FINAL REPORT

AAIU Report No.: 2001/0019
AAIU File No.: 2001/0034
Published: 13 December 2001

Operator:	Aer Arann
Manufacturer:	ATR
Model:	ATR42-300
Nationality:	Ireland
Registration:	EI-CBK
Location:	Approaching Cork Airport, Ireland
Date/Time (UTC):	29 May 2001, 1700 hrs.

SYNOPSIS

While descending into Cork Airport (EICK) the flight crew experienced severe airframe vibrations. An emergency was declared and the aircraft landed without further incident at EICK. There were no injuries to passengers or crew. After landing it was found that a large panel at the fuselage/wing joint had become detached along its trailing edge. Further examination detected significant cracking in this panel.

NOTIFICATION

This incident was reported to the AAIU on the morning after the event by the operator, and an investigation was launched immediately. The Chief Inspector of Accidents appointed Mr Graham Liddy as the Investigator-in-Charge of this investigation. He was assisted by Mr John Hughes and Mr Jurgen Whyte of the AAIU. The Bureau Enquetes-Accidents, (BEA, the French authority responsible for air accident investigation), the Direction Generale de l'Aviation Civile (DGAC, the French civil aviation authority) and the aircraft manufacturer also participated in the investigation.

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft (EI-CBK) took off from Dublin Airport (EIDW) at 16.27 hours UTC on a scheduled Public Transport Flight to Cork Airport (EICK). A total of 45 passengers and 3 crew members were on board. The flight crew consisted of Captain-Under-Training, designated as the Pilot-Flying (PF), and a Training Captain, designated as the Pilot-Not-Flying (PNF), who was in command of the flight.

The en-route segment of the flight was flown at Flight Level (FL) 140 in Visual Meteorological Conditions (VMC) and was uneventful.

The descent into EICK commenced at approximately 42 nautical miles (NM) northeast of EICK. Passing down through FL 100, the aircraft momentarily entered a puff of light cloud at 230 kts (KIAS) and encountered light turbulence. Shortly thereafter, at 17.00 hours, severe airframe vibrations occurred throughout the aircraft, but particularly in the tail area.

Immediately, the Training Captain took control and the autopilot was disengaged. The aircraft was checked for evidence of icing, but none was found. The engine and propeller parameters were checked and found to be normal. In addition the propellers were checked and the flap position of 0° was checked against the flap level position which was found to be set at "Fully up".

The flight crew determined that the control column vibrations were severe in the fore and aft axis, and that each time pitch trim was used the vibrations increased. There were no control column vibrations felt in the roll axis. General cockpit vibration was described as severe, with the level of vibration increasing towards the rear of the aircraft. The level of vibration was sufficiently high to cause the crew to briefly consider a forced landing, rather than continuing to Cork Airport, as the flight path crossed a large urban area.

In the belief that there was a problem with the tail, the Training Captain reduced the rate of descent (ROD) and the indicated airspeed (IAS). However there was, initially, no appreciable reduction in vibration.

The PF declared an emergency to Air Traffic Control (ATC) and requested clearance for an Instrument Landing System (ILS) approach Runway (RWY) 17 at EICK. The cabin crew was instructed to prepare the cabin.

During the approach to EICK, it was noted by the flight crew that the level of vibration reduced after the selection of Flap 15° and the lowering of the undercarriage. This coincided with a reduction of airspeed to 150 kts. Further selection of Flap to 30° brought about the cessation of all airframe vibration, as sensed by the crew. The aircraft landed on RWY 17 at Cork without further incident.

In a post incident discussion between the flight crew and the Cabin Crew Member (CCM), it was determined that immediately prior to the on-set of the airframe vibration, the CCM had heard a loud bang coming from the ceiling of the aircraft.

1.2 Injuries To Persons

There was a total of 3 crew and 45 passengers on the aircraft. There were no injuries.

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor	0	0	0
None	3	45	

1.3 Damage To Aircraft

The only damage suffered by the aircraft was cracking in the trailing edge section of Panel 291BL. This panel is part of the wing-to-fuselage fairing and is located at the wing leading edge above the fuselage (see **Appendix A**).

1.4 **Other Damage**

There was no other damage.

1.5 **Personnel Information**:

1.5.1 PNF (Commander)

Personal Details	Male aged 39 years.
Licence	ATPL, Venezuela
Last Periodic Check	10 Jan 2001
Medical Certificate	3 April 2001. (Class 1).

Flying Experience:

Total all types	17,316	hours
Total all types PI	10,000	hours
Total on type	6,000	hours
Total on type PI	6,000	hours
Last 90 days	98	hours
Last 28 days	45	hours
Last 24 hours	43	minutes

Duty Time:

Duty Time up to incident	1 hour 30 mins.
Rest period prior to duty	28 hours 50 mins.

1.5.2 PF (Captain Under Training)

Personal Details	Male aged 46 years.
Licence	ATPL, Ireland
Last Periodic Check	5 May 2001
Medical Certificate	6 April 2001. (Class 1)

Flying Experience:

Total all types	2,450	hours
Total all types PI	1,600	hours
Total on type	55	hours
Total on type PI	15	hours
Last 90 days	48	hours
Last 28 days	15	hours
Last 24 hours	43	minutes

Duty Time:

Duty Time up to incident	1 hour 30 mins.
Rest period prior to duty	28 hours 50 mins.

.

1.5.3 The PNF was a highly experienced ATR 42 Line-Training Captain and was employed by the operator to train personnel for command on the ATR 42. On this flight he was supervising the PF who was preparing for command checks on the ATR 42.

1.6 Aircraft Information

1.6.1 Leading particulars

Aircraft type	ATR 42-300
Manufacturer	ATR
Constructor's number	199
Year of manufacture	1990
Certificate of registration	Issued on the 10 January 2001
Certificate of airworthiness	Issued on the 10 January 2001
Total airframe hours	20,243 hours
Total cycles	19,937 cycles
Engines	2 Pratt & Whitney PW 120 Turboprop engines
Maximum authorised take-off weight	16,800 kg
Actual Take off weight	16.324 kg
Estimated weight at time of incident	15,400 kg
Centre of Gravity limits (at incident weight)	16.8 to 32.5 % Mean Aerodynamic Chord (MAC)
Centre of gravity at time of incident	23.3% MAC

1.6.2 General Information

The ATR 42 is a high wing, pressurised, regional airliner. It is powered by two wing-mounted turboprop engines, each of which drives a large propeller clockwise, when viewed from the rear. There are approximately 250 examples of the ATR 42-300 currently in worldwide service. The wing is mounted above the fuselage and is attached to the fuselage by tie-rods. This avoids direct transmission of normal wing flex stresses to the fuselage, but results in slight relative movement between the fuselage and wings when the wing flexes under normal flight loads. The fairings, which cover the gap between the wings and the fuselage, are rigidly attached to the fuselage, or to substructures mounted rigidly on top of the fuselage. Where these fairings meet the wings, they are secured to the wing by means of clips, rather than rigidly bolted to the wing. This method of attachment permits some relative movement between the fairings and the wing structure, thereby reducing loadings on the fairings. The normal relative movement can be of the order of 3 mm.

This system has an additional advantage in that it is not necessary to have securing holes in the wing mainspar, which is the portion of the wing to which these fairings are secured. Such holes would weaken the spar structure.

