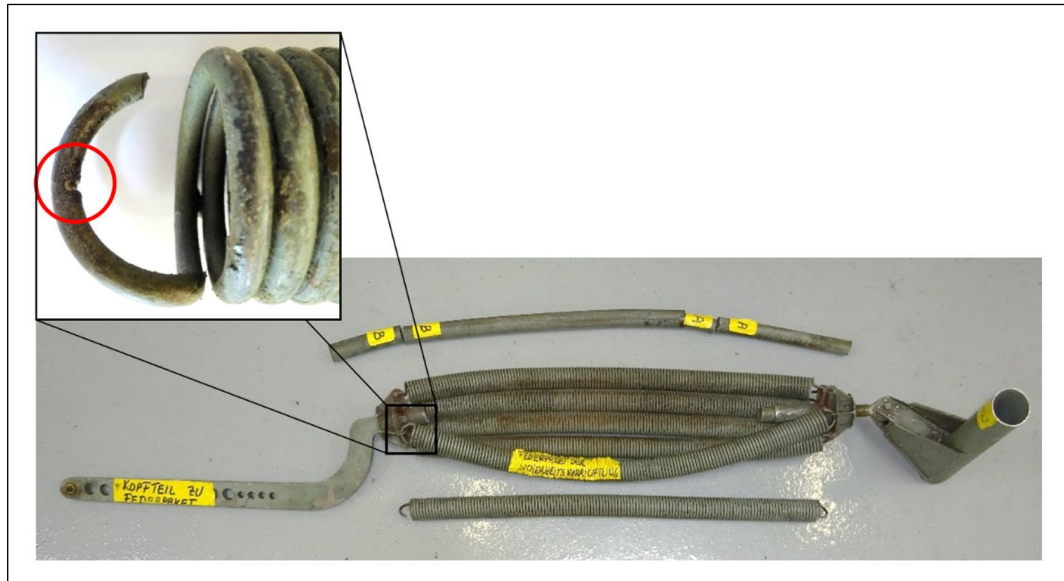


Figure 21: Spring assembly (auxiliary-wing adjustment safety device); spring hooks weakened by wear and tear.

A1.12.3.5.2 Horizontal-stabiliser adjustment

On the left-hand side of the aft fuselage near the leading edge of the horizontal stabiliser, there is a plaque marked with angles from $-2\frac{1}{2}$ to $+3\frac{1}{2}$ degrees. The angle set for the horizontal stabiliser can be read using a pointer mounted on the leading edge of the horizontal stabiliser.

It was possible to establish that the horizontal-stabiliser adjustment on the wreckage displayed an angle of approximately $+1\frac{1}{2}$ degrees.

A1.12.3.5.3 Horizontal-stabiliser adjustment spindle

The pivoted horizontal stabiliser is operated using a horizontal-stabiliser adjustment spindle and an adjustable push-pull rod (see figure 22). Information regarding horizontal-stabiliser adjustment is described in the aircraft's operating instructions.

The angle of the horizontal stabiliser is displayed in degrees on an indicator in the cockpit. On the horizontal stabiliser, at the end of the fuselage, there is an additional indicator, which also shows the horizontal stabiliser's angle. Both displayed values must match when the angle is set.

The horizontal-stabiliser settings must be adjusted based on the limit positions and the zero position of the stabiliser. The adjustment is made using the push-pull rod sleeve (1) and the locknut (2).

