BIRD IMPACT RESISTANCE OF THE SMALL TRANSPORT AIRCRAFT

Experience Gathered from Tests and Structural Changes

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Summary.

Airworthiness regulation require that the safety of transport aircraft and successful completion of flight be ensured after impact with a bird. This requirement is not easily met by light transport aircraft without having to significantly increase their mass. The experimental test in itself is relatively demanding.
This article relates to the solution of these problems for the L610 regional aeroplane developed in the Czech Republic by the company, LET a.s. Kunovice.
Briefly described are testing equipment, methodology of the tests, registration of parameters and other significant factors used in the test conducted by VZLÚ Praha.

Attention is paid mainly to the attained results and structural changes in the wing, tail unit and fuselage that led to the fulfilling of the FAR 25 regulation requirements. The criterion of these modifications was the fulfilling of the regulation requirements with a minimal increase in mass and simplicity of production. Tests on the resistance of cockpit wind screens developed by the company, LUCAS Aerospace Ltd, were performed simultaneously with the airframe structure tests. Even though the windscreen design was based on the long-term experience of this company, the tests allowed the originally proposed thickness of the windscreens to be lowered and the mass to be limited.

Testing equipment.

The testing equipment was developed at VZLÚ Praha and in addition to the tests described below is also used in the testing of power plants. It works on the same principle as an airgun in that a bird is projected by compressed air, which is funnelled into the barrel via a fast-opening valve from the storage cartridge. The relationship of velocity to air pressure for the specified mass of the bird was determined by firing trial shots. A scheme of the testing equipment is shown in Figure 1.

The projected bird's velocity was measured using two different methods :

- When leaving the barrel, the bird disturbed two thin wires positioned at a predetermined distance from one another. These wires constituted part of two electrical circuits. The time measured between them being disturbed was estimated as being the bird's velocity.
- A high-speed camera with a frequency of 1000 shots per second filmed the flight path, which was afterwards used to estimate the velocity as well as to adjust the impact speed used in the first method.

The points of impact were zoned-in on by laser instruments inserted into the barrel. The structural part being tested was attached to a high-lift truck. The position of the bird's impact was adjusted according to the movement of the high-lift truck.

Chickens were chosen as the species of birds with which to conduct the tests. They were put to death shortly before being projected in order to simulate impact with a bird as realistically as possible. Chickens weighing slightly more than the required 4 lb were purchased. After putting them to death and weighing them, their mass was adjusted by cutting away the limbs or head. Two chickens stuffed into a linen bag were used on the tail unit, where a bird mass of 8 lb is required. Specialised equipment was utilised to cut the linen bag at the end of the barrel so as to permit natural deformation of the chickens at impact. The velocity and distance of the muzzle from the target (about 2 m) guaranteed simultaneous impact.

The points on the aeroplane were selected so as to reflect the most likely positions where contact with a bird could take place and where the proper functioning of the aeroplane systems could be jeopardised. This subject will be discussed in the descriptions of the test mentioned below. Overall 65 shots were fired at the various parts of the aeroplane. The power plants were tested separately and therefore are not included in this report.

Wing.

It is required that the bird makes impact with a plane flying at a speed of V_C and at an altitude of 8000 ft. The speed for the L 610 is 450 km/h, thus impact is assumed be on the leading edge. In order to investigate the effects of a failure, the wing was tested :

- in the area of the integral fuel tank
- in the area exterior to the integral tank.

By no means can the tightness of the tank be jeopardised by loose rivet joints or defective beams or webs of the foremost spar. Damage to the wing's leading box does not prevent completion of the flight and is thus admissible. Wing specimens were used in the tests. The shots were fired at the centre of the leading edges between ribs or close to them. A wing specimen and its attachment are depicted in Figure 2. The original structure and its state following the test are shown in Figure 3. Damage was inflicted onto the wing's leading edge and the front spar's web. Other structural variants that were tested but did not conform to the requirements are shown in Figure 4. Figure 5 shows the final variant, which had minor damage evident on its leading edges. Its spar remained unharmed. This variant was applied on the aeroplane.

The effects of damage to the exterior of the integral tank do not pose as much of a threat. Wing parts not damaged in this area during the static strength tests were used in the tests. The shots were aimed at the centre of the areas between ribs. The leading edge was always destroyed but the front spar did not suffer any such damage which would affect its carrying capacity. The rear box was unscathed. It must be highlighted that the smaller radius of the leading edge resulted in greater stiffness. Hence the results were acknowledged as meeting the requirements and the structure left unaltered.

