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NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

A300-600R Vertical Stabilizer Structure
Design & Certification

(30 Pages)

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AIRBUS	**Technical Note**	

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Title

A300-600R Vertical Stabilizer Structure

Design & Certification Approach

Date:

Summary:

Key Words (Retrieval Terms):

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	1				

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Name: Date: Signum:					

1. General

The composite fin structure was designed for A300-A310 including A300-600R. First introduction to series took place with A310-300. Up to that time the airbus fin boxes were made of aluminium alloy.

The composite rudder used on the A300-600R was developed earlier and installed on the A310-200 and A300-600.

Aircraft type	Type Certification date	Fin Box Composite	Rudder Composite
A310-200	March11,1983	No	Yes
A300-600	March9,1984	No	Yes
A310-300	December 5, 1985	Yes	Yes
A300-600 R	March 10, 1988	Yes	Yes

In order to have full interchangeability with the existing fins the following design principles had to be met :

- The outer geometry had to be identical to the metal one.
- All interface points to the fuselage leading edge and rudder had to be identically positioned and shaped.
- The structural design had to meet the requirement that interface forces must not increase more than 5% which is within tolerance with respect to the strength of the adjoining parts.
- The use of CFRP had to result at least in the same level of safety as with metallic structure.

The design/justification approach had to run iteratively with respect to calculation, testing of elements and subcomponents.

The environmental conditions must be met as there are temperature, moisture pick up, production deficiencies, fatigue, possible defects during service.

Especially for justification the static strength, fatigue and damage tolerance could not be considered independently.

The final certification tests took account of this.

Static Strength

The proof of static strength had – as agreed with STPA (refer to STPA note 81/04 edition 2) and accepted by FAA to be demonstrated by testing representative components to ultimate load in environmental conditions adequate for checking the properties of material (temperature and humidity as appropriate) unless experience on similar structures used in similar conditions show the validity of an analysis based on specimen tests.

Under certain conditions tests could also be performed under ambient parameters. The justification methods selected by the manufacturer had to be approved by the authorities.

For the fin box components as well as for attached structure parts (rudder, leading edge, fittings etc) it was demonstrated by analysis and tests that the structure was capable to withstand 1,5 times limit loads with sufficient margins under the loading environmental and in service conditions required by / agreed with the authorities (AA).

The development of design allowables for the fin structure was extensively discussed and agreed with the AA. So were the analytical tools for the Finite Element Method analysis (FEM) as well as stability and strength analyses.

As loading conditions for the structural analysis the maximum load cases (gust, maneuvers,...) for A300-600 and A310 as well as previous A300 a/c were taken into account. FEM analysis for the fin box included the rear fuselage, the attachment fittings and a rough idealization representing the rudder stiffnesses.

Static strength analyses for all parts of the fin structure were established, the corresponding documents were presented to the AA prior to certification.

Compliance with the static strength requirements was demonstrated by a number of subcomponent tests as well as by two fullscale fin box tests which also dealt with fatigue and damage tolerance conditions/degradation prior to final testing to ultimate and rupture loads.

Fatigue life

Experience of former executed material investigations with coupon specimen has shown that composite material has a high potential with respect to fatigue. This is valid for in plane loading but a reduction was observed in out of plane loading.

So the behaviour of real structural elements was of higher interest. Selected element and subcomponent residual strength test were carried out following fatigue cycling.

For the full scale test a fatigue program was established.
The program was based on A310-300 load spectrum and 40000 specified flights.
The gust and lateral maneuver cases are the main fatigue load cases for the vertical stabilizer.

The fatigue loads were considered for 8 flight types, 6 for normal operation flights and 2 for crew training flights which are the severe ones according to loads.

The gust and maneuver continuous spectra were transformed into stepped load spectra which simplified further application analysing and testing the structure.

For the test program during one life 176 960 lateral gust load cycles and the same number maneuver load cycles were applied.
Temperature influenced load cycling due to flight conditions (ground to air) were realized.

As a conservative approach the original load spectrum was increased by 15%.

The influence of temperature cycling on fatigue life was found to be negligible by coupon testing.

Damage Tolerance

In agreement with the AA (LBA, STPA) MBB choose to justify the CFRP fin structure in accordance with the damage tolerance requirements, not by fatigue (safe-life) approach, though for fatigue degradation of the full scale specimen 3 times the service life goal of 40 000 flights, even with an enhancement factor of 1.15 on the fatigue loading spectra were applied.

The damage tolerance justification by analysis and test had to be performed for structure with certain extents of defects identified but not repaired or those likely to occur in areas not easily inspectable in operation.

Appropriate conditions of degradation due to fatigue, structural deficiencies, environmental effects (moisture content, temperatures, etc.) had to be applied.

These conditions have been presented to the AA and were agreed in the course of the certification.

At the end of this chapter the damage tolerance concept is summarized.

The initial size of defects to be considered depends on the means of inspection used and their reliability.

For immediately detectable damages (i.e. uncontained engine failures, bird strike, hail stones ....) the loads to be considered for the residual strength demonstration were those expected during the completion of the flight (FAR 25-571).

Types and extend of damage to be considered were related to the properties of composite materials, delaminations, porosity, ruptures, considering previous experience, ageing tests and manufacturing controls, The evaluation is done by analysis based on component or coupon tests and by experience.

The damage tolerance is demonstrated for various types of defect/damage and for agreed conditions.

The following types of defect/damage had to be considered :

Manufacturing defects

Manufacturing defects are porosities, flaws, voids and also delaminations caused by impact during manufacturing or assembly.

Small defects which do not decrease the structural strength below ultimate load will not be repaired and not inspected during service inspections. Test experience has shown that such defects do not propagate by fatigue cycling even when the fatigue loads during the test are increased for safety.

Defects and delaminations which are detected by squirter inspection and showing an extension above a tolerable size will be repaired before the aircraft goes into service.

The following in-service damages are assumed:

- Large skin/stringer delaminations for two adjacent stringers with two different rib bays
- Debonding of reinforcement frames at rear spar access holes

For these damages the damage tolerance was demonstrated in the large component test '2nd full scale fin box'.

Discrete source damage

The most severe type of accidental damages given in JAR 25.571 d are bird impact, APU fan blade impact and lightning strike damage. In addition low energy impact cases occurring while the aircraft is staying on ground were considered in the damage tolerance evaluation.

Environmental parameters

Environmental tests with aggressive fluids (Skydrol, fuel, de-icing products ...) performed on coupons or composite structures have not shown a particular sensitivity to products used on aircraft servicing.

Environmental tests have shown that moisture in laminate combined with a raised temperature is the major factor, influencing the static strength and stiffness and that no other product in use has a worse effect.

Humidity is absorbed by the resin even through the paint system, which may reduce the strength and stiffness of the composite.
The effects are taken into account for static strength demonstration.

For damage tolerance validation the following combinations of damage, environmental conditions and loads were defined for all kinds of tests :

I For damages and defects of allowable size not detected or repaired :

-- ultimate loads, under hot/wet conditions --

II For damages and defects to be detected by periodical inspections (1c ; 4c intervals) and repaired prior to the next flight.

-- Residual strength loads based on the likelihood --
-- of flight in this condition, i.e. the frequency --
-- of the inspection able to detect the damage. --
-- These residual strength loads are equal or above --
-- limit loads, under hot/wet conditions. --

III For obviously detectable damages (discrete source)

-- 'get home flight loads' under ambient conditions --

These accidental impacts cause different damages with individual impact marks on the composite surface.

The impact marks on the surface are defined as follows :

I <u>NON VISIBLE IMPACT DAMAGE</u>

The impact damage can be detected only by non destructive testing.

II <u>VISIBLE IMPACT DAMAGE</u>

The impact damage can be detected by visual inspection during 1c or 4c inspection.

III <u>OBVIOUSLY VISIBLE IMPACT DAMAGE (discrete source)</u>

The impact damage can be detected by walk-around inspection.