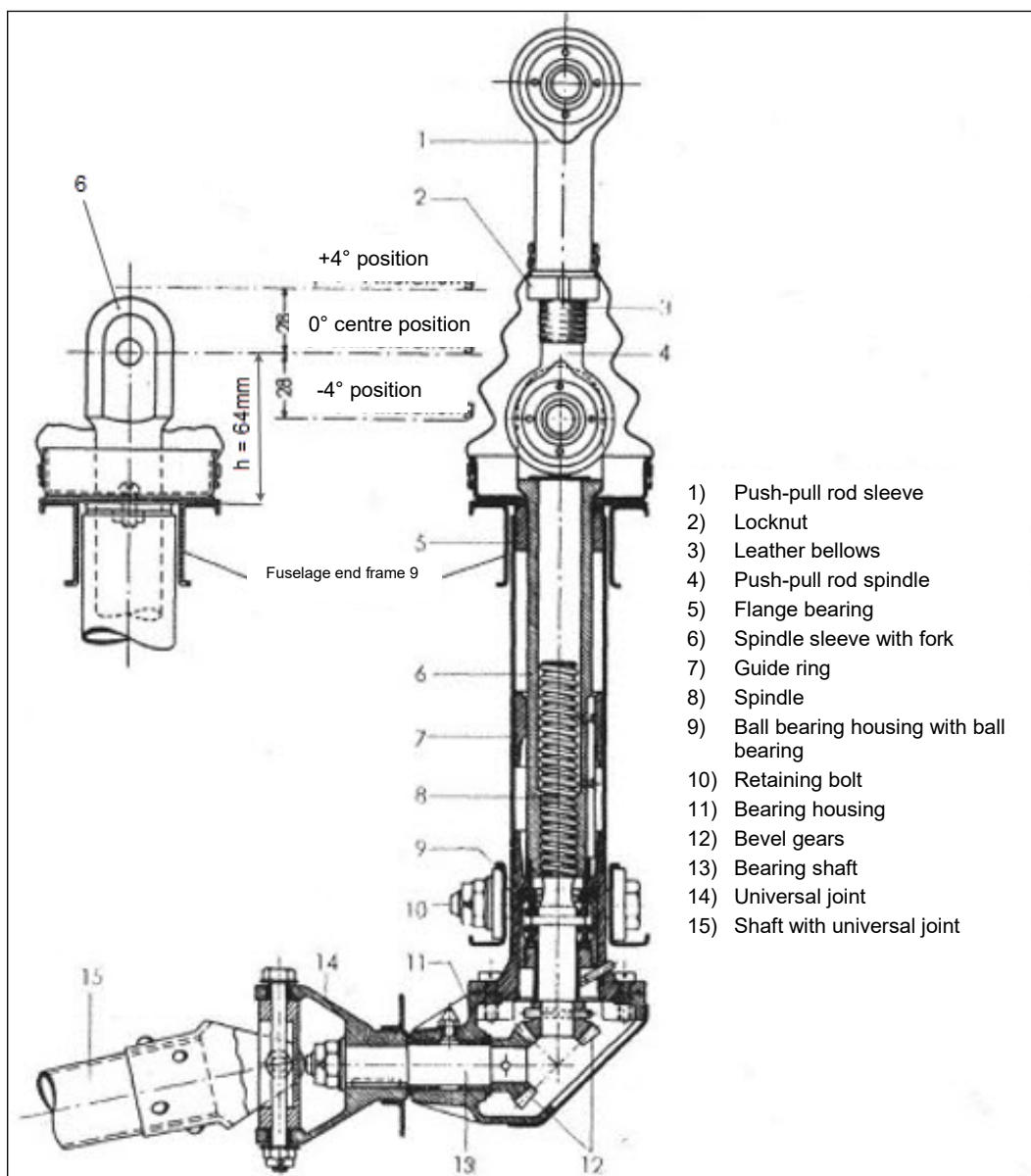


Figure 22: Dimensioned drawing for determining the horizontal stabiliser's angle. Source: "Betriebsanweisung Ju 52/3m g4e" (operating instructions).

The adjustment spindle and the bevel gear were not damaged in the accident. In order to determine the condition and position of the horizontal stabiliser at the time of the accident, the adjustment spindle – including bevel gear – was first removed from the tail of the wreckage, measured and dismantled. A functional check was also carried out.

The detailed examination revealed the following:

- The assembly was in working order.
- No damage could be identified.
- No abnormal wear and tear was found.
- The axial play of the spindle was 0.2 mm.

The measured distance between the hole in the spindle sleeve's fork and the fuselage frame 9 ($h = 56.53$ mm) equates to an angle of -1.03 degrees for the horizontal stabiliser. Since the indicator in the cockpit for the horizontal stabiliser's angle setting was destroyed in the accident, no displayed value for the position of the stabiliser could be determined.

The horizontal-stabiliser position of approximately $+ 1\frac{1}{2}$ degrees determined at the aft fuselage was approximately $2\frac{1}{2}$ degrees greater than that calculated based on the spindle sleeve measurement.

During repairs to the elevators and ailerons on 11 March 2003, various work was also carried out on the horizontal-stabiliser adjustment spindle, which was removed and reinstalled in the process. The question of whether any misadjustments were made during this work remains open. No misadjustments were found during the last progressive inspection.

Since the tech logs did not contain any complaints regarding the functionality of the horizontal-stabiliser trim during the last months prior to the accident, it can be concluded that the misadjustment of the horizontal-stabiliser adjustment spindle did not lead to any restrictions in flight.

A1.12.3.6 Findings on the engine frames

The frames of the three engines were severely damaged in the accident and were torn off from the corresponding wing and fuselage connection frames where they had been attached. All three engine frames were plastically deformed upon impact and broke up into several pieces.

An initial visual assessment of the engine frames revealed the following findings:

- The fractures as well as the type of plastic deformations were not consistent in all three of the engine mounts.
- The material thickness of the engine mount for the right engine was different to that of the other engine mounts.
- The surface structure of the three engine mounts was different.
- All three engine frames exhibited several areas that had been repaired (see figure 23).
- Parts of the engine frames were painted differently.

All three engine mounts were then subjected to metallurgical examinations in the laboratory (see annex [A1.16](#)).



Figure 23: Tubular strut from the centre engine frame repaired with a doubler (see annex [A1.6](#)).

A1.12.3.7 Findings on the engines

A1.12.3.7.1 General

Prior to the investigation, the engines were cleaned whilst still assembled using dry-ice blasting (see figure 24). The advantage of this minimally abrasive and non-corrosive process is the low amount of damage to the material being cleaned.



Figure 24: Engine cleaned using dry-ice blasting.

Due to the high degree of damage, dismantling some parts of the engines was difficult. Nevertheless, their condition before the accident could still be assessed. However, it was not possible to check the function of the magnetos from any of the engines as they had been destroyed.