1.6.3 Panel 291BL

A particular wing/fuselage fairing, which is at the core of this incident, is designated as Panel 291BL and is sometimes known as the Karman Panel. It is a rectangular panel measuring 1.470 metres wide (spanwise) and 0.51 metres deep (front to aft). The panel is located above the fuselage centre-line, immediately in front of the wing forward mainspar (ref **Appendix A**). The panel, which is almost flat, is mounted approximately 20° to the horizontal. It is attached, by screws, along its leading (forward) edge by 13 screws at 130 mm spacing and along each side by 4 screws at 155 mm spacing, to fixed elements of the fuselage structure. The trailing edge is secured, by 8 clips, to the forward mainspar, forming a flush joint with the top of the wing. These clips are at 180 mm spacing. Details of the clips are shown in **Appendix B**. The tongues of the clips locate under the spar and the clip screws are then torqued to a set value to secure the panel.

The Panel 291BL is constructed from composite material. The outer skin is constructed of 2 layers of Kevlar and the inner skin from 3 layers of Kevlar. The centre of the panel is made from honeycomb. The honeycomb does not extend to the edges of the panel, but stops about 75 mm from the edge. The direct bonding of the outer skin to the inner skin makes up the trailing edge lip of the panel. **Appendix B** shows this construction.

1.6.4 Aircraft History

EI-CBK had been owned by a leasing company and operated in the USA for several years. On termination of this lease, it was sent to an approved maintenance facility in France in July 2000. It remained at this facility, on a care and maintenance basis, until it transferred to the current operator in February 2001. Prior to this transfer, the aircraft was partially repainted, including the area of the Panel 291BL.

1.6.5 Maintenance History

At the end of its period of care and maintenance in France, the aircraft underwent a "C" Check, which was completed on 13 January 2001, at 19,760 airframe hours and 19,115 flight cycles.

The aircraft returned to the same facility for an "A" check, and Traffic Collision Avoidance System (TCAS) modification, which was completed on 11 April 2001, at 20,054 airframe hours and 19,620 flight cycles.

At the time of the incident the aircraft had completed 20,243 airframe hours and 19,937 flight cycles.

1.6.6 History of the Panel 291BL

Prior to 1997, there had been problems with the panel coming loose at its trailing edge. The manufacturer had issued 3 Service Bulletins relating to wing-to-fuselage panels, including the Panel 291BL:

SB ATR 42-53-0063 issued 29 April 1991. Revised 6 June 1994. Status Recommended. (Mod. 2601) *Wing to fuselage fairing panels – add cup washers under the fastener countersunk holes.* (32 pages)

SB ATR 42-53-0081 issued 6 June 1994. Revised 9 Dec 1994. Status Mandatory. (Mod.3942) *Fuselage/Nacelles-Wing to fuselage fairing/upper cowls- change plier attach material* (15 pages)

SB ATR 42-53-0082 issued 6 June 1994. Revised 13 June 1998. Status Mandatory. (Mod. 2601 & 3941) *Wing to fuselage fairing panels and upper cowls-add cup washers under the fasteners and change plier attach material.* (32 pages). This SB, in fact, incorporated the two previous bulletins SB ATR 42-53-0063 and SB ATR 42-53-0081. (Mod. 3941 is a retro-fit modification, applicable where Production Mod 3942 was not incorporated).

In addition the French Aviation regulatory authority, DGAC, issued the following two Airworthiness Directives (AD) relating to the Panel 291BL:

In July 1994 **Airworthiness Directive 94-162-056 (B)** was issued by DGAC "*in order to avoid a possible deformation of the fairings clips at level of wing front and rear spars upper flange attachment*". This AD also made the above S.B. ATR 42-53-0081 mandatory.

In July 1997 another **Airworthiness Directive 97-159-071 (B)** was issued "*in order to avoid severe in-flight vibrations induced by a loosening of wing to fuselage fairing panels attachments consequent on an incorrect installation of these panels*." This AD required the mandatory modification of the attachments in accordance with SB ATR 42-53-0082.

Since the above action was taken, there have been 7 reported incidents of in-flight vibration, including this current incident, which were associated with the Panel 291BL. In some of these cases reinstallation of the panel, with the correct torque applied to the clip screws, rectified the problem. Where the panel was not damaged, this action was satisfactory. In 5 of these previous incidents damage was found on the panel, but in these cases it was thought, at the time, that this damage was the result of the panel becoming loose.

Details of these 7 events are:

Event Number	Date	Aircraft Cycles	Aircraft Hours	Event	Notes
1	25/03/1998	20017	19654	Drag increase	Damaged panel
2	13/04/2000	25830	22240	In-flight vibration	Damaged panel
3	16/09/2000	35691	28619	In-flight vibration	
4	31/08/2000	21117	20753	In-flight vibration	Damaged panel
5	07/03/2001	25477	24647	In-flight vibration	Damaged panel
6	07/05/2001	30739	39120	In-flight vibration	Damaged panel
7	29/05/2001	19937	20243	In-flight vibration	Damaged panel

The above data is shown graphically in **Appendix C**.
EI-CBK had been modified in accordance with Service Bulletin ATR 42-53-0082 by a previous operator in the United States, in June 1998. Thus the requirements of SB 42-53-0063 and SB 42-53-0081 were satisfied on this aircraft and the aircraft complied with the above ADs. However a recent SB, classified by the manufacturer as recommended, had not been accomplished: -

> Service Bulletin ATR42-57-0059 was issued on 6 December 2000 and was "recommended" by the manufacturers. The title of this SB was "*Wing-centre box-modify forward and rear spar top flanges" (23 pages).* This SB included the chamfering of the forward edge of the wing-to-fuselage fairing panel 295BL, the installation of PTFE adhesive tape on the upper surface of the top flange and the installation of new bonding plates.

1.6.7 Aircraft Servicing Requirements

In accordance with the aircraft maintenance schedule the requirements on an "A" Check (every 400 or 500 hours flying time, depending on the approved maintenance schedule) for pre-Mod. 2601 top fairings state: "*General visual inspection of top fairings. Note: Check particularly top centre panels 291BL, 295BL, for presence and condition of all attaching screws."*
For post-Mod.2601 aircraft, an inspection of panels is only required on the "C" Check (every 3200 hours flying). Because this modification had been accomplished on EI-CBK, inspection of the Panel 291BL was only required every 3200 flying hours on this aircraft.

1.6.8 Manufacturer's Initial Action

Following the current incident, the manufacturers stated that the vibrations encountered by the aircraft were due to a known problem, caused by the lifting of the rear edge of the Panel 291BL. On the 30 May 2001, the day following this incident, the manufacturers issued an All Operators Message (AOM 42/72 /01/005). They stated *"Repetitive maintenance not performed strictly following the relevant JIC (Job Instruction Card) could have damaged the panels leaving them loose."*

They reminded operators *"to perform the installation of panels* _strictly_ *following the JIC 53-93-00 RAI-10000. This will eliminate the risk of damages to the panels and hence the vibrations"*
After this incident, the manufacturer said that if Panel 291BL was found loose then the vibration in flight was 'most probably' induced by this panel being loose. The operator was instructed to inspect the fairing for wear, cracks or delaminations of the composite material. The manufacturers referred the operator to the correct instructions for the installation of this panel, stating that "*the check of the correct installation of all wing to fuselage fairing panels attached to the wing front and rear spars will permit to make sure that they are correctly fastened"*.