For the CFRP fin box of the A310-300 the following philosophy for the damage tolerance evaluation of defects/damages is established :

I <u>NON VISIBLE DEFECTS/DAMAGES</u>

Must not lead to degradation below 'design ultimate' level. The effects of such damages and of adverse environmental conditions are accounted for in designing the undamaged structure to 20% above ultimate loads.
This 20% margin being shown adequate by component and element tests.

II <u>VISIBLE DEFECTS/DAMAGES</u>

Must not lead to degradation below 'limit load' level
('limit load or more') .

III OBVIOUSLY VISIBLE DAMAGE

Must not lead to degradation below 'get-home load' level.

Tests with impacted specimens

1. Subcomponent test 'CFRP fin for assembly demonstration'.
   Investigated were the visible impact marks and the real delamination size depending on the parameters impact energy, impactor radii, laminate thickness, design configuration (midbay, skin over stringer) and material (Hexcel F550 or CIBA 913C).
   The impacts were introduced to the lateral panels, spar plates and some web ribs of the 1st full scale fin box before assembly.

2. Element tests on stiffened panels investigating the degradation effect of delamination size for midbay impact and impact on skin over stringer.The tests were performed with compression/shear strength test components conforming to the agreed DA standard for this kind of development test with shell panels of the A 310-300 fin box design. Hot/wet conditions were considered.

3. Component tests '1st full scale fin box' investigating the static strength of impacts in a whole component.

4. Component test '2nd full scale fin box' investigating the fatigue behaviour, static strength and damage tolerance resistance of impacts in a whole component. The impacts were introduced to the lateral panels and spar plates and some web ribs of the 2nd full scale fin box before assembly.

High energy damages may occur by

- bird strike
- APU-rotor failure
- Lightning strike

Justifications of these cases are summarized in the following.

Deformation measurements

Comparison test/calculation is given for the span wise deflection of the fin box at the front spar position.

The calculated values were found as the lower ones. Max. difference found for the maneuver case was 10%.

The influence of temperature on deflection is shown. The elevated test temperature of 70° C revealed an increase of the deflection up to 10% versus ambient temperature test. Max. tip deflection was found to be 295 mm at 1.6 x limit gust load and 70°C test temperature.

No permanent deformations were found after load relief.

Strain measurements

A summary is given on the strain measurements carried out for maneuver and gust case at load step j = 1.5 (ultimate load).

These values are given for the test condition ambient temperature which are very tight to those measured at +70°C test condition.