In several cases, nylon locknuts had been used (see figure 25) instead of the castellated nuts with locking-pin retention as per the aircraft's original design. Firstly, the bolt threads were too short to use this kind of nut as the thread does not engage sufficiently with the nylon insert. Secondly, the use of nylon locknuts is not permitted on engine parts that see an increase in temperature. For the castellated nuts fitted, wire had been used instead of locking pins. This method of securing the nut is not standard in the aviation industry.

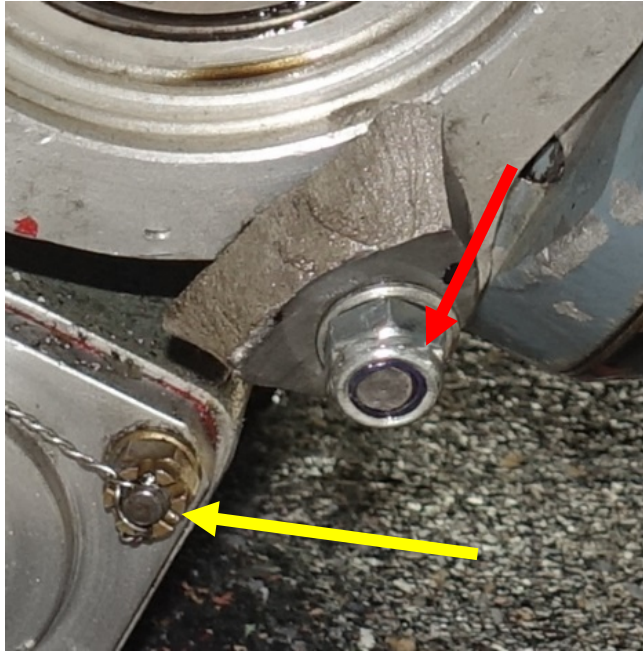


Figure 25: Engine housing – a nylon locknut (red arrow) on a bolt with a thread that is too short, and a castellated nut secured by wire (yellow arrow).

A1.12.3.7.2 Pistons and cylinders

All three engines were dismantled and generally revealed a similar picture. Burn residue was prominent on the pistons and in the cylinders' combustion chambers (see figure 26).



Figure 26: Pistons in cylinder positions 1, 2 and 3 in the right engine.

The condition of the cylinder bores was first assessed visually. In a large number of the cylinders, fine surface cracks distributed in a net-like pattern were visible in the bores. On some cylinders, the bores had a red discolouration. Subsequently, three cylinders were subjected to metallurgical investigations (see annex [A1.16](#)).

A1.12.3.7.3 Cam discs

The cam discs are part of the cam drum. On the running surfaces of the cam discs from the centre and the right engines – which had been manufactured according to service bulletin no. 1028 by a company not certified to provide parts for use in aviation – clearly visible machining marks were found (see figure 27). The quality of the surfaces was poor. In several places, the running surfaces of the cam discs for the exhaust and intake valves had broken away.



Figure 27: Cam discs from the centre engine – the machining marks (regular, finely grooved surface) and the chipping on the upper running surface are clearly visible.

The quality of the running surfaces on the cam discs from the left engine was much better than that of the discs from the other two engines. No chipping could be identified on the cam discs from the left engine. This cam drum came from one of a total of three engines that Ju-Air had purchased from the collection of a German historic-aircraft enthusiast and restorer at an earlier date. According to Ju-Air, this was an original cam drum.

The cam discs of the three engines were measured on a measuring machine and the height of the four intake and exhaust cams was determined in relation to the cylindrical part of each disc. Taking into account a valve clearance of 0.25 mm, the tappet stroke and the opening stroke of the valve could be determined.

There were significant differences in the tappet strokes of all three engines' cam discs – this applied for both the exhaust and intake valves. The differences were up to 12% for the left engine's cam discs, up to 4% for the centre engine's cam discs and up to 10% for the right engine's cam discs. This had an unfavourable effect on engine power.

A1.12.3.8 Findings on the bearings

A1.12.3.8.1 General

The specifications of the original bearings were not known. In order to compensate for the different dimensions of the bearings that had been procured over the years, spacers and bushings had been manufactured. This does not make any sense from a technical viewpoint and is not permitted.

The bearings installed were standard spare parts used in general mechanical engineering and, according to Ju-Air, had been selected in collaboration with the various manufacturers based on their conformity with specifications for their particular area of use. In 2017, a supplier wrote the following note on the invoice for supplying several types of bearing: *“Warranty only for the delivered product, not for the application!”*

A1.12.3.8.2 Propeller bearings

The engine’s single-pin crankshaft has three bearings. Either side of the crank webs features a roller bearing, while a ball bearing – referred to as the propeller bearing – positioned directly behind the propeller hub is subjected to both propeller thrust and radial loads.

The engines were fitted with propeller bearings that did not correspond to the designation stated in the approved service bulletin (SB) no. 1007 (see table 1).

| Designation according to service bulletin no. 1007 | Bearings found | | |
|--|----------------|---------------|--------------|
| | Left engine | Centre engine | Right engine |
| 43M-6218/P6 | FAG 6218ZR | FAG 6218ZR | FAG 6218 USA |

Table 1: Overview of the propeller bearings.