The following deductions were made from these results :

The best type of structure is one that through local deformation deflects the bird across the wing. The destructive energy applied to the wing is substantially reduced. However, it is difficult to apply such a solution to a thick leading edge. It is possible though by strengthening the skin and supporting it. Even if the bird would not be deflected from its path, a substantial quantity of its energy would be absorbed and damage prevented to the front spar. However, the elements must be well attached to the structure. The final variant selected for the L 610 aeroplane conforms to all these principles.

Wing flaps.

The flaps were hinged on the wing and deflected into a landing position (38°). Impact at a speed of V_F = 220 km/h was tested. Shots were fired at 3 points :

- at the cover of the flap's guide. Though the cover was deformed, no damage was done to a carrying or functional part.
- at the joint of the middle and outer flap. The joint remained undamaged. Only the corner of the middle flap's trailing edge was deformed.
- at the flap itself. The impact between the ribs and between the spars only slightly deformed the skin without actually tearing it. Since the flap's function remained operational, the flaps were left unaltered.

Tail unit.

The tail unit was subjected to tests using birds weighing 4 lb, travelling at a speed of 450 km/h (FAR 25.571) as well as birds weighing 8 lb, travelling at a speed of 400 km/h (FAR 25.631). The impacts were imparted parallel to the fuselage's axis.

Fin.

The impacts were directed to the composite section covering the connection of the stabilizer and fin and to the fin's leading edge located under this connection. The bird weighing 8 lb inflicted greater damage. The composite cover was damaged and the rudder's horn balance partially damaged. Despite this, it was possible to deflect the rudder in the range of 9.5 degrees. The web of the stabilizer's front spar (three spar structure) was deformed but the hinges were not damaged. The leading edge of the fin's bottom section, inclusive of the front spar web (three spar structure), was damaged. The slight deformation of the centre spar did not reduce its carrying capacity. The fin structure is still capable of completing a flight even if it has suffered such damage and therefore did not have to be altered. A specimen of the fin and the condition the structure was in following the test are shown in Figure 6.

Stabilizer.

The stabilizer was tested together with the mounted elevator. When tested on the original structure (Figure 7), the bird broke right through the leading edge and webs of all three spars, in the process deforming the elevator. Structural alterations were executed and variants A, B, C and D tested. The specimen and various variants are given in Figure 8. The leading edges of variant C did not break and thus did not significantly increase the magnitude of damage done to the structure. The structure deformed and the bird slid away, causing no more damage. Based on these factors, this variant was chosen as the final solution. The solidly shaped pipe, situated not far beyond the leading edge, allows it to deform without actually ever breaking. The deformation is sufficient to alter the bird's path. As a consequence of this the structure only has to absorb a portion of the bird's energy, thus preventing any major damage.

Fuselage.

The following points were selected for impact :

- The radome. A radar is situated behind it and a front pressurised wall present in the bird's flight path.
- The area of the fuselage located in front of the cockpit windows. The pressurised wall would most certainly also be damaged should the skin tear.
- The area of the fuselage located above the cockpit window. Several electrical switches, circuit breakers and other components are found underneath the skin.
- The cockpit windscreens (middle and side) and their frames.

As illustrated in Figure 9, the front section of the fuselage, inclusive of a pilot dummy sitting in the cockpit, was put through the tests.

The radome, made of a Nomex honeycomb structure 16 mm thick, first frame and front pressurised wall were damaged by the impact on the radome. The outer layer of the honeycomb structure was strengthened, whilst the first frame was strengthened by utilising a titanium sheet 1.2 mm thick. The ensuing shot was aimed at a point away from the nose landing gear. The radome was penetrated and although the titanium-strengthened first frame partially deformed, it withstood the impact of the bird, hence shielding the front pressurised wall.

The fuselage sections in front of and above the pilot windows are so inclined so that the bird only tore the skin and slid away without any serious consequences. The longitudinal skin joint had to be overlapped and the screws strengthened about the aeroplane's axis, above the windows, to prevent the projected birds from tearing the skin in the location of the joint. No major alterations were necessary. The original condition, how the damage was done and repair are illustrated in Figure 9.