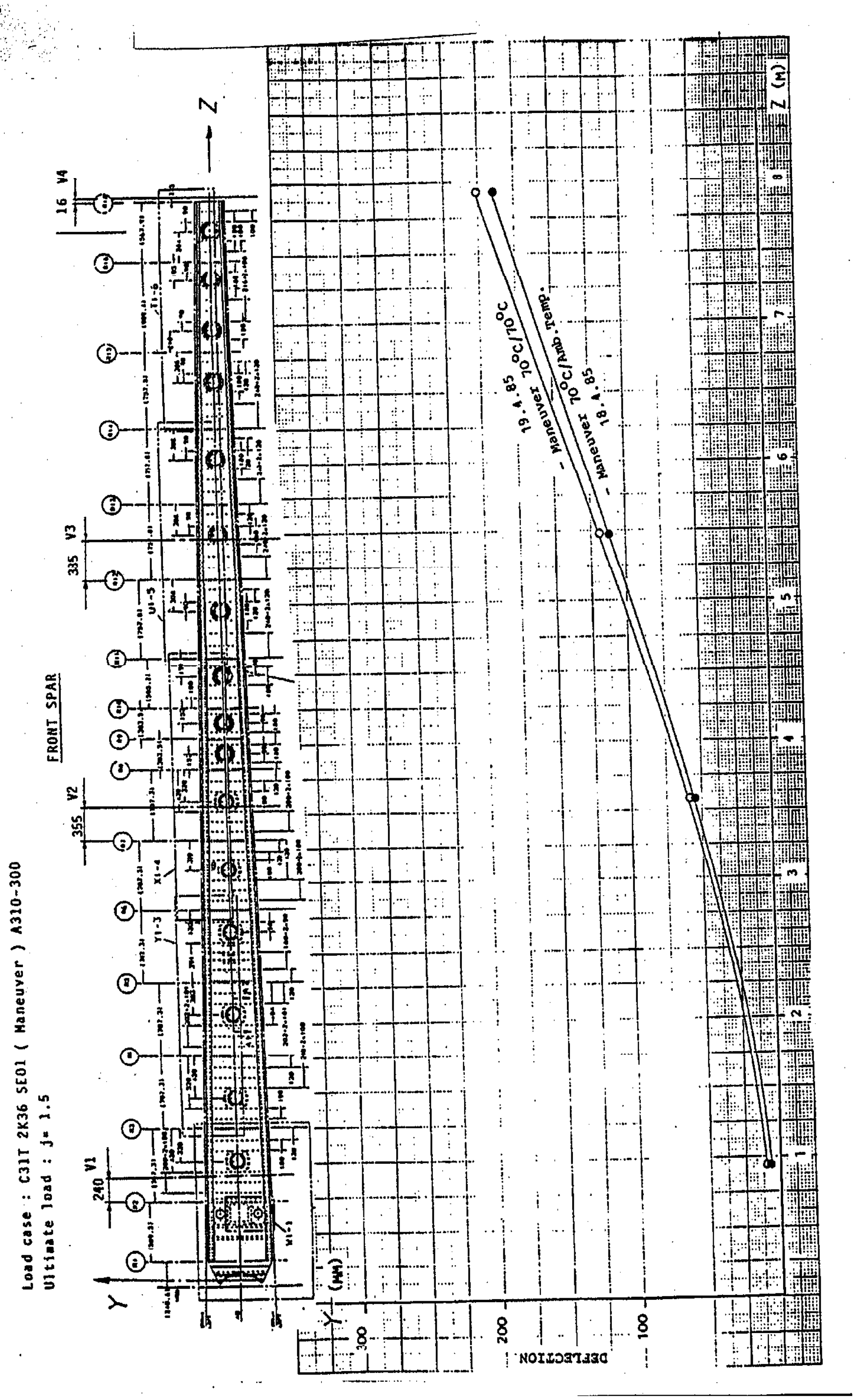
DEFLECTION COMPARISON

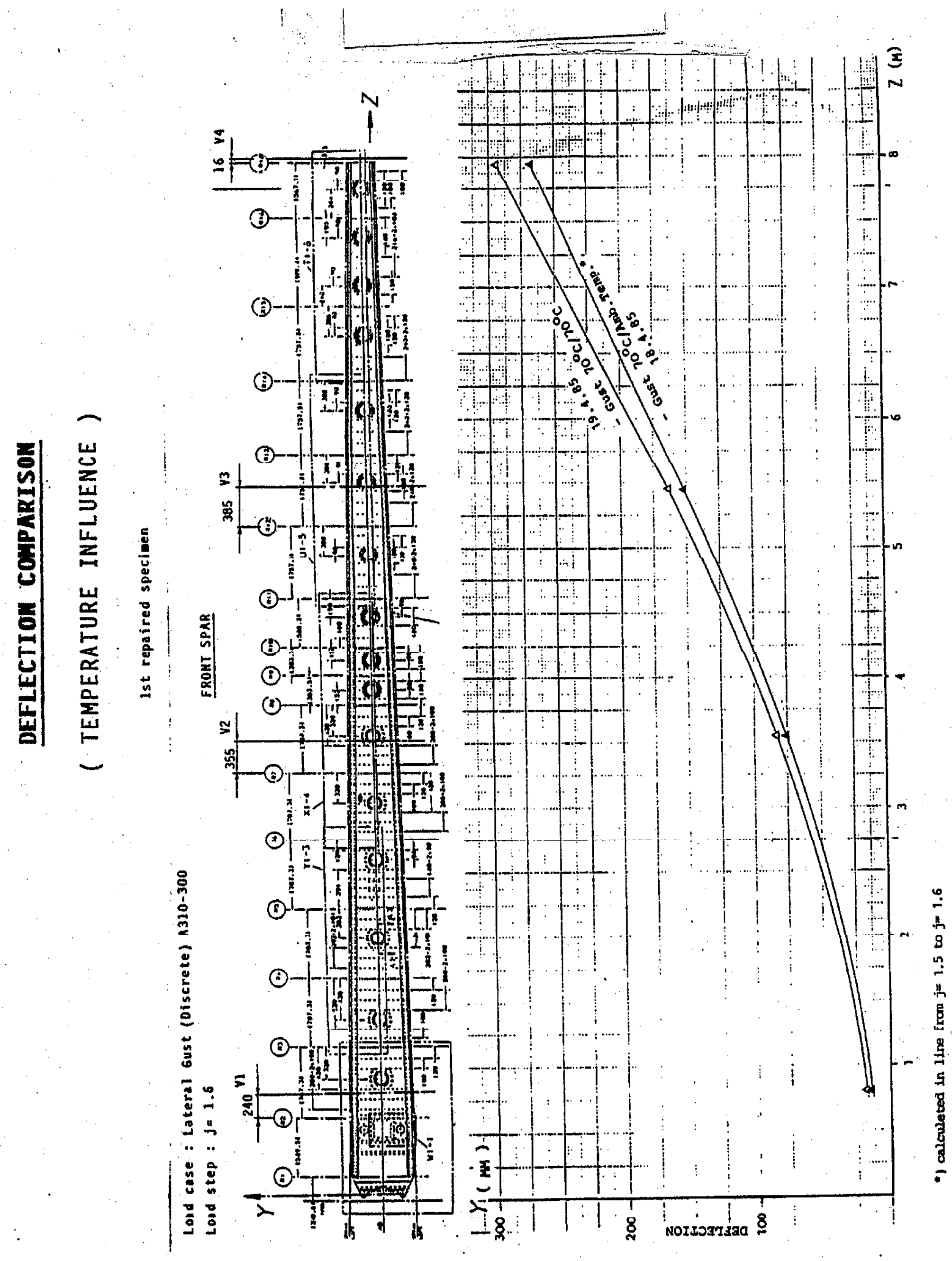
(TEMPERATURE INFLUENCE)

1st repaired specimen

Load case : C31T 2K36 SE01 (Maneuver) A310-300

Ultimate load : j= 1.5




DEFLECTION COMPARISON
(TEMPERATURE INFLUENCE)
1st repaired specimen
Load case : Lateral Gust (Discrete) A310-300
Load step : j= 1.6
FRONT SPAR
240 V1
355 V2
385 V3
16 V4
Y
Z
Y (MM)
DEFLECTION
300
200
100
Z (M)
1
2
3
4
5
6
7
8
– 19.4.85 Gust 70°C/70°C
– Gust 20°C/Amb.-Temp.* 18.4.85
*) calculated in line from j= 1.5 to j= 1.6

The following ultimate strains were measured :

- Framework ribs ? ? 1800 ? m / m
- Main ribs ? ? 3500 ? m / m (corner of a access hole)
- Spars ? ? 2100 ? m / m (corner of a cutout)
- Panels ? ? 2400 ? m / m

All measured strains are well below the design level. Measured and calculated strain distribution over the panels are in satisfying accordance on the unrepaired right hand panel made of the material Hexcel F 550.
On the left hand panel above the panel repair a strain increase due to repair can be observed.

Comparison of the target and actual actio and reactio forces for the justification test (j = 1.6 (1.5) x limit load

A target-actual comparison of the cylinder loads and of the reaction forces showed an acceptable agreement for the full scale certification test.
Plus/minus differences from the target values are system conditioned and in fungible limits in the load range.
Differences appear over proportional as percentage in lower forces.

A comparison of the sum of the specimen-loads shows no unacceptable differences.

A comparison of the resultant bearing forces shows prevalent slight positive differences.

Summary

The ultimate strength demonstration is carried out with a repaired vertical-stabilizer at 70°C test temperature up to J = 1.6 x limit load). Signs of damage were not observed in spite of relative high local strains.

Crackl noises were not audible during load application to the test specimen. Also sound emission measurements showed no indication for damage propagation.

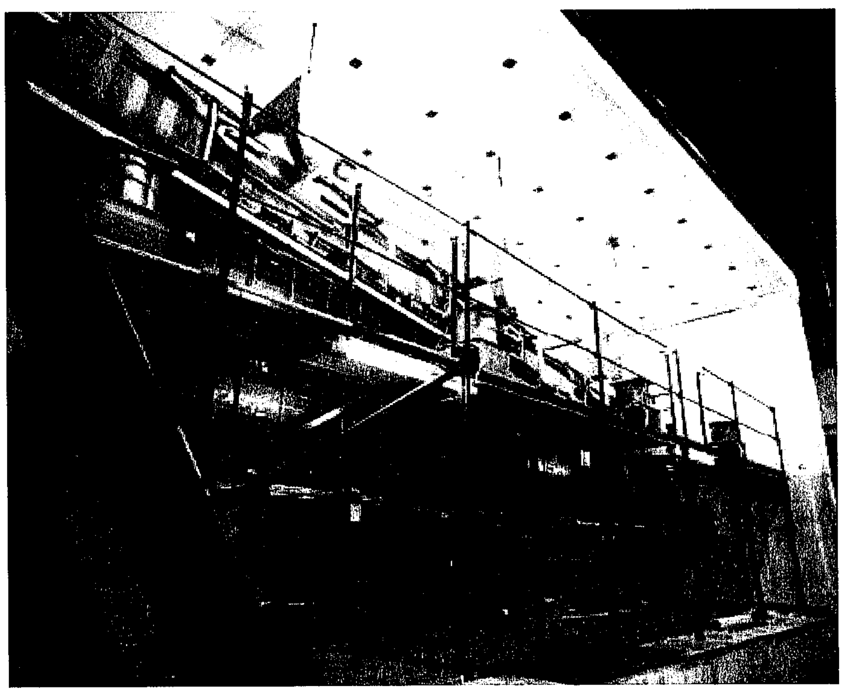
The original test program had to be repeated with the 2nd full scale specimen because of the missing environmental and mechanical ageing.

Full scale certification test

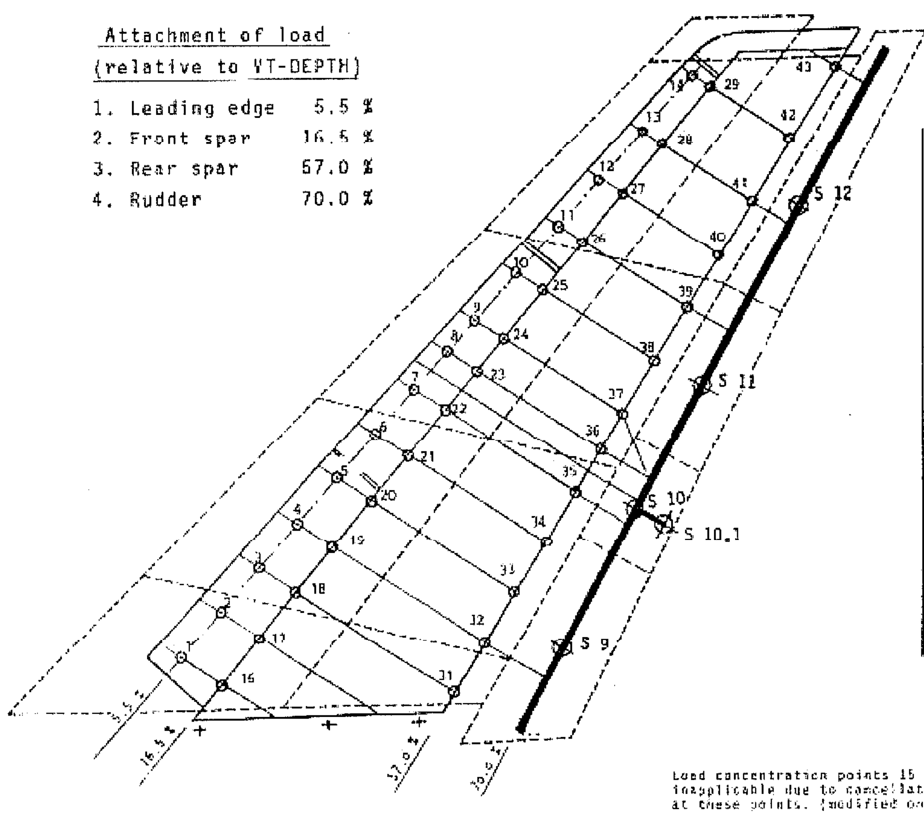
General

Because of an accidental fracture at the first specimen due to valve malfunction in the hydraulic test system, a new production fin box was prepared for testing in the already existing test rig. Only minor modifications were necessary to run the test. As for the first specimen the aim of this test was to demonstrate static strength, fatigue and damage tolerance for the new and aged structure. Severe climatic conditions had to be taken into account.