After dismantling the engines, the propeller bearings were visually inspected and were found to be worn and corroded. A crack was found on the outer race of the propeller bearing from the centre engine before disassembly. After disassembling the engine, it became apparent that the outer race was broken into two pieces (see figure 28). When comparing bearings from the left and the right engines, it was evident that the bearing used in the centre engine had eleven balls, but the ball bearings from the other two engines only had ten. All three bearings were subjected to metallurgical investigations (see annex [A1.16](#)). These investigations revealed that there was a high risk of failure for these bearings.



Figure 28: Broken outer race of the propeller bearing from the centre engine.

A1.12.3.8.3 Supercharger bearings

The bearings installed in the superchargers were of different origins and were also marked differently. None of the supercharger bearings were broken. Bearings number 3, 4 and 5 (see figure 29) of the high-speed supercharger shaft from the left engine were subjected to metallurgical investigations (see annex [A1.16](#)).

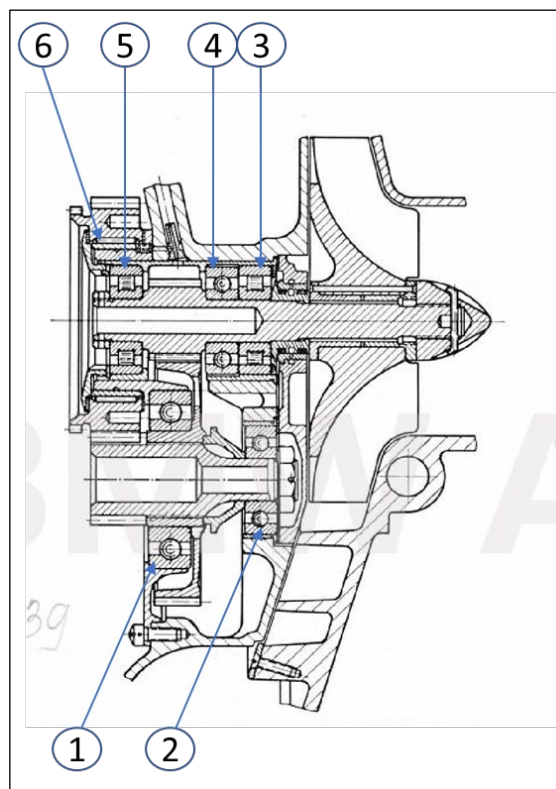


Figure 29: Cross-sectional diagram of the supercharger with bearing nos 3, 4 and 5 on the supercharger shaft. Source: BMW 132-A3 engine operating instructions.

The bearings used in the supercharger had different speed ratings, but none of the three supercharger-shaft bearings met the necessary specifications for speeds of up to 20,500 rpm, which the shaft can be subjected to when running.

None of the bearings in the supercharger corresponded to the designation according to the approved service bulletin no. 1015 (see annex [A1.6](#)).

| Pos. | Description | Designation according to service bulleting | Bearings found | | |
|------|---|--|--------------------|-------------------|---------------------|
| | | | Left engine | Centre engine | Right engine |
| 1 | Deep-groove ball bearing for the counter gear | SKF 6209 | FAG X.HB 6209 | FAG 6209 | FAG6209 Korea |
| 2 | Deep-groove ball bearing for supercharger shaft | FAG 6304 | FAG Y.HB 6304 | FAG 6304 Z.HB | FAG 6304 Korea |
| 3 | Roller bearing for supercharger shaft | FAG N304 EM1 C3 F96 | 746011 | NM-20 FJG Germany | SKF HE NM20 Germany |
| 4 | Deep-groove ball bearing for supercharger shaft | FAG 6304 | FAG Y.HB 6304 | FAG 6304 Z.HB | FAG 6304 Korea |
| 5 | Roller bearing for supercharger shaft | FAG N304 EM1 C3 F96 | FAG 593670 Germany | NM-20 FJG Germany | SKF 198031 Germany |
| 6 | Needle rollers for supercharger counter gear | INA NRA 3 x 19.8: | No marking | No marking | No marking |

Table 2: Overview of the supercharger bearings.

A1.12.3.9 Fuel systems

A1.12.3.9.1 Lines

The fuel and oil lines were up to 30 years old and in some cases showed considerable signs of decay due to age (see figures 30 and 31).



Figure 30: Lines show obvious signs of decay due to age.



Figure 31: Hardened fuel line dated 11 November 1988.

A1.12.3.9.2 Electric fuel pumps

The electric fuel pumps had not been in operation for several years. The fuel therefore did not flow through the pump body but through the bypass. Both pumps were found to have solidified grease in them after dismantling and defective seals due to their age (see figure 32).



Figure 32: Electric fuel pump gear.

A1.12.3.9.3 Fuel filter

Each outer wing was fitted with a fuel filter. However, following the accident, it was not possible to determine which one they had come from. While one set of filter elements was clean, the other set was found to be heavily contaminated (see figure 33). According to the technical files, these filters were last checked and cleaned on 19 June 2018, some 42 flight hours before the accident. The manufacturer's operating instructions stipulate that the filters must be checked every ten flight hours.



Figure 33: Fuel filter elements.

From the different condition of the two fuel filters and the fact that all tanks were filled with the same fuel, it can be concluded that the contamination did not originate from the fuel. The nature of the contamination in the one fuel filter indicates that deposits from one of the tank systems had led to the contamination.

