Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200701935

Final

Depressurisation
343km S Darwin Airport, NT
2 April 2007
VH-AJP
Israel Aircraft Industries Ltd. 1124 Westwind

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Abstract

At 1814 Central Standard Time on 2 April 2007, an Israel Aircraft Industries 1124, Westwind aircraft, registered VH-AJP, with a crew of two, departed Darwin Airport, NT on a scheduled cargo service to Alice Springs, NT. At 1844, during climb, at 34,000 ft, the crew heard a series of loud bangs followed by a loss in cabin pressure. The crew donned oxygen masks, closed the aircraft outflow valves and conducted an emergency descent to 10,000 ft. The aircraft was returned to Darwin.

An inspection of the aircraft revealed a hole in a top rear fuselage skin panel. The examination revealed that approximately 60% of the panel had been damaged by exfoliation corrosion. The damage was most severe at the primary site of rupture, in the centre of the panel.

The panel was clad with a corrosion resistant pure aluminium alloy sheet; however, the aluminium cladding was removed on the chemical milled areas. Over time, the coating protecting of the chemical milled areas had deteriorated, leading to the corrosion on the panel.

The panel was located in an area that was not considered susceptible to corrosion, so there were no detailed inspections required for the area.

As a result of this occurrence, the manufacturer has issued a notice to all 1124 Westwind aircraft operators informing them of the event and the corrosion that was found. The operator has carried out an inspection of the area on their entire fleet of 1124 Westwind aircraft. Where corrosion was present, the operator replaced the panel. The operator has also included an inspection of the area in their Corrosion Control Program.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

Sequence of events

At 1814 Central Standard Time[1] on 2 April 2007, an Israel Aircraft Industries 1124, Westwind aircraft, registered VH-AJP, with a crew of two, departed Darwin airport, NT on a scheduled cargo service to Alice Springs, NT. At 1844, during climb, at 34,000 ft, the crew heard a series of loud bangs followed by a loss in cabin pressure. The crew donned oxygen masks, closed the aircraft outflow valves and conducted an emergency descent to 10,000 ft. The aircraft was returned to Darwin.

An inspection of the aircraft revealed a hole in a top rear fuselage skin panel[2] (Figure 1). The panel was removed from the aircraft and sent to the Australian Transport Safety Bureau (ATSB) for examination.

Figure 1: Outside of the damaged fuselage skin panel in situ

1 The 24-hour clock is used in this report to describe the local time of day, Central Standard Time, as particular events occurred. Central Standard Time was Coordinated Universal Time (UTC) + 9½ hours.

2 The panel was located between Fuselage Station 219.05 and Fuselage Station 269.87, adjacent to the rear pressure bulkhead.