The aging had to include effects of fatigue, moisture pick up and the degradations that might occur during the life time. The test was carried out in a climate chamber.



In addition of gust and maneuver loads the test program took care of the differences of temperature expansion coefficients of aluminium fuselage and CFRP fin box resulting in forces in the root area.
The resulting root loads were taken from the FEM calculation.
For damage tolerance justification impacts, artificial delaminations and saw cuts were applied.



LOAD CONCENTRATION POINTS ON FIN AND RUDDER

Fig.: 8.29

Static load

The strength demonstration test on the CFRP vertical stabilizer was conducted similar to that on the A300 aluminium stabilizer with gust load (discrete) for A310-300 and maneuver load C31T 2K36 SE01 for A310-300.

Fatigue loads

Fatigue test program for the A310 CFRP vertical stabilizer was based on the EF/rear fuselage test program and included type, size and sequence of loads per flight and life. The influence of changes in temperature had also been taken into account for the first time as an additional load. The life of an aircraft corresponds to 40 000 flights = 353, 920 load cycles in test. Reference to the chapter Fatigue Life.

The demonstration was scheduled to cover 3 lives, the last one being the damage propagation test on natural and artificial damages.

Damage-Tolerance-Demonstration

The concept "Damage Tolerance" included all admitted damages visible and invisible that reduced the strength of the structure. Reference is made to the chapter damage tolerance.

Scheduled test program (tests sequence)

The following procedure was agreed, in case of deviations during test run, agreement with authorities had to be reached.

- Basic inspections, documentation of particular occurrences by sketches, photos and NTD reports.
- Functional test of all load and measuring equipment at ambient temperature and + 70° C.
- Check on temperature distribution.
- Loading the structure to a maximum of j = 0.4
- 1st analysis of strain gauge measurements, replace strain gauges, if required.
- Loading the structure at ambient temperature to j = 0.8 in steps of 20% on both sides with measurements of stress and deformation (basic measurements).

  Load : gust and maneuver
- Loading the structure at + 70°C to j = 0.8 in steps of 20% on both sides with stress and deformation measurements.
- Analysis of stress measurements and observations.

- Determination of actual moisture content of the structure from component traveller specimens. Differences of different material behaviour Hexcel/Ciba to be considered.

- Moistening of the structure and periodic control of moisture pick up to a value of the standard specimens of > 0.5 % by weight moisture content.

- Demonstration of fatigue strength and damage tolerance at ambient temperature with wet structure (2 lives).

- 2nd inspection after 40 000 flights with special check on artificial and natural damages.

- Check on moisture content of the structure, moistening, if required (i.e.) interruption of mechanical ageing).

- Continue (2nd life at ambient temperature).

- 3rd inspection after 80 000 flights (as 1st inspection)

- Moistening to 0.85 – 0.9 % by weight moisture content in standard specimens (Hexcel 550) This value corresponds to 1.2 % by weight moisture content for Ciba-913.

- Ultimate load : gust and manoeuvre (1.5 x limit load) under worst ambient conditions (0.85 – 0.9 % by weight moisture content, 70° C) Measurements of strains, deformation and acoustic emission. The load had to be increased from j = 1.0 to j = 1.5 in 10% steps with brief pauses for measuring. The min. pause at ultimate load is 3 seconds.

  Decrease load immediately afterwards. If there were any indications of premature fracture the test had to be stopped. (The presence of certification authorities and those responsible for the demonstration was required).

- 4th inspection, check on damage propagation, repair if necessary and continuation of mechanical ageing (3rd life).

- Demonstration of damage tolerance at ambient condition the maximum extent of damage which does not exceed the critical propagation rate during one inspection period.

  ?? Note : Inspection of critical damages had to be performed continuously and the propagation had to be controlled so that the structure remained functional.

- 5^{th} inspection after 100 000 flights (same inspection procedure as for the 2^{nd} and 3^{rd} inspections).

- Continuation of fatigue cycling to 120 000 flights.

- 6^{th} inspection after 120 000 flights (same inspection procedure as for the 2^{nd} and 4^{th} inspections).

Damage Tolerance Demonstration (severe damages) following ultimate load

- Debonding of 2 modules (stringer debonding) fatigue testing 1 life and lmit loads.

- Damage due to lightning strike. Get home loads

- Effect of APU rotor blade separation on fin structure. Get home loads

- Rupture test with repaired test specimen.

Realized Test Performance

Progress of Test Run (generally)

After delivery of the test piece for testing on 04.04.85, the remaining strain gauges were applied, accessible from the outside, prior to assembly in the test rig and the impacts were applied to the side shell sections, front and rear spar.

Starting with a basic inspection (visual, ultra-sonic manual tap test, ultra-sonic autos can), static loads:

? maneuver j = 0,8

? gust j = 0,8

were applied on 18.06.85 at ambient temperature (+20°) to determined the distribution of stresses in the test specimen and to check the load application and weight compensation according to program.

CFRP-FIN BOX 2

STATIC LOAD-PROGRAM (Flight-No. 0)

Program-No	Load-Typ-	Load-Steps (j=1,0):	Measurements: DMS	Def	Loads	AE	Remarks:	Date
2.0	BASE MEASUREMENT	0					DMS: Strain Gauges; Def: Deformations; Loads; AE: Acustic Emission; AT: Ambient Temperature	14.6.85
2.1	ONLY FUSELAGE +70°C/AT	0 0,2 0,4 0,6 0,8 1,0 / 0 0,2 0,4 0,6 0,8	X	X	X			17.6.85
2.2	ONLY FUSELAGE -50°C/AT	0 0,2 0,4 0,6 0,8 1,0 / 0 0,2 0,4 0,6 0,8	X	X	X			17.6.85
2.3.1.1	+MANEUVER +70°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X			18.6.85
2.3.1.2	-MANEUVER +70°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X		max Def of Rib 18 FS 107mm	18.6.85
2.3.2.1	+MANEUVER -50°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X		-"- 109mm	18.6.85
2.3.2.2	-MANEUVER -50°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X			18.6.85
2.3.3.1	+GUST +70°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X		max. Def. of Rib 18 FS: 142 mm	18.6.85
2.3.3.2	-GUST +70°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X			18.6.85
2.3.4.1	+GUST -50°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X		max. Def of Rib 18 FS 100mm	18.6.85
2.3.4.2	-GUST -50°C/AT	0 0,2 0,4 0,6 0,8 / 0 0,2 0,4 0,6	X	X	X			18.6.85

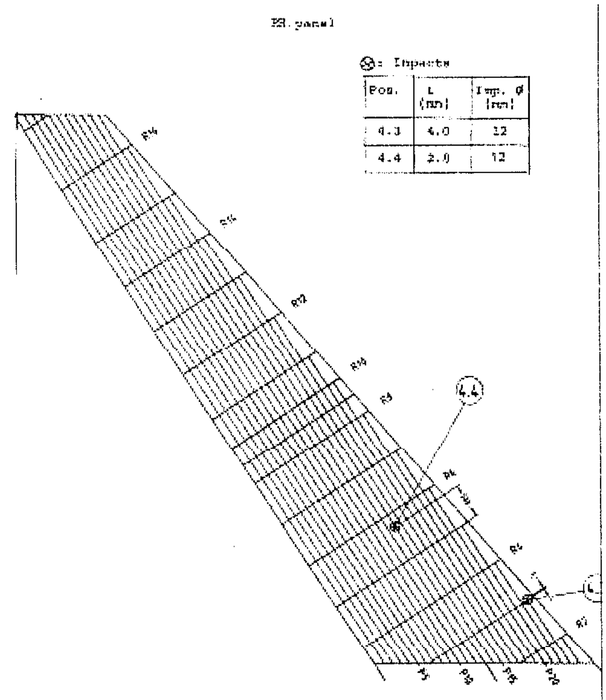
The stress values and corresponding load values are recorded on data storage media.