There is no evidence to suggest that the contamination in the one fuel filter had any influence on the performance of the engine during the accident flight. However, there was a risk of restricted fuel supply.

A1.12.3.9.4 Oil filter

Each engine had an oil filter, which was fitted with a magnet in the housing cover (see figure 34). Loose pieces of red sealing compound were found in the oil filter element of the right engine. Metallic debris was found in all of the oil filters.

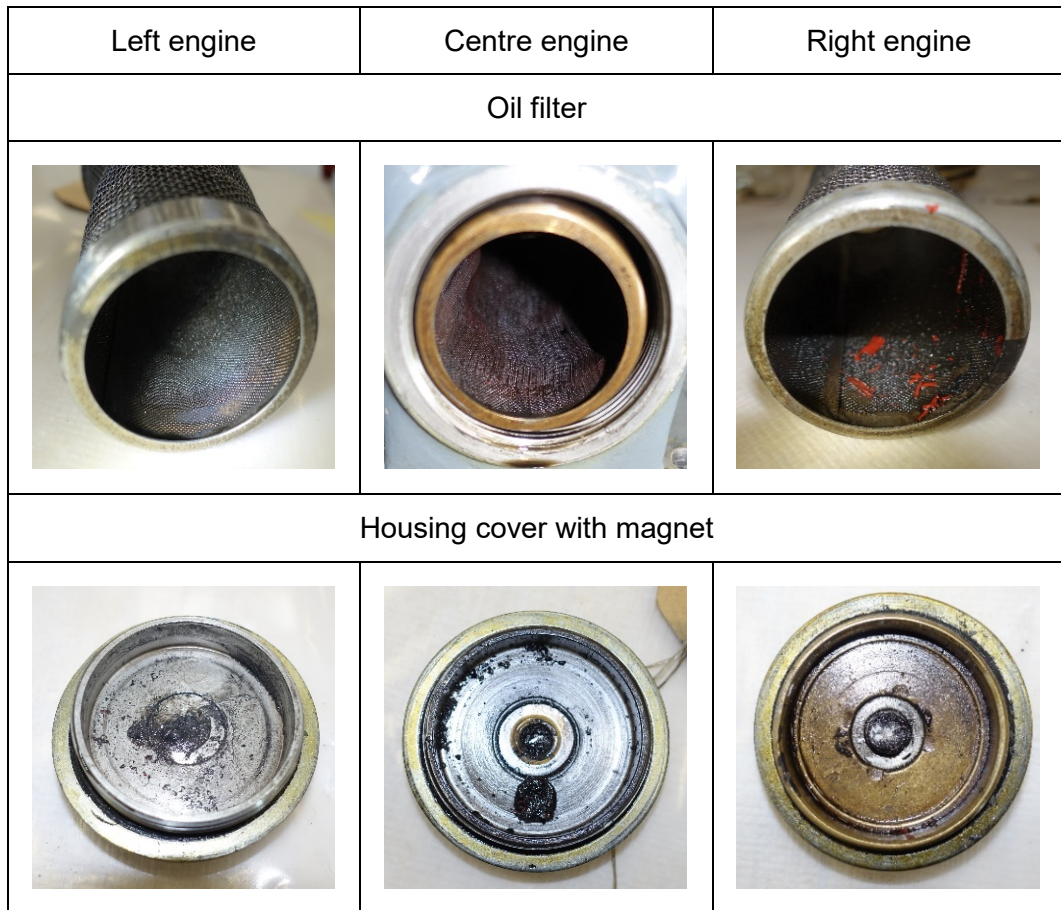


Figure 34: Oil filter and housing cover with magnet from all three engines.

A1.12.3.10 Findings on the propellers

A1.12.3.10.1 Propeller-blade pitch

Due to the high degree of damage, the pitch of the propeller blades could not be reproduced. Traces of a red marking could be seen on one propeller blade (see annex [A1.6](#)).

Upon removing the anti-corrosion paint, an adjustment scale became visible on the propeller hubs (see figure 35), which is intended to be used to adjust the pitch of the blades once they are installed on the aircraft. The maintenance team had no knowledge of this scale.



Figure 35: Adjustment scale on a propeller hub.

A1.12.3.10.2 Propeller blades

Blade 2 of the left propeller was still attached to the hub. All the other propeller blades had broken off at the root. The propeller blades all exhibit a similar degree of damage. The marks indicate that the three propellers were rotating on impact (see figures 36 to 38).