1.7 Meteorological Information

1.7.1.1.1 Met Eireann, the Irish Meteorological Service, provided the following information after the incident.

General Situation: At the surface a low pressure system centred northwest of Ireland maintained a slack southwest airflow over the area. There was a shallow trough off the west coast associated with a weak quasi-stationary front. There was a jet (jetstream) of 110 kts at FL 330 between Shannon and Cork at 1200 UTC. This jet was drifting slowly northwards.

Wind: The wind situation (from tephigram analysis) at the relevant levels was:

At 1200 UTC: 24030 kts at FLO50, 24040 kts at FL100, 24066kt at FL180

At 1800 UTC: 26022kt at FLO50, 25028 kts at FL100, 24068kt at FL 180

Turbulence: Light turbulence could be expected with a risk of moderate turbulence. However, there was an indication of light to moderate mountain waves.

Cloud: Tephigram and satellite analysis suggests that the cloud was broken with tops at a maximum of 10,000 to 11,000 feet.

Icing: The freezing level was approximately 7500 feet in the area. Radar analysis suggests that there was at most intermittent light precipitation. Light icing could be expected with a slight risk of moderate icing.

1.7.2 The crew stated that they had flown through very light clouds just prior to the onset of the airframe vibration and that there was no indication of icing. They also stated that they had passed through some light turbulence immediately before the airframe vibration started.

1.8 Aids to Navigation

Not applicable

1.9 Communications

Not applicable

1.10 Aerodrome Information

Not applicable

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The aircraft was equipped with a Fairchild 93-A100-83 Cockpit Voice Recorder (CVR).

As the CVR remained "ON" during the subsequent engine ground run and tests at Cork, the contents of the CVR relating to this incident were taped over. This was because only the last 30 minutes of recording are retained. Consequently no CVR data relating to this incident was available to the investigation.

1.11.2 Flight Data Recorder

The aircraft was equipped with a Fairchild 17M800-251 Flight Data Recorder (FDR). The FDR was brought to the UK AAIB for downloading.

The FDR data showed that the aircraft started the descent 18 minutes prior to landing at Cork airport. The aircraft pitch was reduced from +1° to -2° and the Calibrated Air Speed (CAS) increased from 210 kts to about 240 kts. Three minutes into the descent the aircraft experienced some turbulence, which can be seen on the roll channel. At this point severe vibrations were recorded on the pitch channel, and, to a lesser degree, in the roll, CAS and vertical acceleration (G) parameters. The pitch of the aircraft was then gradually increased to approximately 7° and CAS was reduced to approximately 150 kts. While vibration was still recorded at this airspeed, particularity on the vertical acceleration (G), the amplitude had significantly reduced.

1.12 Wreckage and Impact information

1.12.1 Initial Inspection

Following the incident, an inspection of the fairing panels revealed that most of the trailing edge of the Panel 291BL was protruding 10 mm above the forward mainspar. The panel had lifted over the forward wing spar flange and the tongues of 7 of the 8 attachment clips were resting on top of the spar flange. The single clip that was still in the correct position was the clip on the extreme left end of the panel's trailing edge.

1.12.2 Inspection of the Aircraft

The aircraft skin was painted white in the area of the Panel 291BL. The unexposed parts (internal surfaces) were painted with green primer. There was evidence of white over-spray on the spar area normally covered by the Panel and also on some of the structural members underneath the sides and front of the Panel.

1.13 Medical Information

Not applicable

1.14 Fire

There was no fire

1.15 Survival Aspects

Not applicable

1.16 Tests and Research

1.16.1 Initial Determinations

The aircraft was initially inspected at Cork by the operator's personnel. Initial inspection failed to reveal an obvious airframe problem and initial tests centred on the possibility of propeller-induced vibrations. When inspection of the propellers and engine test runs failed to show the source of the vibration, a more detailed inspection of the airframe was conducted. Further inspection found that the Panel 291BL had become loose along its trailing edge and that the tongues of 7 of its 8 securing clips were now sitting on top of the wing spar flange. The result was that most of the trailing edge of the panel was unsecured and was sitting approx 10 mm proud of its normal position. It should be noted that this problem is virtually undetectable from the ground level and could only be seen when personnel got up onto the high, over-fuselage wing.

The panel was removed and visually inspected. It was found to be cracked on its upper (outer) skin, along a line parallel to its trailing edge located approximately 70 mm forward of the trailing edge. The crack started 240 mm from the left edge and extended 630 mm towards the right edge, stopping 600 mm from the starboard edge. The crack could be seen with the naked eye. There also appeared to be damage on the inner skin corresponding to the external crack. However, due to the rough texture of the inner skin and because the skin was covered with aluminium foil for lightening protection, the extent of this damage was difficult to determine by visual inspection. It was also noted that there was a marked reduction in the bending stiffness of the panel in the area of the visible crack, when the panel was manually subjected to modest bending loads.

The panel was then replaced by a panel from another aircraft, and during fitting it was ensured that the clip screws were torqued to the correct value. When the aircraft was flown with the replacement panel, no vibration was experienced.

1.16.2 Test Flight

Following further analysis (as discussed in Section 2, Analysis), it was decided to re-install the cracked panel on an ATR 42 at the manufacturer's facility in Toulouse. In preparation for this test flight, it was particularly ensured that the panel clip screws were correctly torqued.

The results of this test flight indicated that all indications were normal up to a speed of 200 kts. At 225 kts slight vibrations were noted. These increased with the application of right sideslip and decreased with left sideslip. At 245 kts the level of vibration increased slightly. When right sideslip was applied at this speed, the vibrations increased to a high level. The aircraft was then decelerated, in the clean configuration (no flap or undercarriage lowered). The high level of vibration continued down to an airspeed of 160 kts. At 150 kts the vibration had disappeared.

After landing it was found that 6 of the 8 clips of the Panel 291BL had become displaced and had their tongues resting on top of the spar flange.

The FDR records from the test flight showed an increase of about 80 drag units, which would cause a speed reduction of approximately 16 kts at 200 kts. The aircraft also experienced a slight nose pitch down of 0.45°, equivalent to an elevator forward deflection of 1.5°. The test pilots reported that the extra drag generated is moderate at high speed and negligible at low speed. The basic handling qualities were not affected. Their report also stated that the onset of the high level vibrations was sudden, and that this would lead a regularly trained commercial crew to suspect the possibility of structural damage to the aircraft.

The manufacturer estimated that the trailing edge of the panel rose approx 40 mm above its normal position during the test flight.

1.16.3 Post Test Flight Inspection

Following the test flight, it was agreed to subject the panel to further testing, including cutting it open. Initially the foil lining in the inner face was removed. This revealed the failure in the inner skin (See **Appendix D**). The panel was then subjected to C-Scan inspection, which revealed that the inner Kevlar skin had lost structural integrity along the entire length of the panel. This is shown by the yellow area in **Appendix E**.

The panel was then sectioned. This revealed that significant telegraphing and failure of the honeycomb had occurred in the area where structural integrity was lost. (The phenomenon telegraphing is explained in **Appendix F)**

Careful examination was made throughout these tests and inspections to detect any evidence that the panel had suffered any damage or impact prior to the incident. There was a particular concern that the panel may have suffered a hard knock, dropping or impact during maintenance that may have caused the structural cracking. No evidence of such pre-existing damage was found.