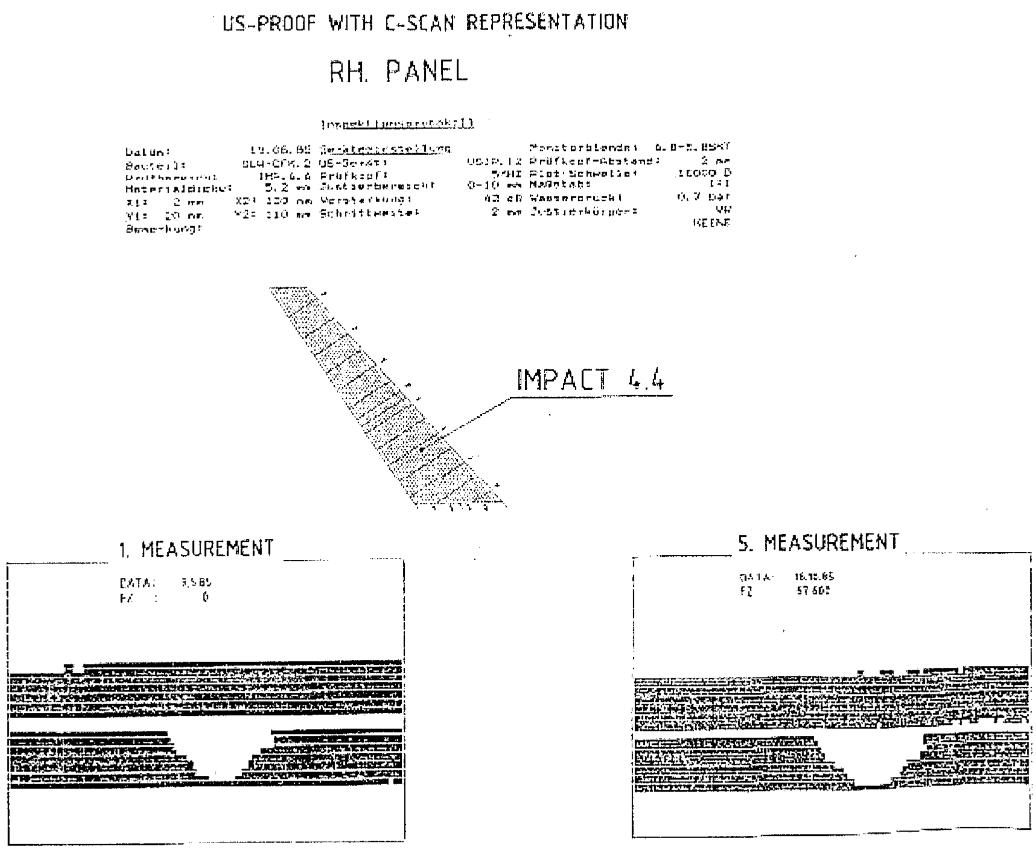
After a subsequent inspection which showed no sign of change in the test-specimen, the climatic chamber was closed and the test-specimen was conditioned at average climatic conditions of +48°C / 96% relative humidity

During the elapsed period all accessible areas such as skin panels, spars, ribs 1 to 6 and fuselage joints were visually inspected every day; in addition, repairs and impacts were checked in intervals of approx. 2,000 flights by ultra-sonic manual procedures.

As from 05.09.85 after performance of the static tests and inspections, conditioning of the test-piece was resumed at an ambient temperature of +45 °C / 90 % relative humidity and at the same time, the fatigue test was continued, to inspection intervals and inspection areas, until the preparation deadline for maximum load cases j = 1.5.

At flight status fl 67,600 the test and conditioning were stopped and a general inspection was made of all accessible areas, other and especially impacted areas were tested by ultra sonic.





As can be seen at impact no. 4.4 (example) there were no signs of change in the test-specimen and so it could be prepared for testing up to ultimate load. Similarly, all safety devices in the load apparatus were adjusted to the anticipated forces and courses of travel.

On October 26th, 1986, 24 hours prior to the ultimate load test, the climatic chamber was brought up to +72 °C / 95 % relative humidity so that the test-specimen temperature was approx. 70 °C continuously at the time of loading (the 11 temperature test points indicated a temperature distribution of +66.4 to 71.4 °C).

The certification static tests for critical load cases under worst environmental conditions were carried out at September 27th, 1985.

CFRP-FIN BOX 2

STATIC LOAD-PROGRAM (Flight-No: 67600)

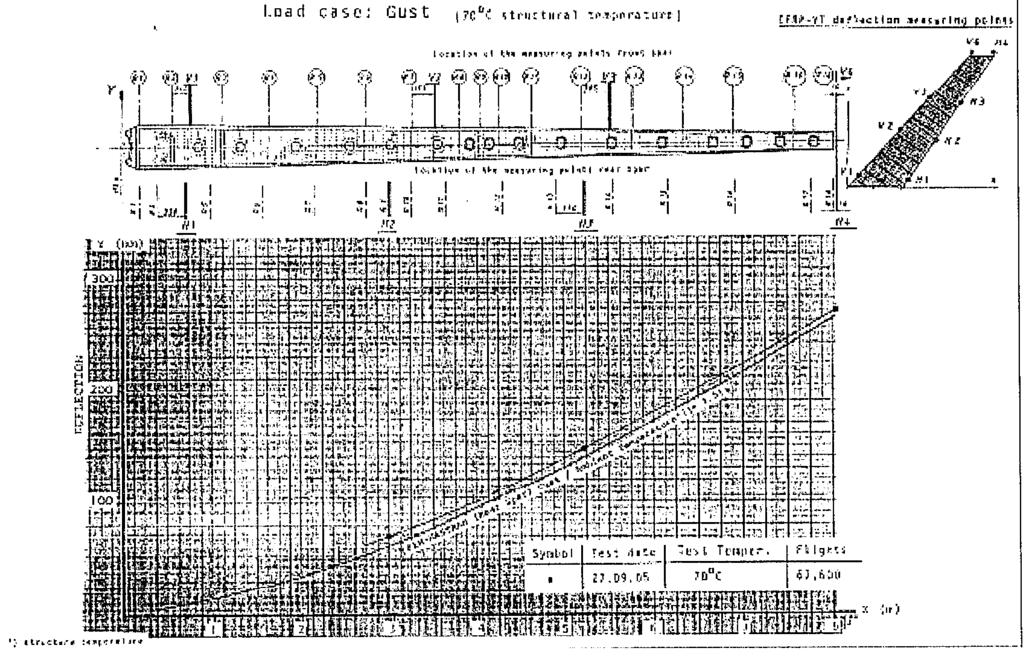
Program-No	Load-Typ:		Load-Steps [j=1,0]	Measurements: DMS	Def	Loads	AE	Remarks. DMS: Strain Gages; AE: Acustic Emission; Def: Deformations; Loads	Date
3.3.2	-MANEUVER	+70°C/+70°C	0 0,2 0,4 0,6 0,8 1,0 1,3 1,5 / 0 0,2 0,4 0,6 0,8 1,0 1,3	X	X	X	X	max. Def. of Rib 18 FS 197mm	27.9.85
3.4.1 a	+GUST	+70°C/+70°C	0 0,2 0,4 0,6 0,8 1,0 / 0	X	X	X	X	shut down caused by security limitswitch	27.9.85
3.4.1 b	+GUST	+70°C/+70°C	0 0,2 0,4 0,6 0,8 1,0 1,3 / 0	X	X	X	X	-"-	27.9.85
3.4.2 a	+GUST	+70°C/+70°C	0 0,2 0,4 0,6 0,8 1,0 / 0	X	X	X	X	-"-	27.9.85
3.4.1 c	+GUST	+70°C/+70°C	0 0,2 0,4 0,6 0,8 1,0 / 0	X	X	X	X	-"-	27.9.85
3.4.1 d	+GUST	+70°C/+70°C	0 0,2 0,4 0,6 0,8 1,0 1,3 1,5 / 0 0,2 0,4 0,6 0,8 1,0 1,3	X	X	X	X	max. Def. of Rib 18 FS: ~264 mm	27.9.85
3.4.2 b	-GUST	+70°C/+70°C	0 0,2 0,4 0,6 0,8 1,0 1,3 1,5 / 0 0,2 0,4 0,6 0,8 1,0 1,3	X	X	X	X	max. Def. of Rib 18 FS: ~265 mm	27.9.85