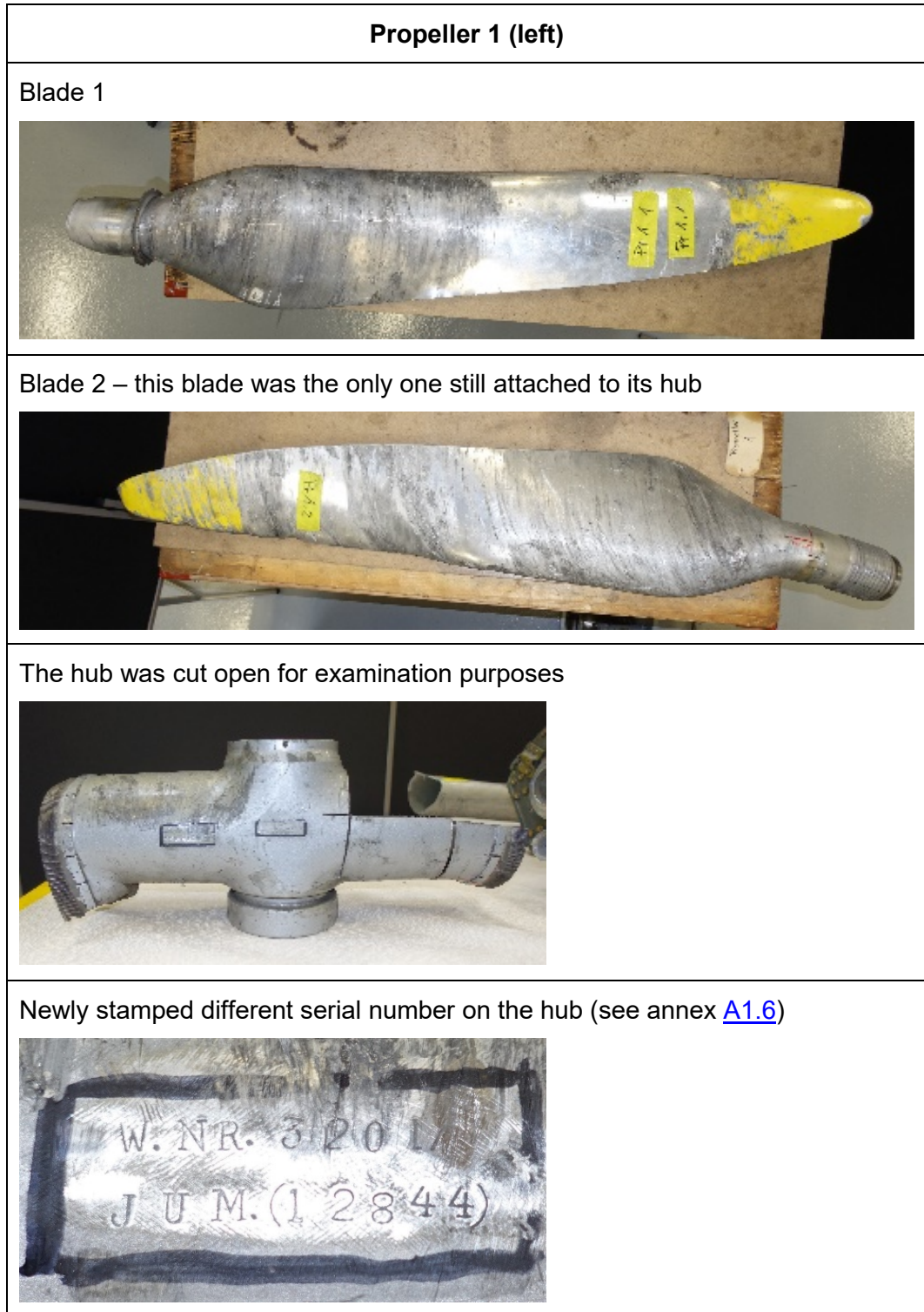


Figure 36: Propeller 1 – blades and hub.