The tests involving the glass and frames of the cockpit were relatively extensive. The centre glass and the glass in front of the pilots were tested. The company Lucas Aerospace Ltd designed and produced the actual glass. A dummy pilot head covered with plasticine was placed inside the cabin in order to be able to assess any possible injury to pilots caused by glass fragments. However, no glass shattered within the cockpit during any of the tests and therefore the dummy was not injured.

The glass was tested at extreme operating temperatures i.e. + 55°C from the outside (attained using an electrical glass heater installed for de-icing) and - 55°C (-30°C inside) corresponding to the drop in temperature measured for an aeroplane in flight. The cooling effect was achieved by applying carbon dioxide from a pressurised bottle placed under a cover fastened to the window. This was removed prior to the shots being fired. The positions selected for impact were in the centre and corners of the glass so as to test positions of various stiffness. Since all sections of the glass withstood impact, it was decided to weaken the centre glass by 5 mm and the glass in front of the pilots by 3 mm. Following impact with a bird, only a few small cracks were perceivable on the outer layers of the weakened centre glass, which remained transparent. The outer siliceous layers of the glass situated in front of the pilots fractured and fragments broke off resulting in the glass losing its transparency. The inner layers were also cracked but no fragments broke off.

When making a comparison of the test results obtained at various temperatures, it was obvious that the damage was greater to heated glass. Impact of the birds with the window frames did not damage or deform the frames. The condition of the windscreen following the tests is shown in Figure 10.

Conclusion.

The purpose of this report was to give an idea of the attention devoted to the whole dilemma surrounding bird impact, mainly the issue of finding solutions for resistant and light structure. There are surely many possible alternatives to pick from, but it was demonstrated that the most effective of these are those that prevent the bird from actually penetrating into the structure. Instead it is more viable that the bird only slightly deform the structure which in turn results in the bird harmlessly sliding away. The outcome of this is that the structure only has to absorb a portion of the bird's kinetic energy and so doing substantially reduces the magnitude of damage done.

Bibliography.

Documentation supplied by LET Kunovice.

FAR Part 25.

Report No. 130.20.002/94 supplied by VZLÚ - Turbo Motor s.r.o.

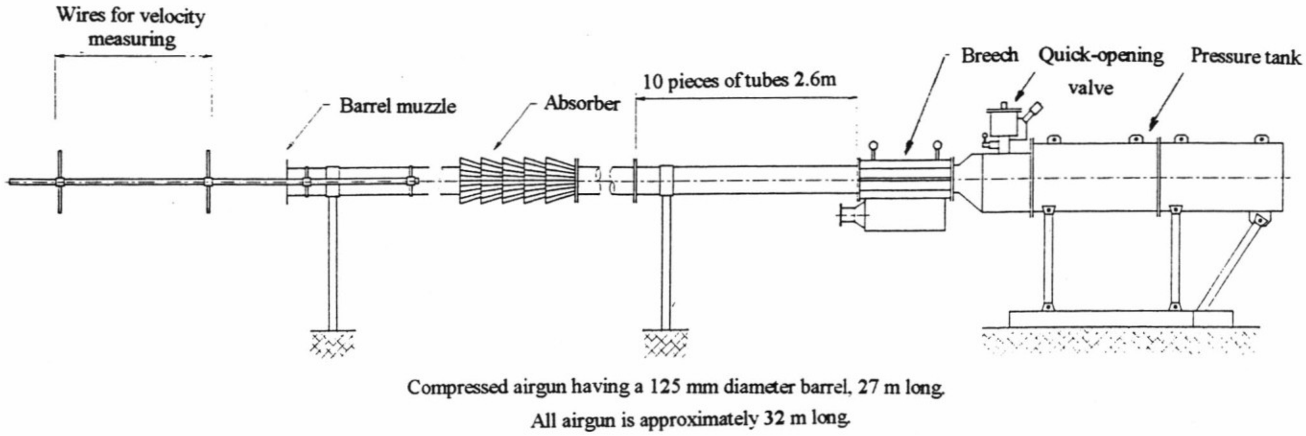
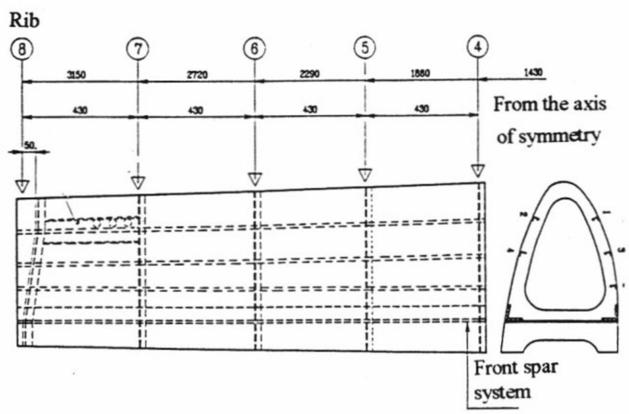