1.17 <u>Organizational and Management Information</u>

Not applicable

1.18 Additional Information

1.18.1 It was ascertained that the Panel 291BL had not been removed and refitted since the completion of the aircraft re-painting in France, approximately 4 months prior to this incident.

1.18.2 After initial investigation of this incident, the AAIU issued a preliminary report on 11 June 2001, which contained the following interim safety recommendations: -

- The French Authorities should consider issuing an Airworthiness Directive requiring operators to inspect ATR 42 Panel Part No. 291BL for lateral cracks in the upper surface of the panel forward of the retaining clips and that cracked panels should be removed from service. (**SR 23 of 2001**)

- ATR should review the design of the ATR 45 Panel 291BL to prevent development of lateral cracks and the possibility of the panel becoming partially detached. The service life of the current design should also be reviewed. (**SR 24 of 2001**)

1.18.3 Following the AAIU preliminary report the Irish Aviation Authority (IAA) issued Aeronautical Notice Nr A.65. This required that operators of Irish registered ATR 42 aircraft, and operators operating ATR 42 aircraft on an Irish Air Operators Certificate (AOC), should inspect this panel for lateral cracks in the upper surface, forward of the retaining clips, and remove any cracked panels from service.

1.18.4 ATR, the manufacturer of the ATR 42, has launched a programme addressing issues raised in this investigation, featuring: -

- The issue of a service bulletin requiring the Panel 291BL to be inspected on the next "A" check and repeated every 2-A check (every 400 or 500 hours depending on the approved servicing schedule).

- The withdrawal from service of all Panels 291BL with similar cracks longer than 180 mm (the distance between 2 adjacent trailing edge clips.

- The modification of all ATR 42-300 Panels 291BL in service, or alternatively the replacement of all panels in service with a new design.

1.18.5 As a result of the foregoing, ATR has issued SB ATR42-53-0123 on 6 November 2001, which requires all Panels 291BL to be inspected for damage and cracks within 3 months, and thereafter every 1000 hours, until the Panel 291BL is replaced in accordance with SB ATR42-53-0125.

1.18.6 ATR has also issued SB ATR42-53-0125 on 6 November 2001, which is to be accomplished before 1 November 2004. This SB requires the replacement of the Panel 291BL with a panel of improved design.

1.18.7 The French DGAC issued AD 2001-554-087(B), effective from 24 November 2001, which classified SB ATR42-53-0123 and SB ATR42-53-0125 as mandatory.

1.18.8 Later versions of the ATR 42, and also the larger ATR 72, which were manufactured subsequent to the ATR 42-300, feature a different design of panel in the Panel 291BL position, and do not appear to suffer similar problems.

1.18.9 During this investigation, details of a similar event to another ATR 42, on 28 May 1997, come to light. A pilot's report of this event indicated that the aircraft had suffered an un-commanded descent during this event and even with the application of full power the aircraft continued to descend. This was cited in the preliminary report of the event involving EI-CBK. It is now understood that subsequent investigation of the 1997 event discounted certain aspects of the pilot's report.

2. <u>ANALYSIS</u>

2.1 Initial analysis focused on the possibility that the Panel 291BL was not correctly installed on the aircraft; specifically that the clip screws had not been torqued to the correct value, or that the panel may have been installed with some of the clip tongues resting on top of the spar flange, rather than correctly clamped underneath the flange. The presence of paint over-spray on the normally hidden area of the spar flange gave rise to this suspicion. However, it was noted that paint over-spray was found on the structural supports underneath the other edges of the panel. These edges are screwed in place, and these screws were all in place when the panel was examined after the incident. It was only the trailing edge, retained by tongued clips that had become displaced. Furthermore, the front and side edges of the Panel 291BL were sealed, using a sealant, which would have prevented the ingress of paint over-spray after the panel was fitted.

2.2 It was deduced from the above that the panel was loosely secured, by means of a few screws and/or clips, during the repainting, and that this allowed the ingress of paint over-spray. The panel was subsequently correctly fitted and sealed. The panel then successfully completed 4 months of service, comprising 483 hours and 821 cycles, following the repainting, before the incident. The fact that the panel stayed in place for this period further indicates that it was correctly installed.

2.3 In both the incident flight and the subsequent test flight, the onset of severe vibration was sudden, indicating a sudden disengagement of a number of the retaining clips. This is consistent with the bang heard by the CCM in the cabin of EI-CBK.

2.4 The conditions of the test flight, in terms of aircraft speed and rate of descent when the vibrations commenced, were very similar to the conditions when EI-CBK experienced similar vibrations.

2.5 All indicators are that the events on the incident flight and on the test flight were virtually identical. Because the panel was correctly secured on the test flight, one is led to the conclusion that the cracks in the panel were the cause of the trailing edge becoming loose on both flights.

2.6 In normal use the panel was subjected to a negative aerodynamic pressure (lift) on the external upper face. This force tended to suck the panel up into the shape on an inverted "U". This force was resisted by the bending stiffness of the panel.

This in turn produced compressive loads in the inner skin and tensile loads in the outer skin. Due to the effects of telegraphing, the inner skin's ability to resist repeated applications of compressive loads was reduced. This ultimately led to failure of the inner skin along the line parallel to the trailing edge. This is shown by the C-Scan test.

Due to the failure of the inner skin, the outer skin now had to carry an increased load which led, in turn, to failure and cracking of the outer skin. The result of this damage was to significantly reduce the ability of the panel to withstand the bending stress. The net result was loss of bending stiffness, which allowed the panel to deform, under aerodynamic lift forces, into a slightly inverted "U" shape. Because the leading edge of the panel was secured to the fuselage, the result was the trailing clip tongues being pulled forward until they lost contact with the spar flange. This allowed the trailing edge of the panel to spring free. The panel's trailing edge was then free to be sucked upwards into the airflow, by an estimated 40 mm. This produced a substantial step in the airflow over the top of the wing and caused substantial turbulent eddies to form. When these turbulent eddies passed over the tailplane and elevators, the result was the severe vibrations felt by the crew.

2.7 In addition to aerodynamic load cycles, the Panel 291BL was also subject to flexing loads due to relative movement between the wing and fuselage on this aircraft type. Normal in-flight turbulence and take-off and landing loads caused these relative movements. It is possible that the resultant flexing stresses may also have induced compressive loading of the Panel 291BL, thereby contributing to the failure of the panel.

2.8 Because both propellers turn clockwise when viewed from the rear, the vortex coming from the left propeller decreased the effective angle of attack over the Panel 291BL, and the vortex from the right propeller tended to increase effective angle of attack over the Panel 291BL. Therefore, when the aircraft on the test flight was subjected to sideslip to the right, the effect of the vortex from the right propeller was more pronounced. As the effect of this vortex was to increase the effective angle of attack, the result would be to increase the low-pressure area above the Panel 291BL, thereby increasing the bending loads on the panel. On the approach to Cork the aircraft experienced turbulence and the aircraft rolled from side to side, as recorded by the FDR. During these roll oscillations the aircraft would have experienced some sideslip, thereby creating similar conditions as on the test flight. Furthermore the relative movement of the fuselage and wing during this turbulence would have exerted flexing forces on the Panel 291BL, thereby increasing the tendency for the securing clips to become displaced. The fact that the only clip not to be displaced on the Cork incident was the extreme left clip, confirms the effect of the sideslip to the right.