TARGET-ACTUAL-COMPARISON

(at ultimate load)

Deflection of the rear spar

Load case: Gust (70°C structural temperature*)



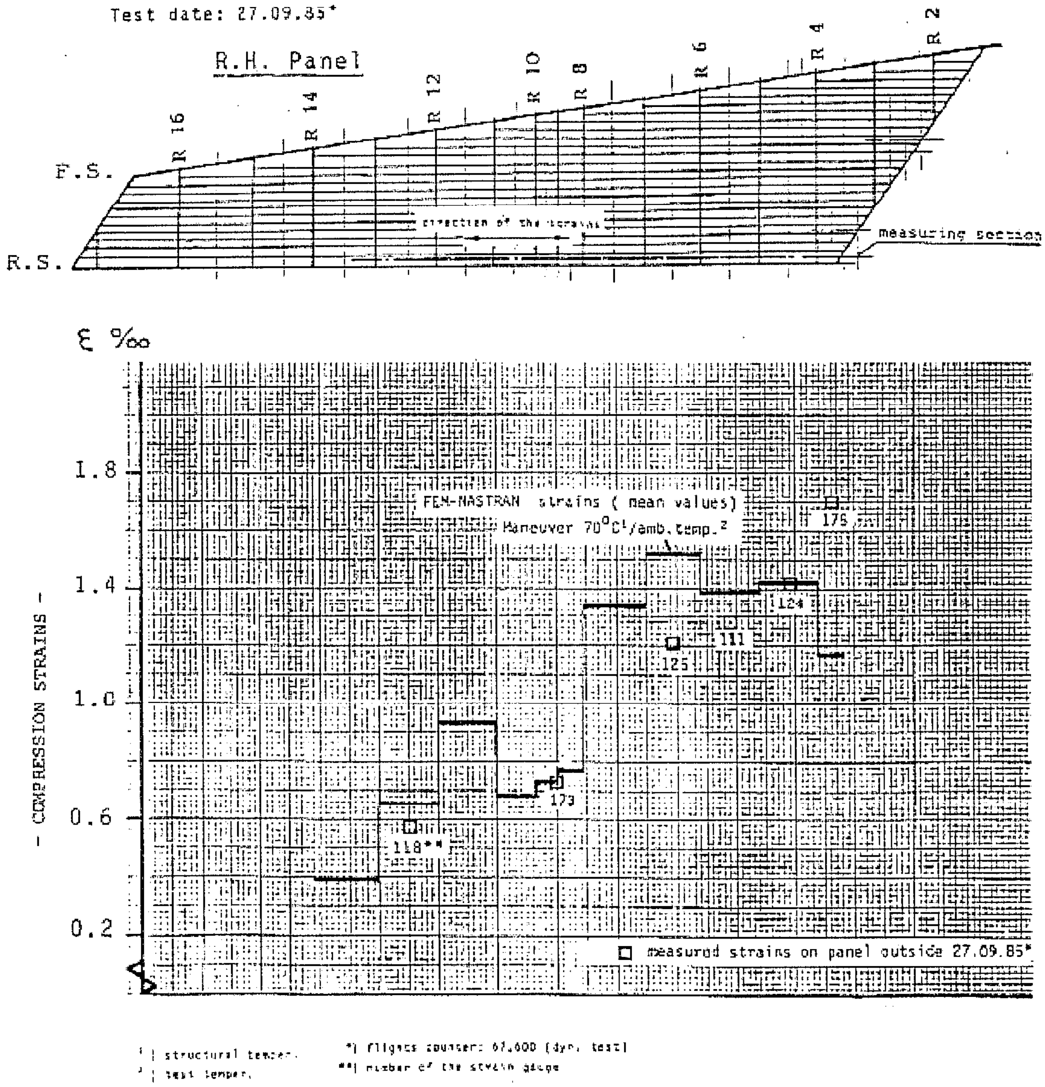
*) structure temperature

The span wise measured fin deflection was found slightly higher than calculated

TARGET-ACTUAL-COMPARISON

Strains in the rear spar level
(at ultimat load)

Load case: negative Maneuvrer 70°C¹/70°C²
Test date: 27.09.85*



As by calculation predicted, after 67 600 life cycles acceptable strain level was measured at ultimate load.

	Ausgabe	1			
	Datum Bearbeitet Geprüft	.02 Name			24

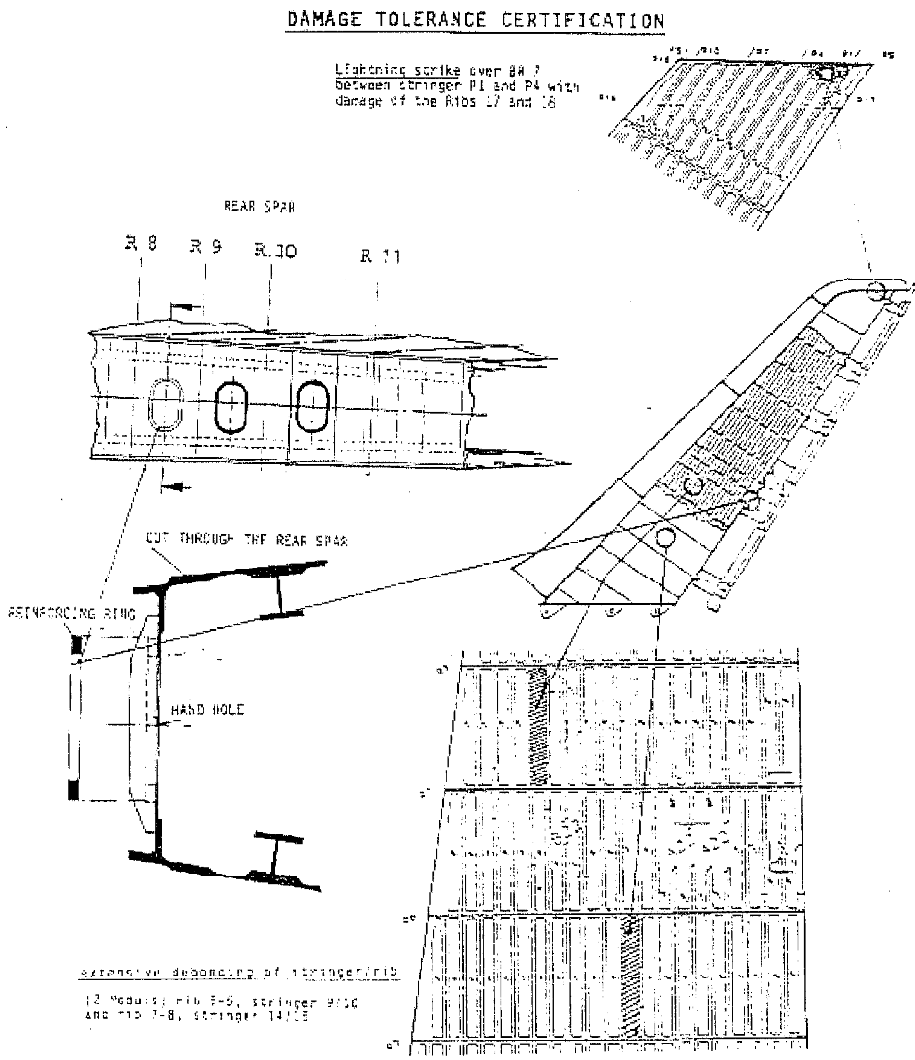
The maximum loads were reached without evident damage to the test-specimen at:

? maneuver 1.5 x L.L. +70 °C (structure temperature)

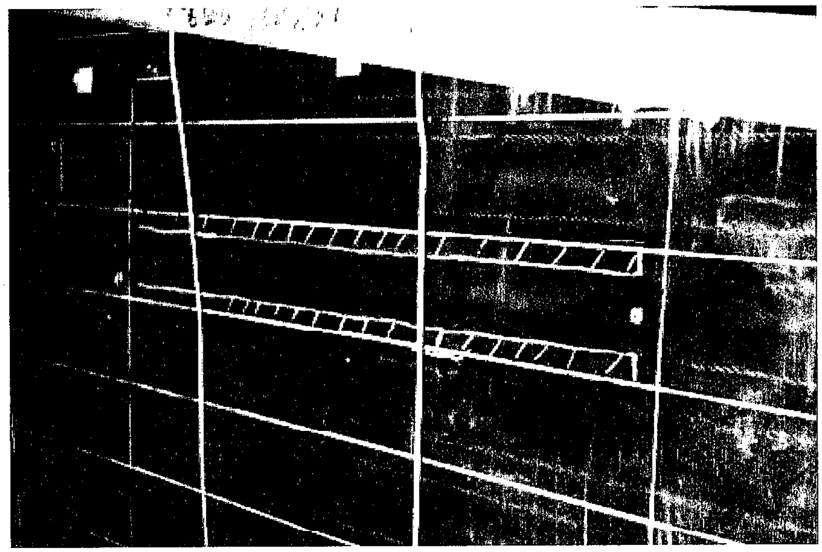
? gust 1.5 x L.L. +70 °C (structure temperature)

At no point in time the acoustic emission readings taken during the test procedure had results that could have indicated a possible period of fracture.
Intensive visual and NDT inspection showed no evidence of propagation of existing artificial damages nor of any new criteria.

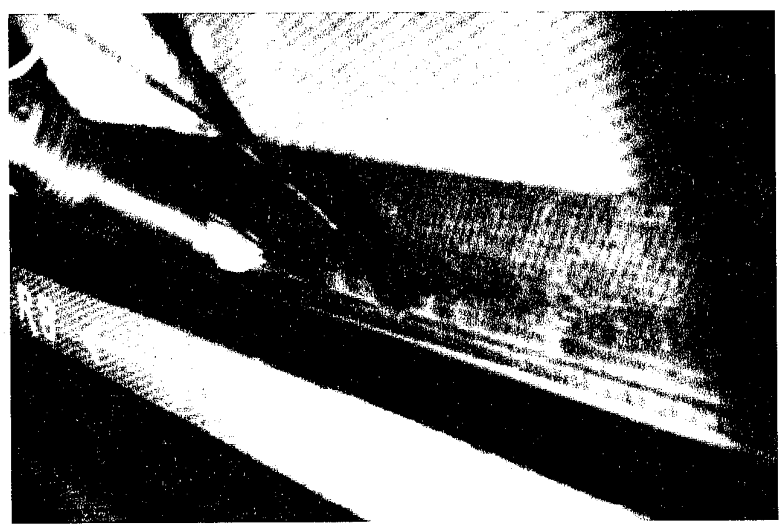
Severe damages



As a verification of the **damage tolerance**, artificial delaminations were produced between stringers and skin panel in the areas R 5/6 – P 9/10 and R 7/8 – P14/15 in the LH panel, and the inspection hole stiffener between R 9/10 was removed



ARTIFICIAL DELAMINATION OF THE STRINGERS SIGNED AT OUTER SKIN



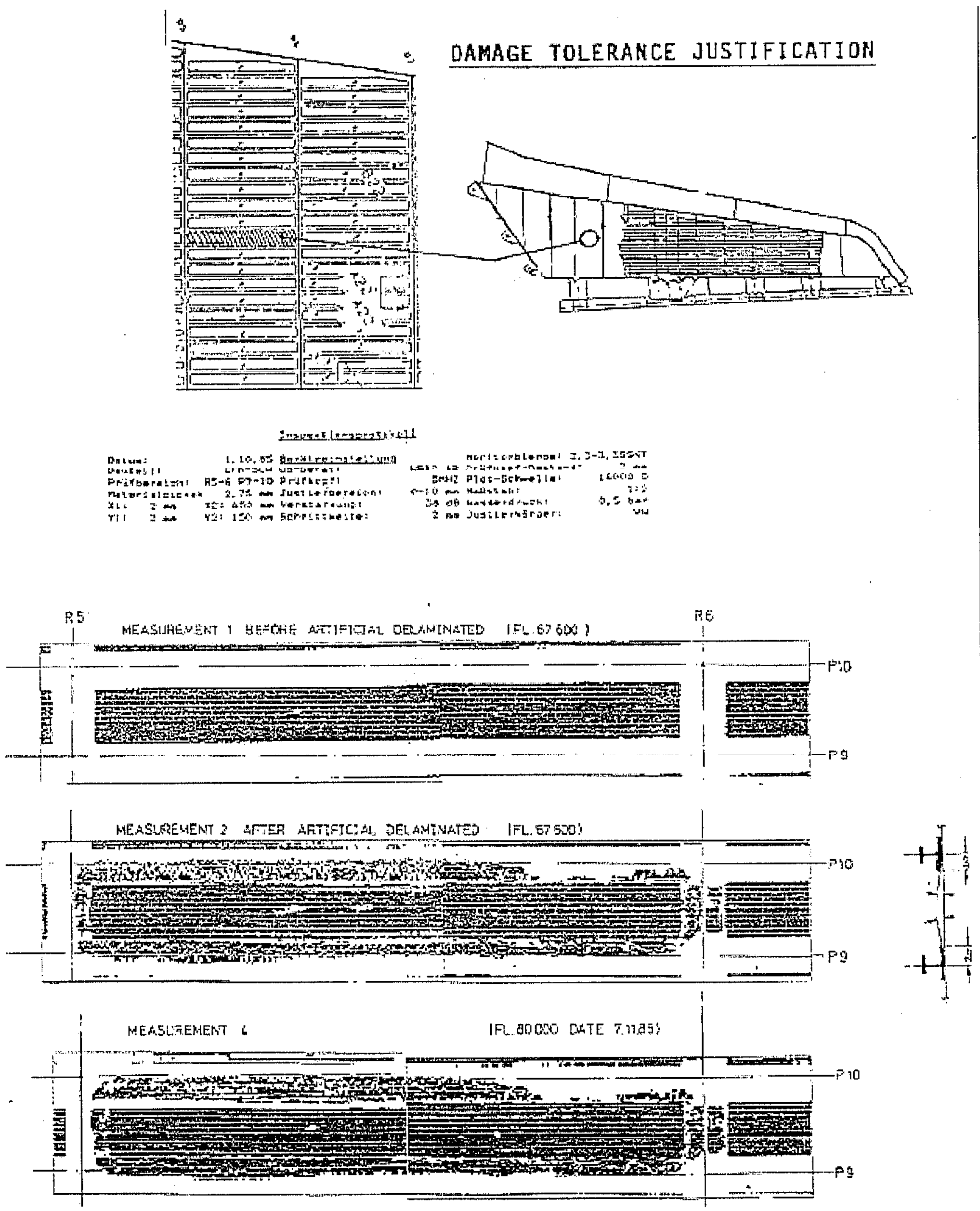
PEELING OF STRINGER BY TOOLS

The static test:

? maneuver 1.0 x L.L.