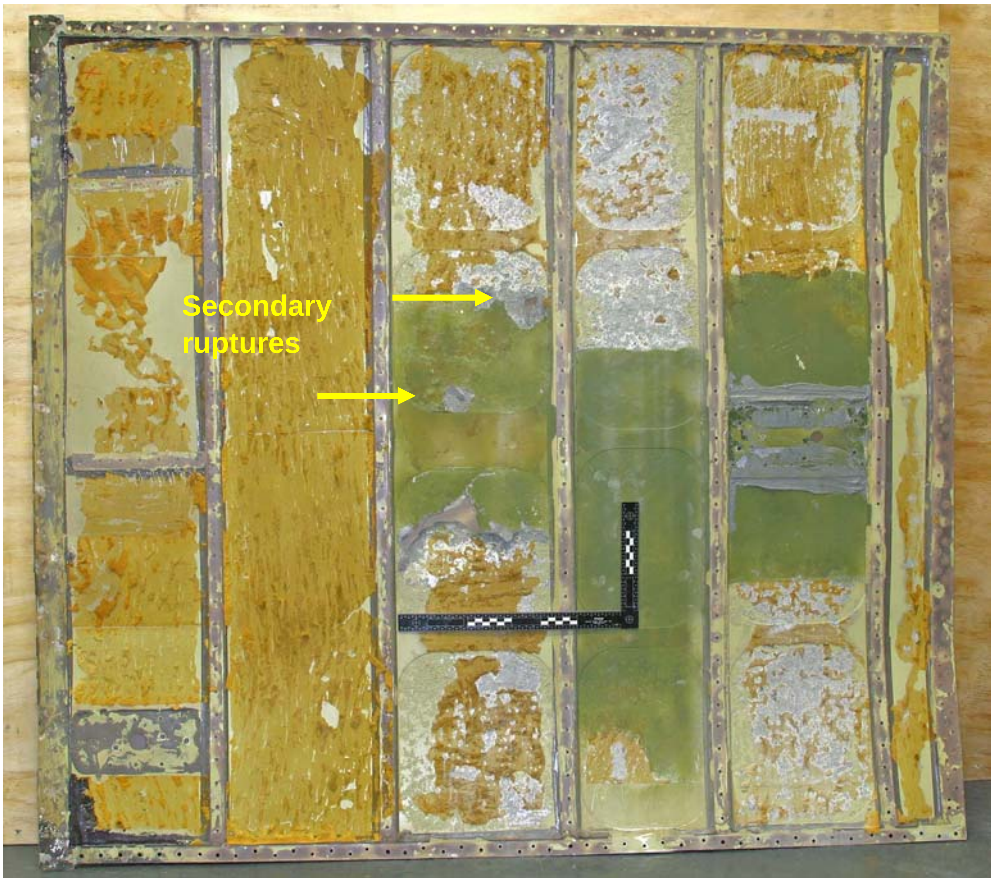
Panel examination

Upon receipt of the fuselage panel, fibrous insulation pads that had been adhesively bonded to the interior panel surfaces, between the frames, were removed in order to quantify the extent of damage to the fuselage panel.

With the insulation removed, initial examination showed that the panel contained one large primary point of rupture. Another two smaller points of rupture were also found. However, these had developed during the panel's removal from the aircraft and transportation to the ATSB.

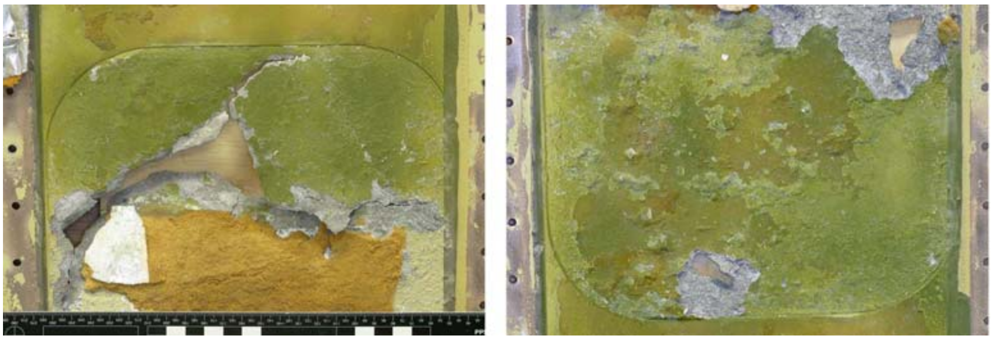
The examination revealed that approximately 60% of the panel had been damaged by corrosion. The damage was most severe at the primary site of rupture, in the centre of the panel, which was located two frames behind an Ultra High Frequency (UHF) antenna mount (Figure 2 and Figure 3). It was also noted that the corrosion damage was predominately contained within the chemically milled[3] sections of the panel.

Figure 2: Internal view of the fuselage skin panel after the removal of the insulation pads. The rupture sites and the location of the antenna mount are shown.



3 Chemical milling is the process of removing material by the chemical action of an etchant. The amount of material removed or cut is controlled by the immersion time in the etchant. Kanzanas, H.C., Baker, G.E. & Gregor T.G. (1981) *Basic Manufacturing Processes*. USA: McGraw-Hill, Inc.

Figure 3: Close-up of the primary (left) and secondary (right) points of panel rupture.



Close examination of the most severely effected regions revealed a substantial reduction in skin thickness. Nearly all of the corrosion damage was categorised by thin flakes of aluminium alloy that had peeled from the panel.

In order to establish the corrosion mechanism that had developed within the panel, some sections of skin in and around the primary point of rupture were removed for further examination. Metallurgical examination determined that the fuselage panel was primarily comprised of 2024 aluminium alloy that had been clad with a thin layer of pure aluminium alloy (ALCLAD). The cladding had been applied during the manufacturing process in order to improve the corrosion resistance of the panel. It was observed that, in the regions that had been chemically milled, the thin protective layer of aluminium had been removed.