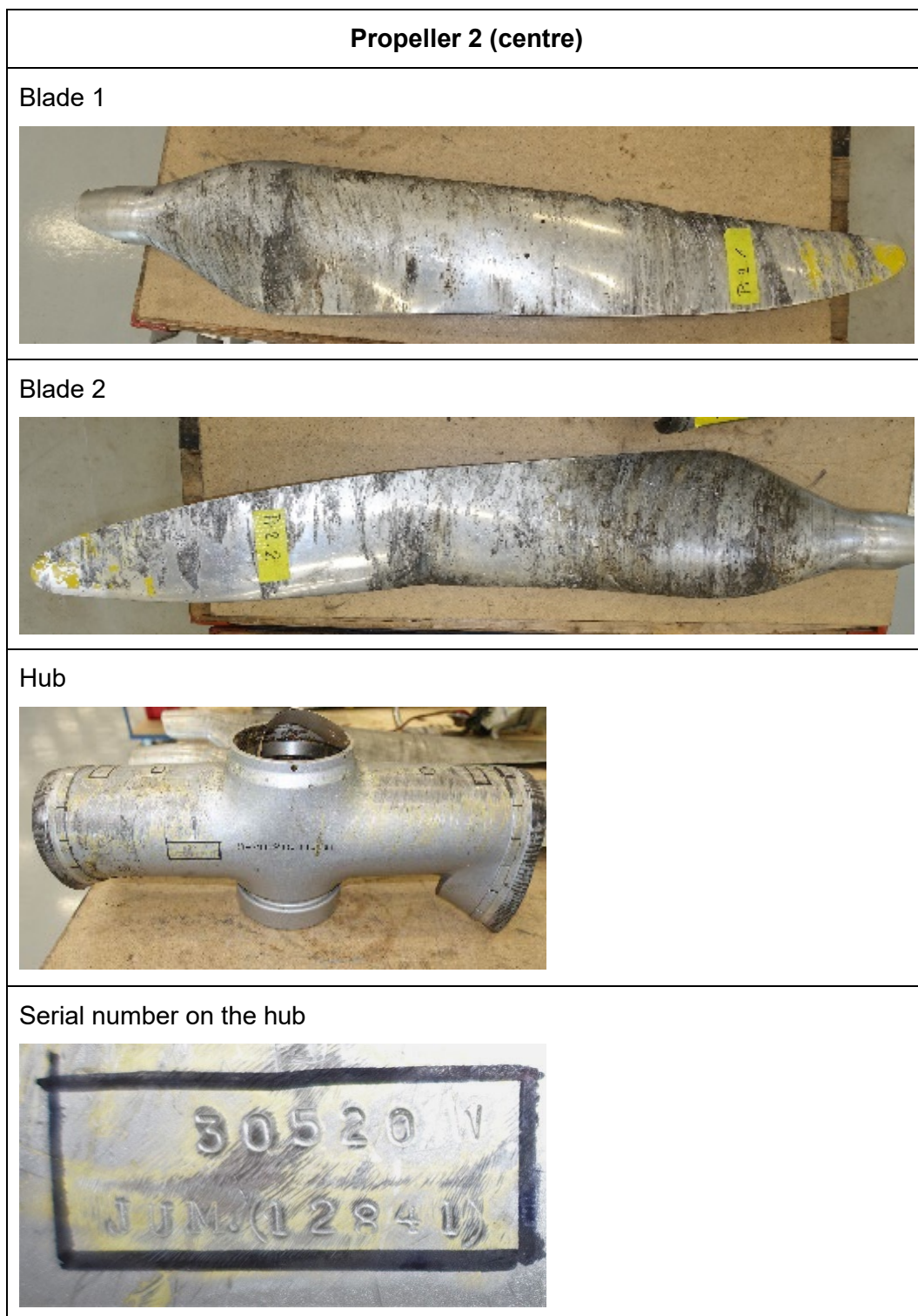


Figure 37: Propeller 2 – blades and hub.