2.9 When the aircraft decelerated to about 150 kts, the aerodynamic lift (negative) pressure on the panel was reduced sufficiently to allow the panel to rest, on the clip tongues, on the spar flange. With the reduced airflow disturbance and the reduced airflow energy, due to the lower airspeed, the turbulence, and hence the vibration, disappeared.

2.10 **Appendix C** shows the historical data for the seven Panel 291BL events (as given in Para 1.6.6 above) in graphical form. This shows that the hours to failure and the cycles to failure show significant consistency.

Furthermore, it shows that the panel which failed on EI-CBK (event no 7) had almost identical hours flown (approx 20,000) and cycles flown (approx 20,000) compared with 2 others of the 7 events (Events 1 and 4). The graph clearly indicates that there is an utilisation ageing factor in the failure of this panel.

2.11 The structural integrity of the aircraft was not compromised, in any way, during the incident.

2.12 The handling characteristics of the aircraft were not compromised, in any way, during the incident.

2.13 Any threat to the aircraft as a result of this incident arose from the possibility of a crew taking inappropriate action when these severe vibrations were experienced. Fortunately, in this incident, the crew took appropriate action. The experience of the Training Captain was undoubtedly a valuable resource in this situation.

2.14 The non-accomplishment of recommended Service Bulletin ATR42-57-0059 is not considered to have any bearing on this incident. The objective of this SB was to prevent chaffing of the mainspar flange by the Panel 291BL and its fastenings.

3 CONCLUSIONS

3.1 Findings

3.1.1 The aircraft and crew were properly certificated for the flight.

3.1.2 The aircraft had been correctly maintained in accordance with the appropriate schedules.

3.1.3 The aircraft was operated within appropriate limits throughout the flight. In particular speeds, weights and centre of gravity were within limits.

3.1.4 The Panel 291BL came loose along its training edge due to a loss of bending stiffness**.**

3.1.5 The loss of bending stiffness of the Panel 291BL resulted in the trailing edge of the panel coming free and this resulted in turbulent eddies over the tailplane, which produced the severe vibrations experienced by the crew.

3.1.6 The loss of bending stiffness in the Panel 291BL was caused by a crack induced by cyclic flexing stresses on the panel, which were due to aerodynamic and wing flexing loads. The "telegraphing" effect contributed to the reduction of bending stiffness of the panel.

3.1.7 The flying characteristics of the aircraft suffered only minor degradation as a result of displacement of the Panel 291BL.

3.1.8 The handling characteristics of the aircraft were not affected in this incident.

3.1.9 The vibrations experienced in this incident were sufficiently severe to possibly mislead a flight crew into thinking that their aircraft had suffered structural failure. This could in turn prompt a flight crew into taking inappropriate action.

3.1.10 Panels 291BL showing substantial cracks are liable to become detached along the trailing edge under normal operating conditions, thereby giving rise to excessive airframe vibration.

3.1.11 The design of the Panel 291BL, in that it features only 3 layers of Kevlar on the inner skin, made it susceptible to "telegraphing" during manufacture, and this compromised its resistance to compressive bending loads.

3.1.12 There is definite evidence that the failure of the skin of the Panel 291BL is related to the service life of the panel.

3.2 Causes

3.2.1 The cause of the in-flight vibration was the displacement of the trailing edge of the Panel 291BL, due to the loss of bending stiffness of the panel.

3.2.2 The bending stiffness of the Panel 291BL deteriorated due to a combination of cyclic loading of the panel and telegraphing of the inner skin of the panel, which in turn caused structural degradation of the inner skin and ultimately a crack on the outer skin.

4 SAFETY RECOMMENDATIONS

The only safety recommendations arising from this investigation are those raised in the preliminary report. They are repeated here to conform to the standard ICAO Annex 13 Final Report format. The action taken by the manufacturer and the DGAC is considered to be a satisfactory response to these recommendations.

4.1 The French Authorities should consider issuing an Airworthiness Directive requiring operators to inspect ATR 42 Panel Part No. 291BL for lateral cracks in the upper surface of the panel forward of the retaining clips and that cracked panels should be removed from service. (**SR 23 of 2001**)

4.2 ATR should review the design of the ATR 42 Panel 291BL to prevent development of lateral cracks and the possibility of the panel becoming partially detached. The service life of the current design should also be reviewed. **(SR 24 of 2001**)