The panel had a protective coating, which consisted of a chromate conversion coating and an epoxy primer. This had been applied during the manufacturing process to provide corrosion resistance to the chemical milled areas and additional protection to the clad areas. This type of coating has been found to be an effective barrier to corrosion, provided it has not been damaged. However, over time, the coating can break down and, in the presence of water, the chromate can leach out of the coating, degrading the protective qualities.

The metallurgical examination also confirmed that exfoliation corrosion[4] was the principal corrosion mechanism that had developed within the panel (Figure 4). This form of intergranular[5] corrosive attack was found to have extensively proceeded through the grain boundaries of the 2024 aluminium alloy and beneath the cladding in some areas.

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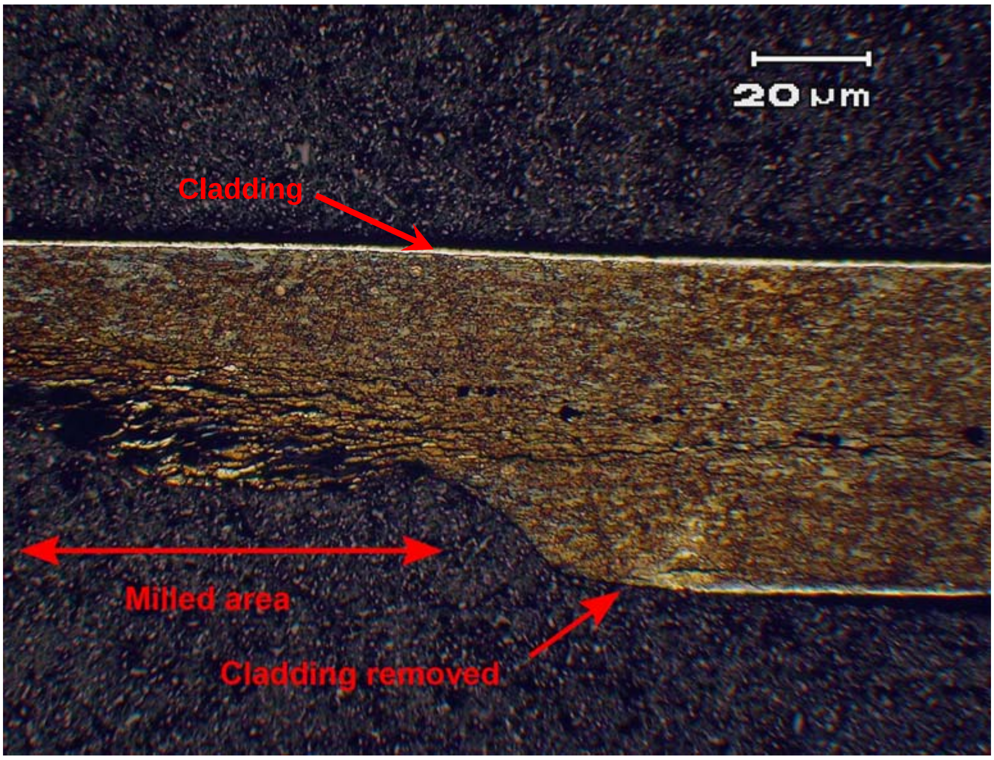
4 Exfoliation corrosion is a type of intergranular corrosion that proceeds along grain boundaries. The corrosion products exert pressure between the grains and result in a lifting or leafing effect. Nui, M.C.Y. (1999) *Airframe Structural Design* 2nd ed. Hong Kong: Hong Kong Conmilit Press Ltd.

5 Referring to between the grains of the metal. *The Macquarie Dictionary* (2nd ed.). Sydney: The Macquarie Library Pty Ltd.

Figure 4: Cross-sectional view through the fuselage skin panel showing extensive penetration of exfoliation corrosion.



Previous repair

Visual examination of the panel found that a section of the panel had previously been treated for corrosion damage. In the treated area, the corrosion products had been abrasively removed and over-sprayed with what appeared to be a dark green chromate-based primer. The primary site of rupture was located at the edge of the treated area; the two later failures were located within the treated area. There was evidence that the corrosion had extended beyond the treated area at the time of the treatment. No records were found for the repair of the corrosion in the aircraft's maintenance records.