FIGURE 1 - Scheme of Testing Equipment



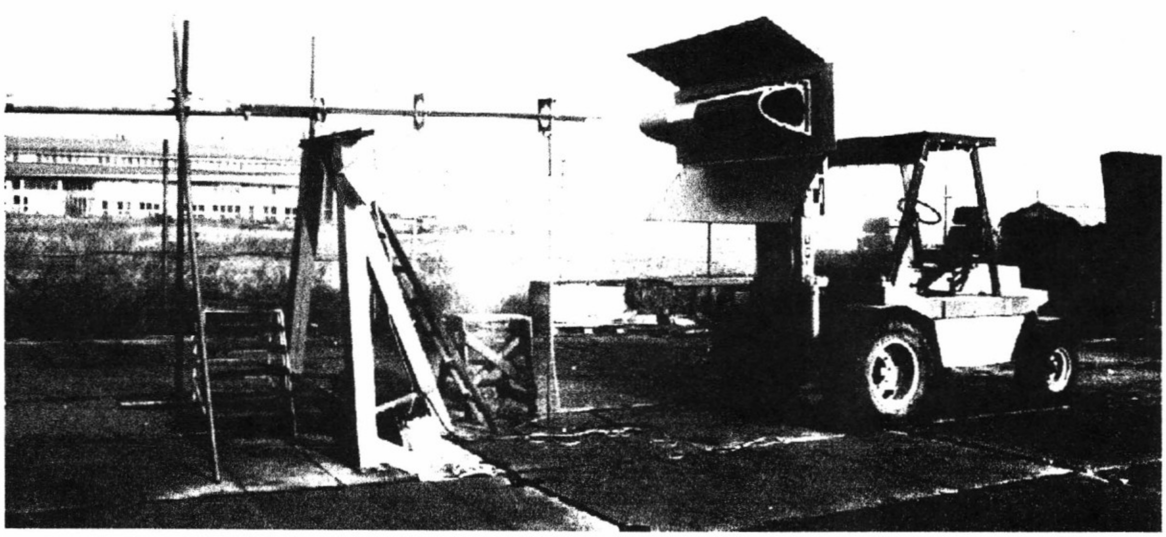


FIGURE 2 - Wing Specimen and its Attachment

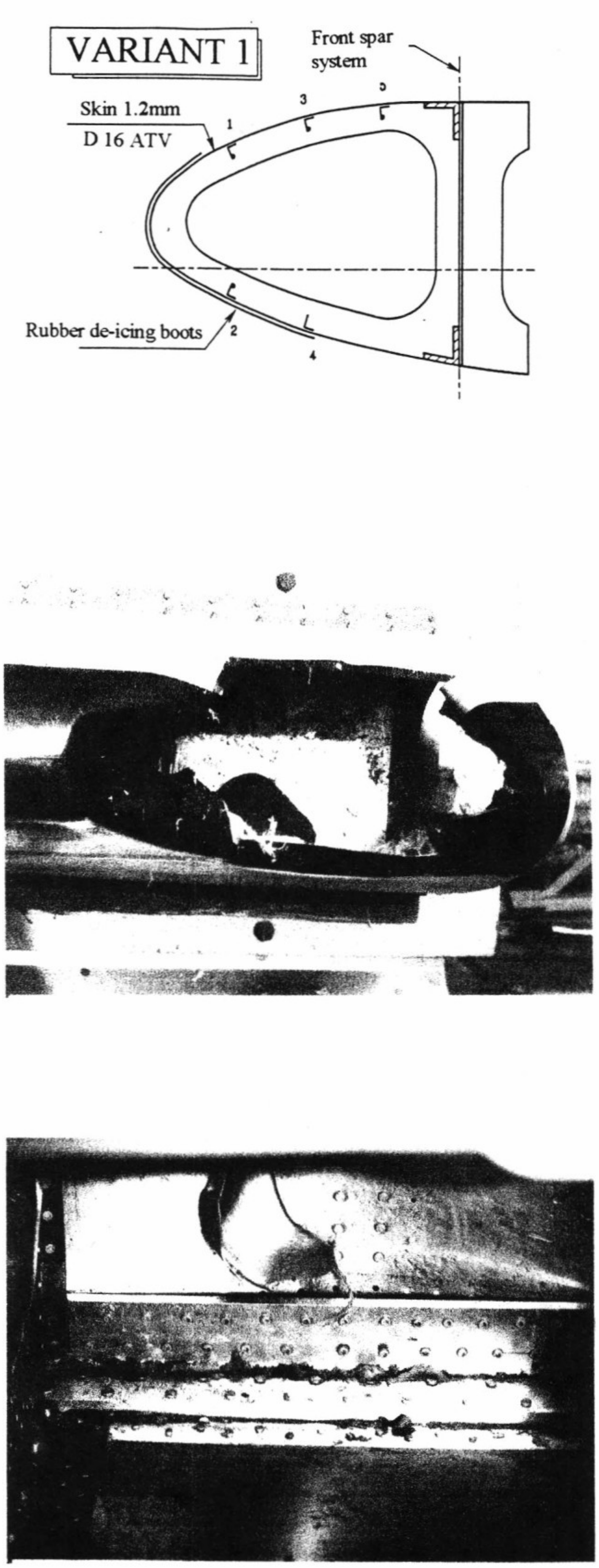