Appendix A

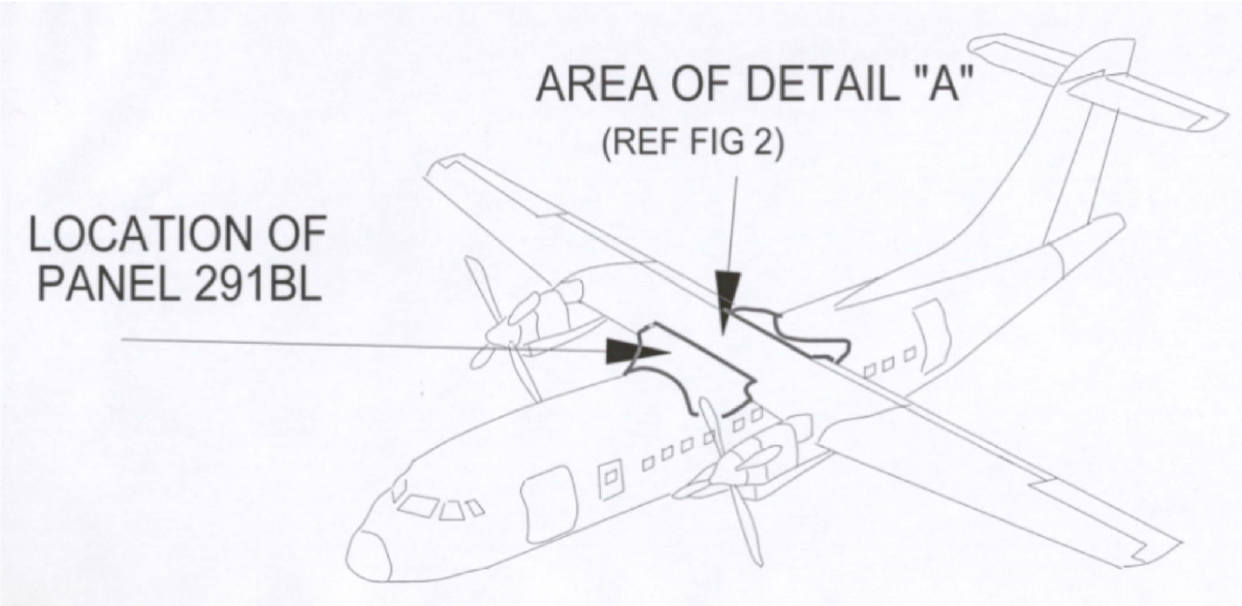


FIG 1

Position of Panel 291BL on ATR-42

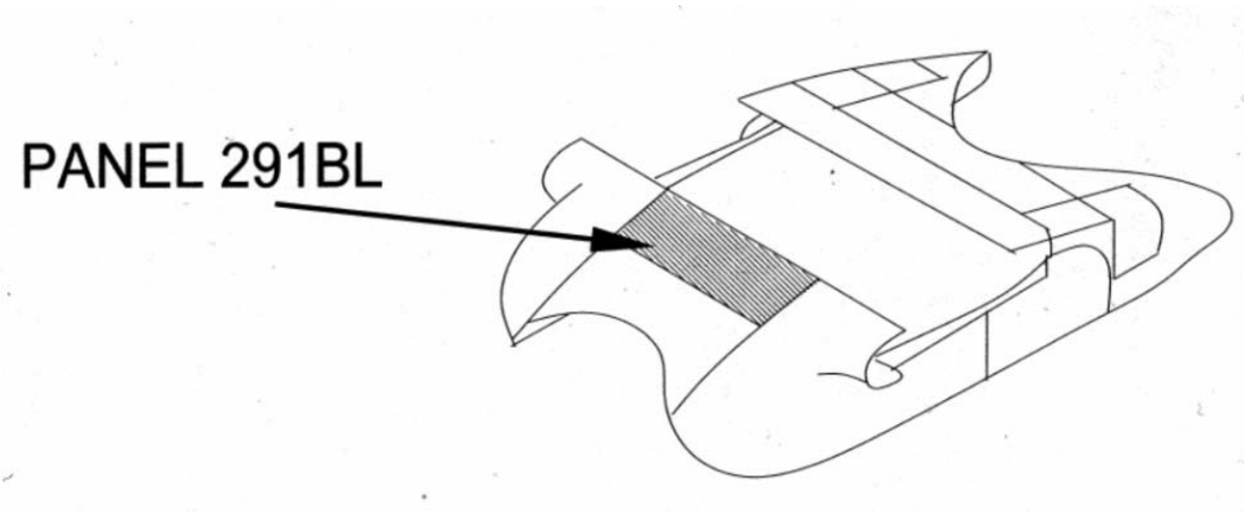
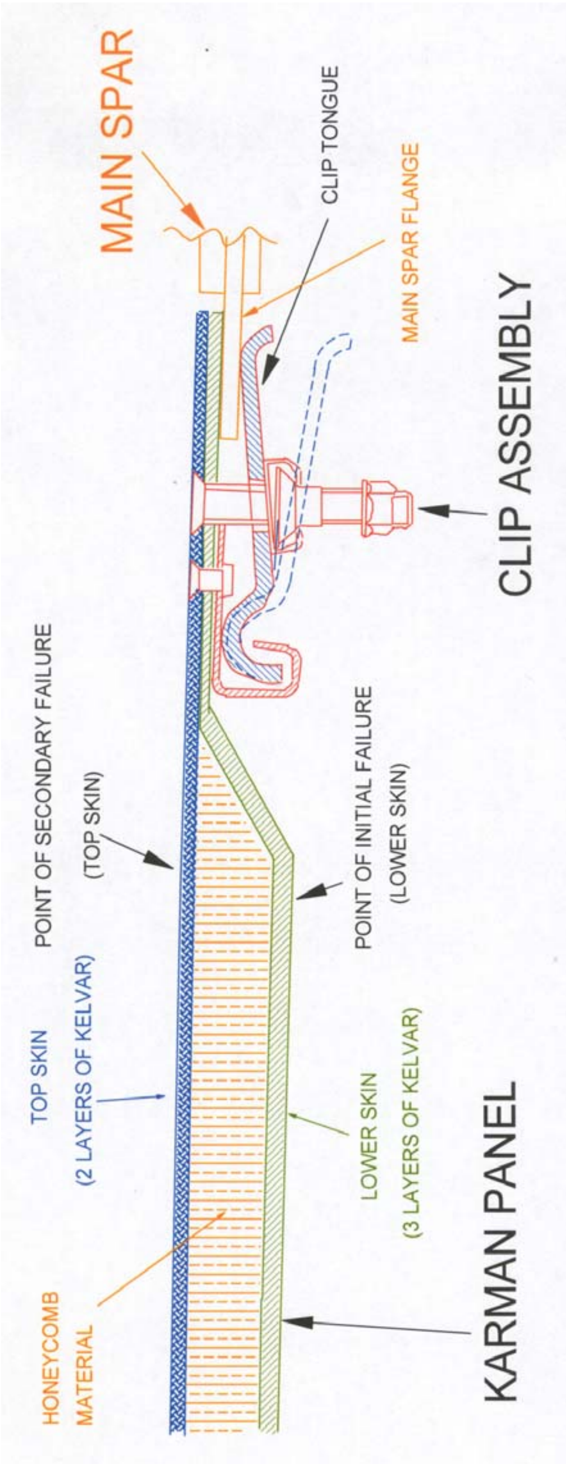


FIG 2

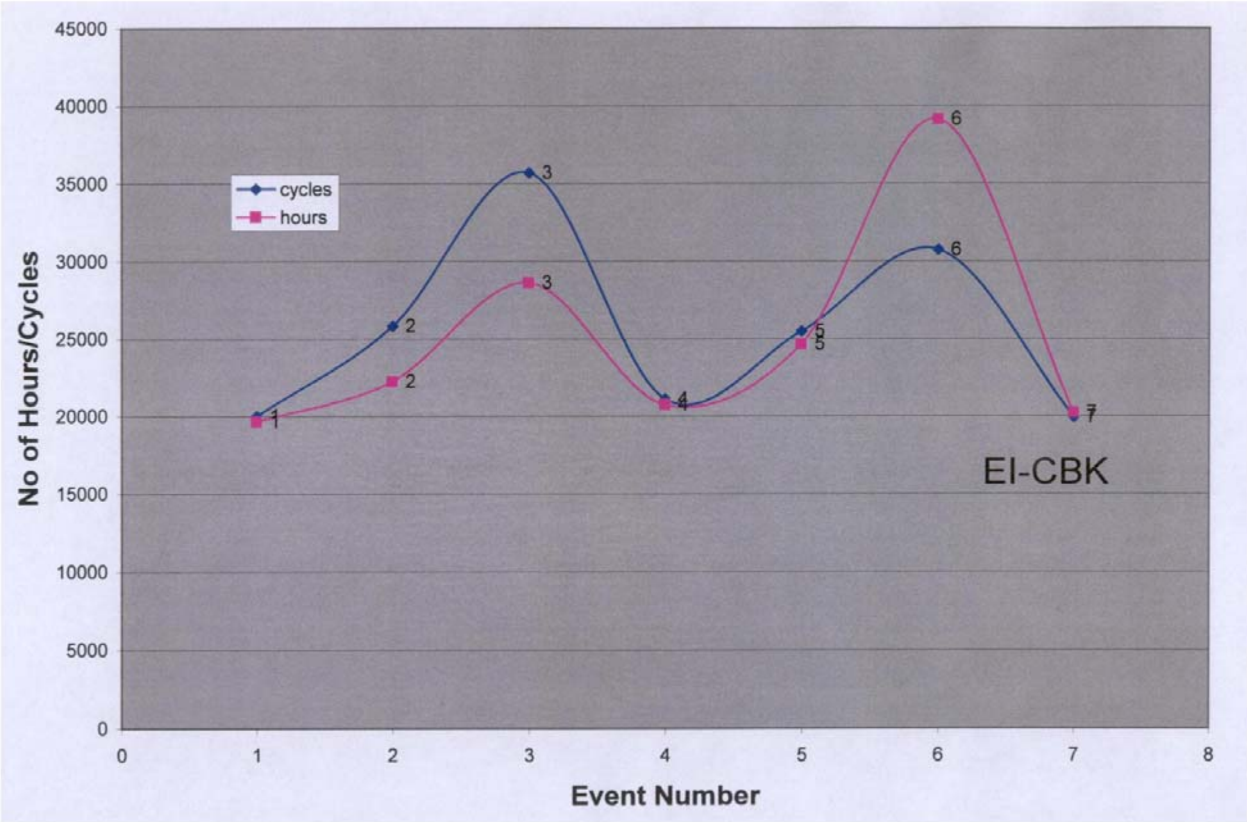
Detail "A" Showing location of Panel 291BL