History of the aircraft

The aircraft was manufactured in 1979 and was entered onto the Australian aircraft register in the same year. At the time of the incident, the aircraft was 28 years old. For 2 years from 1984, the aircraft was stored outside at Sydney Airport, which was located in a coastal environment[6] on Botany Bay. During that time, the emergency exit leaked and it was reported that water had pooled on the floor of the cabin. In 1997, the UHF antenna was installed on the upper fuselage skin. This installation occurred on the panel that failed on the incident flight. At the time of the incident, the aircraft was operating as a freighter and based at Darwin airport, a sub-tropical, coastal, environment. In its role as a freighter, the aircraft would at times carry cargo that was wet, from having been loaded onto the aircraft in wet weather.

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6 Salt water can increase the rate of the chemical reaction that initiates corrosion.

Maintenance requirements

The 1124 Westwind aircraft had a Corrosion Control Program, which was contained within the Structural Inspection Program (SIP)[7] and Non Destructive Testing Manual. The SIP contained information about known corrosion areas. However, these areas did not include the internal upper fuselage skin, and there was no inspection for the internal fuselage skin covered by the insulation pads. That was because the upper fuselage skin was not considered an area prone to corrosion. In addition, the manufacturer had not previously received reports of corrosion in that area.

Additional inspections of the aircraft were contained in the Phase Inspection Program. The program included a general inspection of the fuselage skin; however, that was an external inspection. The only detailed inspection of the fuselage skin contained in the Phase Inspection Program, was an inspection of the under floor for corrosion. That inspection included the removal of the underfloor insulation pads.

On 3 August 1994, the aircraft manufacturer released a Service Information Letter regarding corrosion at antenna mating surfaces. Moisture could permeate between the antenna and the aircraft skin leading to corrosion, so the letter recommended that the antenna mounts be checked for leaks.

The 1124 Westwind aircraft did not have a structural repair manual. The aircraft's maintenance manual included information on some minor repairs to the fuselage but it did not include any information on repairing of the pressurised fuselage skin. The maintenance manual recommended that the Customer Service Representative be consulted for repairs of chemical milled components. In addition, the aircraft manufacturer's customer service representative advised the ATSB that any corrosion found on the aircraft should be repaired in consultation with them.

Inspection of other aircraft in the fleet

After the incident, the operator inspected the internal upper rear fuselage skin, on all its 1124 Westwind aircraft. They found minor surface corrosion in the same area on two of its freighter aircraft. The manufacturer approved the replacement of the corrosion-damaged panels with new non-chemical milled panels. Loose insulation was used on the new panels, so the insulation could be easily removed for inspection. The operator did not find corrosion in the area on their passenger 1124 Westwind aircraft.

Corrosion in ageing aircraft

Corrosion control methods are used in aircraft design to prevent and/or slow down the formation of corrosion. These design methods include material selection, the use of cladding, protective coatings, joint design and water drainage. However, the

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7 A SIP is a supplementary maintenance programme that is intended to be used after the aircraft reaches a specified number of flights or hours. SIPs provide additional maintenance and inspections to ensure the continuing airworthiness of ageing aircraft. ATSB (2007) *How Old is Too Old? The impact of ageing aircraft on aviation safety* (Aviation Research and Analysis Report No. B20050205). Canberra: Australian Transport Safety Bureau.

design of an aircraft cannot fully protect it from corrosion. For example, protective coatings can degrade over time. Therefore, regular inspections and maintenance are used as additional control measures to detect corrosion prior to it becoming a risk to the safety of flight.

Inspections for corrosion become increasingly important as aircraft age because there is a greater probability of finding corrosion. Corrosion Prevention Control Programs are often used in addition to regular inspections on ageing aircraft. These programs take into account the increased likelihood of finding corrosion and include locations where corrosion has been found. The ATSB research and analysis report, *How Old is Too Old? The impact of ageing aircraft on aviation safety*[8], discusses further the importance of managing ageing aircraft.

8 ATSB (2007) *How Old is Too Old? The impact of ageing aircraft on aviation safety* (Aviation Research and Analysis Report No. B20050205). Canberra: Australian Transport Safety Bureau. Available at http://www.atsb.gov.au/publications/2007/B20050205.aspx

ANALYSIS

The upper rear fuselage panel on the aircraft had extensive exfoliation corrosion. The amount and severity of the corrosion indicated that it had been developing over a long period of time. The corrosion would have reduced the capability of the panel to resist the pressurisation loads and led to the failure of the panel and depressurisation of the aircraft.