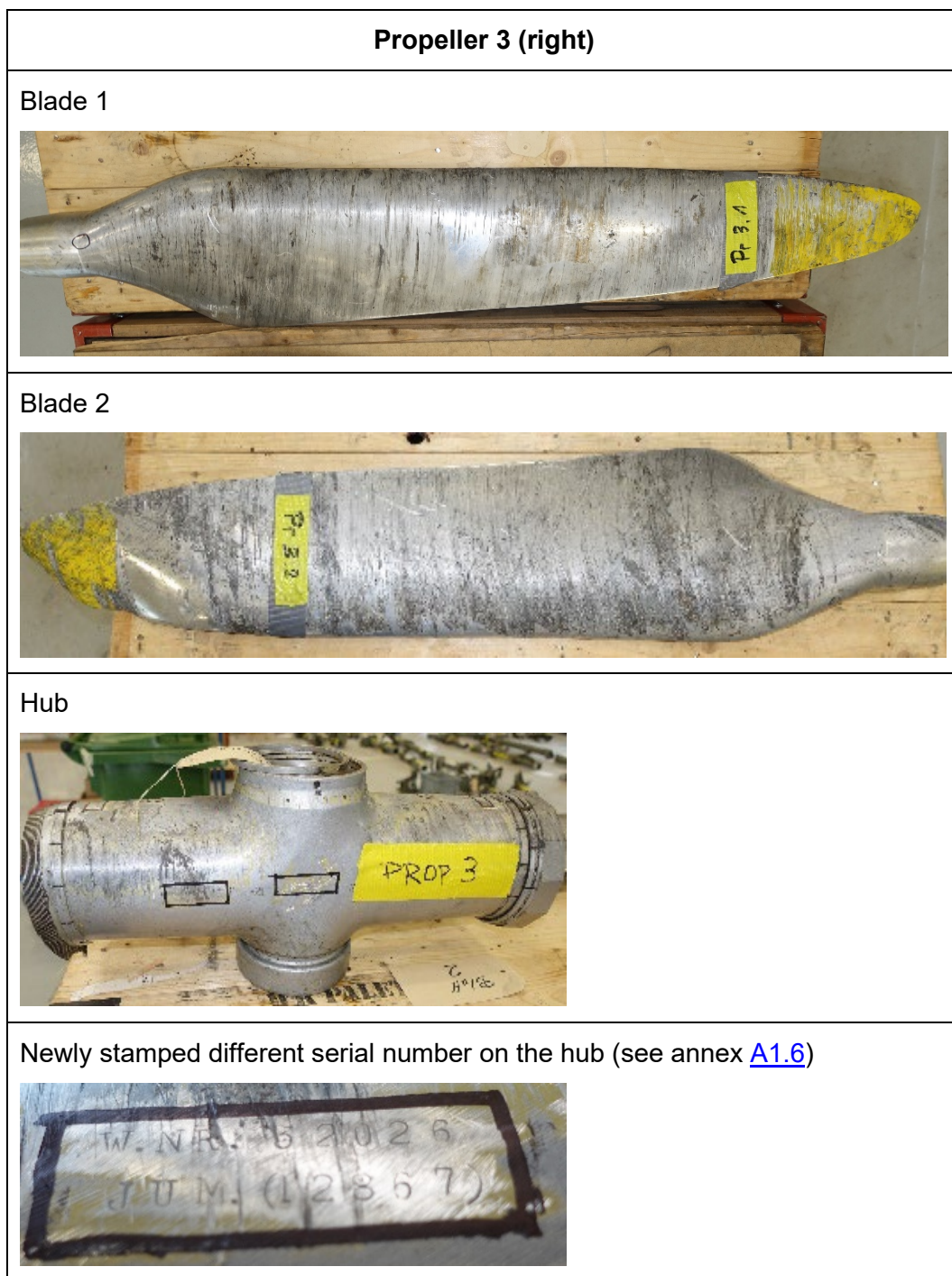


Figure 38: Propeller 3 – blades and hub.

A1.12.3.11 Findings on the airspeed indicator system

The pitot tube was severely damaged in the accident (see figure 39). Its functionality could no longer be assessed.

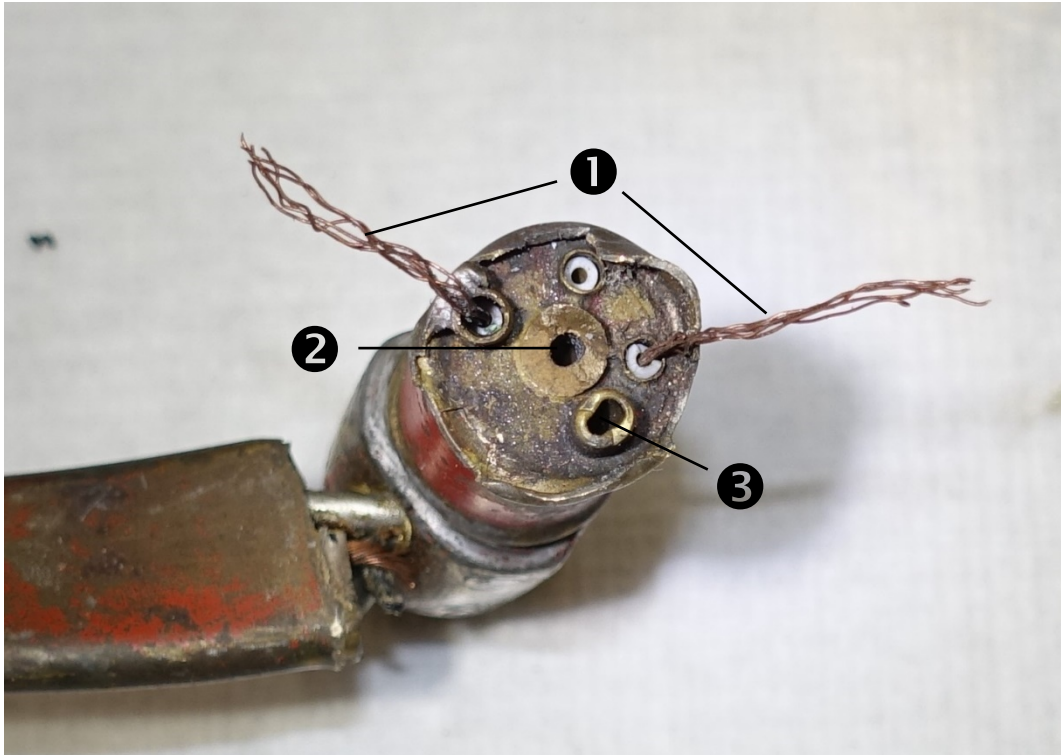


Figure 39: Severely damaged pitot tube. (1) Pitot tube heating element wires; (2) borehole for dynamic and static pressure; (3) borehole for static pressure.

A1.12.4 Luggage in the wreckage

36 pieces of luggage were recovered in the wreckage of HB-HOT – ranging from small handbags to large wheeled suitcases. It could be determined that 12 of these pieces of luggage (a total of 106 kg) had been stowed as ‘checked luggage’ in the rear underfloor storage compartment (see figure 40). Furthermore, it could be ascertained that a 15-kg wheeled suitcase, also ‘checked luggage’, had been stowed in the front rear-storage compartment during the flight (see figure 41). The remainder (around 40 kg of hand luggage) was spread across the passenger compartment and in the cockpit during the flight.



Figure 40: View of the HB-HOT wreckage – underside of the fuselage at the wing root, and luggage in the rear underfloor storage compartment.

Above – red box: Approximate section shown in the lower photo. 1: Wooden storage-compartment floor panel (removed for lower photo). 2: Wheeled suitcase (removed for lower photo).

Below – view into HB-HOT's rear underfloor storage compartment at the scene of the accident after removing the wooden storage-compartment floor panel. The corrugated paneling of the rear underfloor storage compartment had already been ejected during impact. Seven larger pieces of luggage can be identified in particular: six wheeled suitcases (grey, shiny royal blue, red, green, matt blue, black) and a travel bag (black with white print).



Figure 41: View into the fuselage structure below the toilet. A 15-kg dark-blue wheeled suitcase can be seen under a blue and white plastic bag and a brown woollen blanket. The wheeled suitcase ended up in this position after having moved from the front rear-storage compartment during impact.