Appendix B



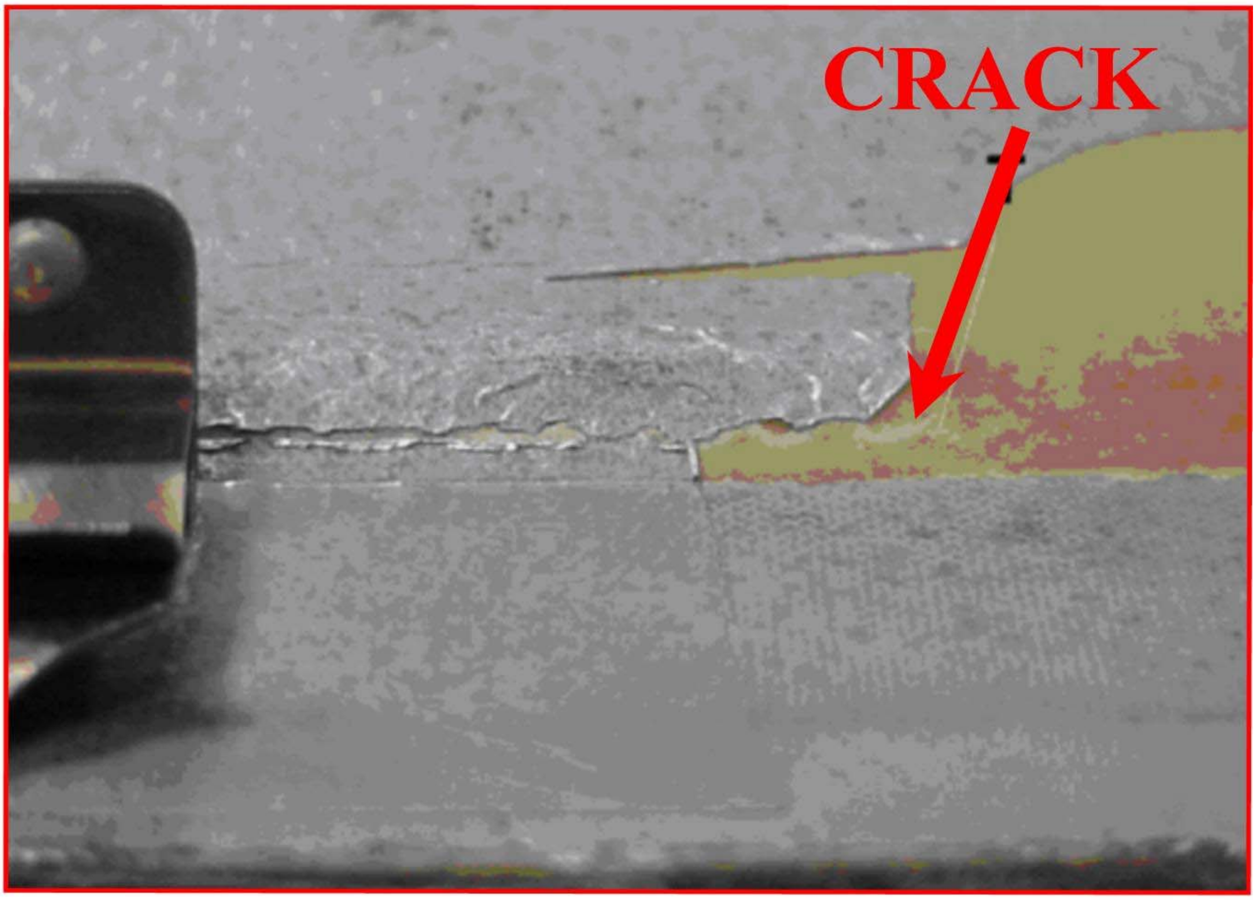
Section of Clip Assembly and Panel 291BL

Appendix C



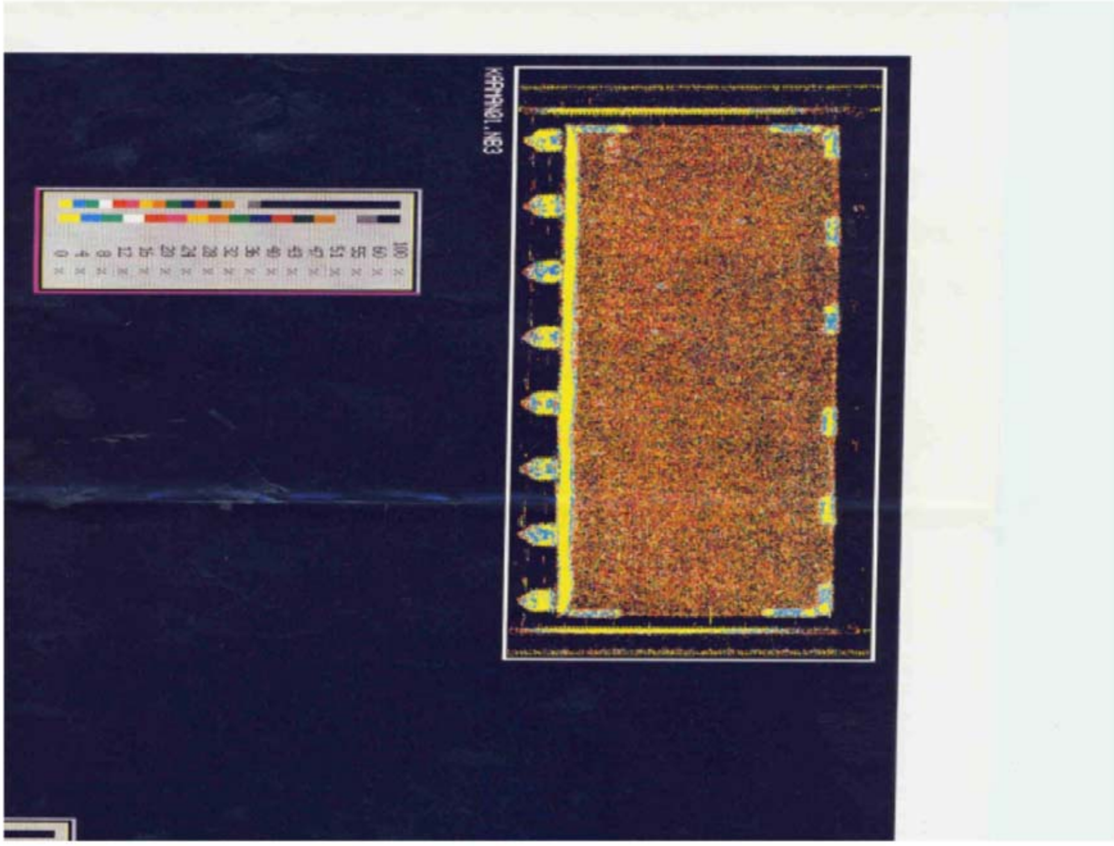
Plot of Flying Hours and Cycles for Panel 291BL Events That Occurred to ATR 42 Aircraft

Appendix D



Inner face of Panel 291BL showing Failure
(Foil Removed)

Appendix E



C Scan Result of Panel 291BL Inner Face
Failure is Indicated by Heavy Yellow Line

Appendix F

<u>Telegraphing in thin layers of Kevlar covered honeycombed structures.</u>

Kevlar is a high strength fibre, applied with a resin bonding agent to produce high strength lightweight structures. It is generally similar to glass fibre, but with several superior characteristics. Components made from Kevlar are normally produced by applying a number of layers of Kevlar and resin. During construction of the component, pressure is frequently used to ensure thorough impregnation of the Kevlar by the resin. Heat is also applied to promote impregnation and subsequent curing of the resin.