The aircraft had been flown and stored in environments that were favourable to the development of corrosion. These environments included the 2 years the aircraft spent parked outside at Sydney Airport and the time the aircraft spent at Darwin Airport, which was its base at the time of the incident. Both these locations were environments of high humidity and were rich in wind borne salt spray, due to their proximity to the ocean.

The insulation pads affixed to the panel were made of a fibrous material and had the ability to act like a sponge, absorbing the moisture in the humid salty air. The moisture would have been trapped close to the surface of the panel creating an environment favourable to the development of corrosion. Because the most severe corrosion was located two frames across from the antenna mount, it is likely that the moisture trapped in the insulation pads came from the humid air rather than from a leak in the antenna mount. Moisture would not have been able to travel across the frames and through the independent insulation pads, from the antenna mount to the site of the rupture.

To prevent corrosion, the aircraft’s design used corrosion resistant pure aluminium sheeting to clad the fuselage panel; however, the chemical milling process removed the cladding. Therefore, to provide corrosion resistance to the chemical milled sections, a protective coating had been applied to the panel. Over time, it is likely that the coating would have deteriorated. Furthermore, with the fibrous insulation pads holding moisture close to the aircraft skin, it is likely that, with time, the chromate leached out of the coating, leaving the chemical milled sections susceptible to corrosion damage from the external service environment.

An aircraft design cannot fully protect an aircraft from corrosion, so regular inspections and maintenance are needed. While the incident aircraft had a Corrosion Prevention Control Program and a number of inspections to manage corrosion, there were no specific inspections of the upper fuselage skin panel. That may have been because the area was considered to be at low risk of corrosion and no prior examples were known to the manufacturer. The under floor skin and antenna mounts were considered areas with a higher risk of corrosion, and there were specific inspections required for these areas.

For the under floor skin of the fuselage, there was the requirement to remove the insulation pads and conduct an internal inspection for corrosion. However, there were no inspections requiring the removal of the insulation elsewhere on the fuselage. Other corrosion inspections of the fuselage skin were general and only required an external inspection. As the corrosion developed on the internal side of the panel, an external visual inspection would not have detected the corrosion, until the corrosion was at full depth.

An internal visual inspection of the antenna mount, as required by the Service Information Letter of 3 August 1994, would have revealed the prior corrosion treatment. However, the treatment may have been interpreted as an appropriate repair and not investigated further.

The examination of the failed panel showed that the corrosion extended beyond the area that was treated for the corrosion damage. The panel also failed within the treated area. Based on this, it is likely that the repair did not prevent further growth of the corrosion on the panel.

The corrosion on the failed fuselage panel had been developing over a long period of time. Over that time, the aircraft had been stored in environments favourable to the development of corrosion. However, because the area was not considered likely to corrode, there was no requirement to inspect it. At some point, corrosion was found on the panel. However, the subsequent repair did not completely treat the corrosion. Without inspections of the area, the corrosion continued unabated, until the panel could no longer resist the pressurisation loads. This led to the failure of the panel and subsequent depressurisation of the aircraft.

FINDINGS

Contributing safety factors

- The aircraft was operated and stored in environments favourable to the development of corrosion.
- The insulation pads attached to the fuselage skin panel trapped moisture close to the skin of the aircraft. The moisture in the insulation pads probably led to the breakdown of the chromate conversion coating.
- There was no requirement for the fuselage skin panel to be inspected, nor was there any expectation that corrosion would be found on the panel.
- The insulation pads bonded to the panel made it difficult to inspect the internal side of the panel.
- Extensive exfoliation corrosion developed on the upper rear fuselage panel.
- The corrosion in the upper fuselage skin panel was not detected prior to its failure.
- The corrosion reduced the ability of the panel to resist the pressurisation loads resulting in failure of the panel and subsequent depressurisation of the aircraft.

SAFETY ACTION

Operator's safety action

As a result of this occurrence, the operator inspected the upper rear fuselage skin on all the aircraft in its fleet. On aircraft where corrosion was present, the operator replaced the skin panel and installed loose fitting insulation to enable future inspections.

The operator updated its Corrosion Prevention Control Program to include an inspection of the internal upper rear fuselage skin.

Manufacturer's safety action

The aircraft manufacturer's customer service representative released a Maintenance and Operations Letter, Westwind MOL-WAV0001, on 10 April 2007, informing operators of the VH-AJP event.

The manufacturer will be adding further guidance on the repair of the pressurised fuselage in the next release of the maintenance manual.