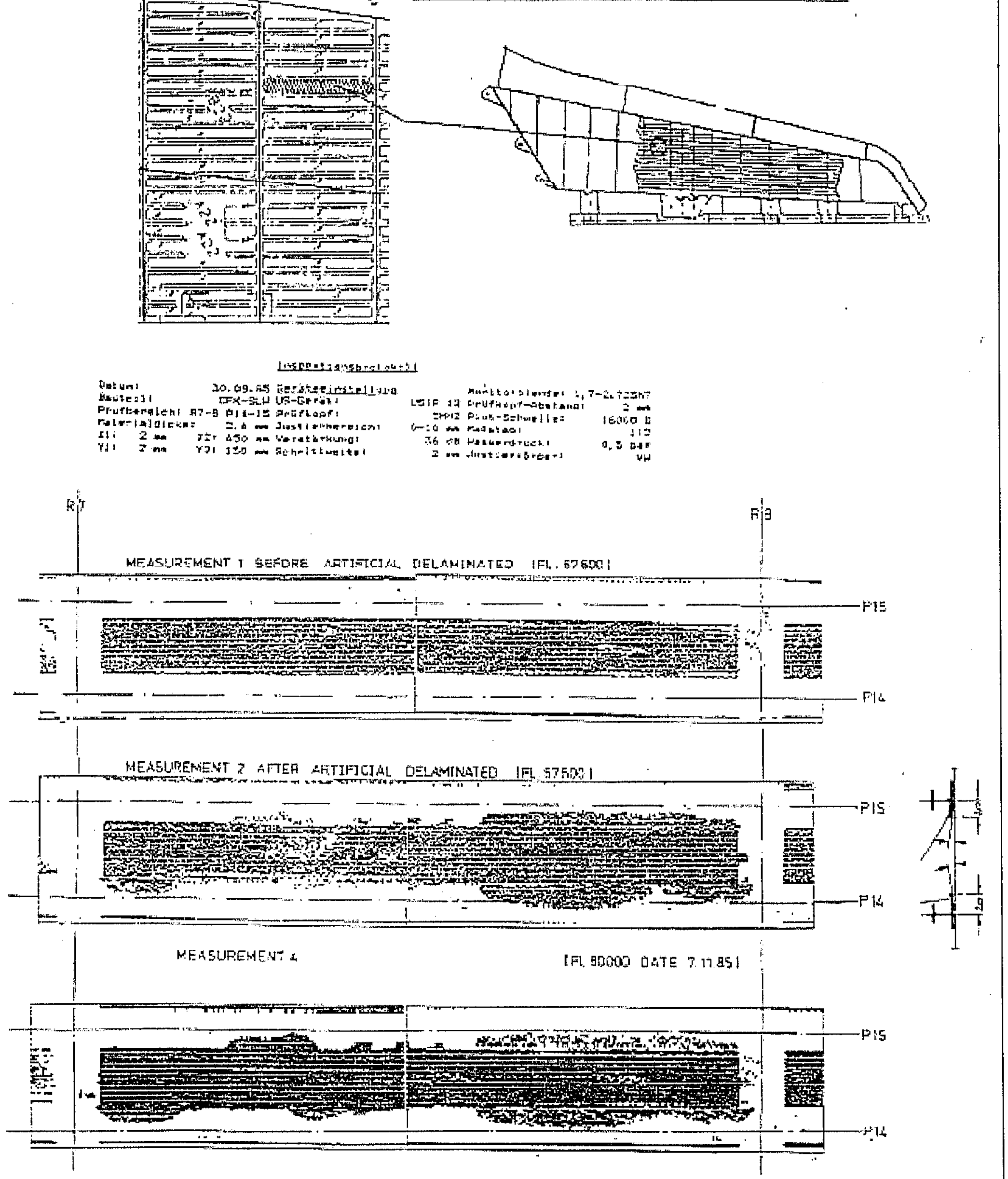
? gust 1.0 x L.L.

was performed on 07.10.85 at a chamber temperature of +70 °C.



NO DAMAGE GROWTH AFTER TEST AND ADDITIONAL 12 400 FLIGHTS

DAMAGE TOLERANCE JUSTIFICATION



NO DAMAGE GROWTH AFTER TEST AND ADDITIONAL 12 400 FLIGHTS

In addition, on 11.10.85 static load was applied with lightning strike damage in the area of R 17 / 18 at ambient temperature (+19 °C)as follows:

? maneuver 0.8 x L.L.

? gust 0.4 x L.L.

as Get Home Loads (FAA requirement)

The data obtained from these tests showed no evident signs of a change in behaviour of the test-specimen. In order to prevent the possibility of uncontrolled damage propagation, the delaminated areas were provided with stop rivets at an appropriate distance to the area limits. These however, permitted unrestricted propagation up to these fixed points. All these damages did not propagate due to the test loading.

All other damage areas retained their original form for the continued fatigue test.

The test target of **120 000 flights was reached on 15.02.86.** After inspection preparations were made to produce simulated rotor damage (diagonal cut of approx 350mm long in RS –P3 area between R 11-12).

The relevant static tests were performed on 07.03.86 at ambient temperature 20°C, as follows:

? maneuver 0,8 x L.L.

? gust 0,4 x L.L.

as Get Home Loads

The behaviour of the test specimen showed no signs of change.

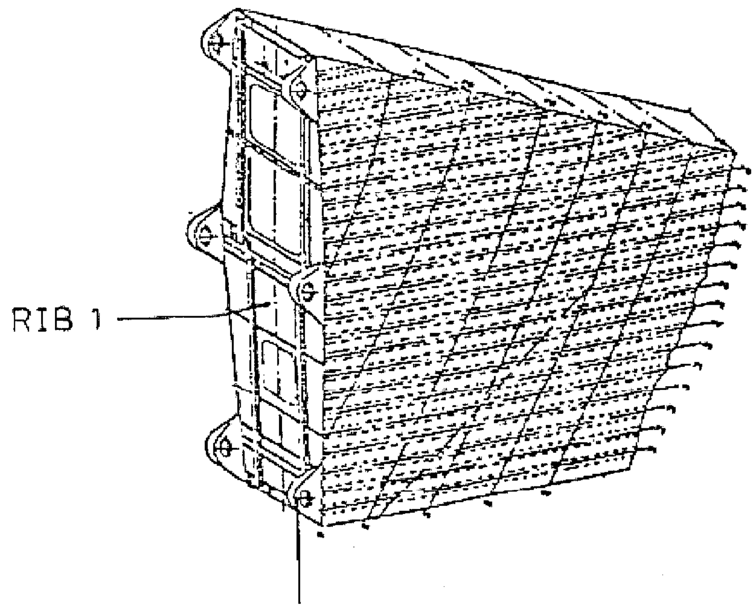
Prior to the rupture test, the damage areas – lightning strike, rotor damage and missing access hole reinforced (RS) were repaired.

The test specimen was then conditioned at +50 °C / 95 % relative humidity, as far as was possible given the preparations for the rupture test, such as adjustment of safety limits, installation of monitoring cameras etc.

On 15.04.86 an equipment test was performed at 95 % relative humidity / +50 °C with a special load test (gust load to L.L.) to check all setting, loading, monitoring and measuring equipment.

The rupture test was performed in the presence of representatives of Airbus Industrie and the LBA on April 17th, 1986.

The test specimen was subjected to gust load at structure temperature of +70 °C.



The rear left main fitting failed at 1,905 x limit load, the subsequent inspections of all accessible areas showed damage in the form of delamination and buckling in rib 1.