Kevlar is used frequently in conjunction with lightweight honeycomb materials to produce components such as aircraft floors and panels. The Panel 291BL is a typical example. In this type of application, layers of Kevlar and resin are applied in both side of a sheet of honeycomb. Honeycomb material is a matrix of hollow hexagonal forms, similar to the hexagonal honeycombs constructed by bees in honey forms. The walls of the hexagonals can be made from a variety of materials, from paper to aluminium foil. The size of the honeycombs can vary. In the case of the Panel 291BL it is approx 6 mm, across flats. The resultant honeycomb/Kevlar structure has excellent strength to weight ratio properties.

It has been found that when a small number of Kevlar and resin layers are applied over a honeycomb structure, the Kevlar layers sags slightly between the uprights of the honeycomb hexagonals. This has the appearance similar to that of telephone wires sagging between telegraph poles and hence the origin of the name of the phenomenon: - "Telegraphing". The effect is shown diagrammatically, in figure 1.

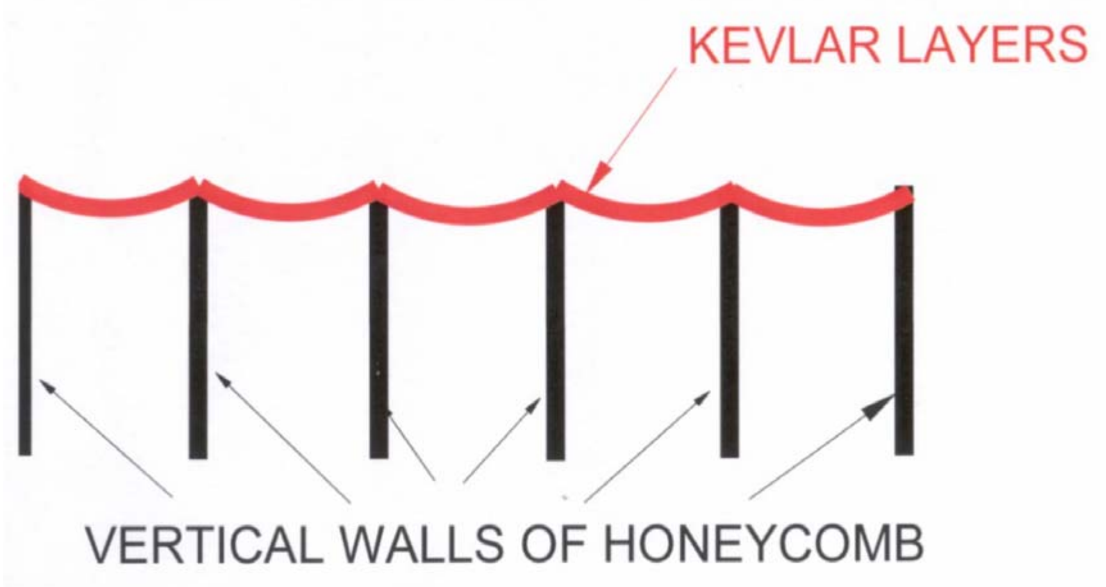


Figure 1
Showing the sagging between vertical supports (exaggerated)

The degree of sagging or telegraphing tends to be inversely proportional to the number of layers, i.e. it is more pronounced when only a very small number of thin Kevlar layers are used in the construction. It is further exacerbated by the pressure of the impregnation process and the heat of the curing process.

The effect of telegraphing is to reduce the resistance of the Kevlar skin to compressive loads. Because the surface is already somewhat buckled by telegraphing, the effect of the compressive load is to increase the buckling effect, thereby further reducing the ability of the skin to resist the compressive load. When the compressive loads are cyclic, such as experiences by the Panel 291BL, the increased buckling, due to these varying loadings, causes working (movement) of the joint at the honeycomb-Kevlar interface. In time, this produces fatigue in the Kevlar fibres and separation between the Kevlar and the resin. This caused deterioration in the strength properties of the skin and, ultimately resulting in failure of the skin. The effect is shown, diagrammatically, in figure 2.

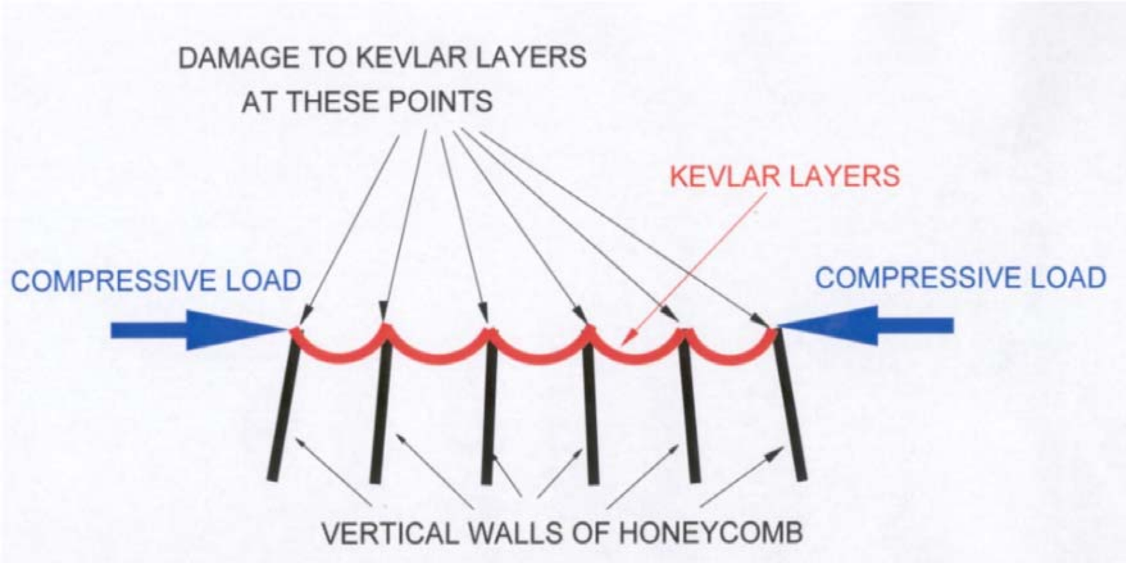


Figure 2
Showing the effect of compressive loads (exaggerated)

Resistance of Kevlar skins to telegraphing is improved by the use of an increased number of Kevlar layers. A 2 layer skin typically looses 30% of its strength due to telegraphing, 3 layers looses 20% and there is negligible loss when 5 layers are used.

It should be noted that telegraphing results in reduced load resistance to compressive loadings, when applied parallel to the laminated layers. It has negligible adverse effect when tensile loads are applied in a similar direction. This is because such tensile loads only straighten out the sagging, and do not cause any buckling effect.