FIGURE 3 - Original Structure of a Wing and its State Following the Test

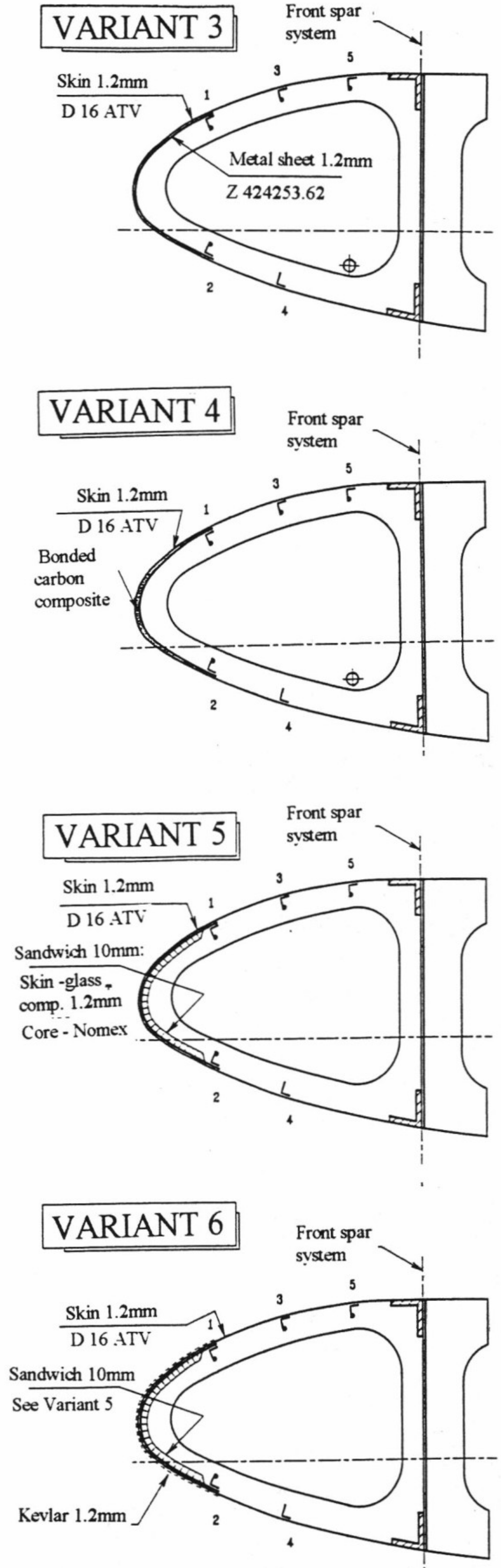


FIGURE 4 - Other Tested Structural Variants

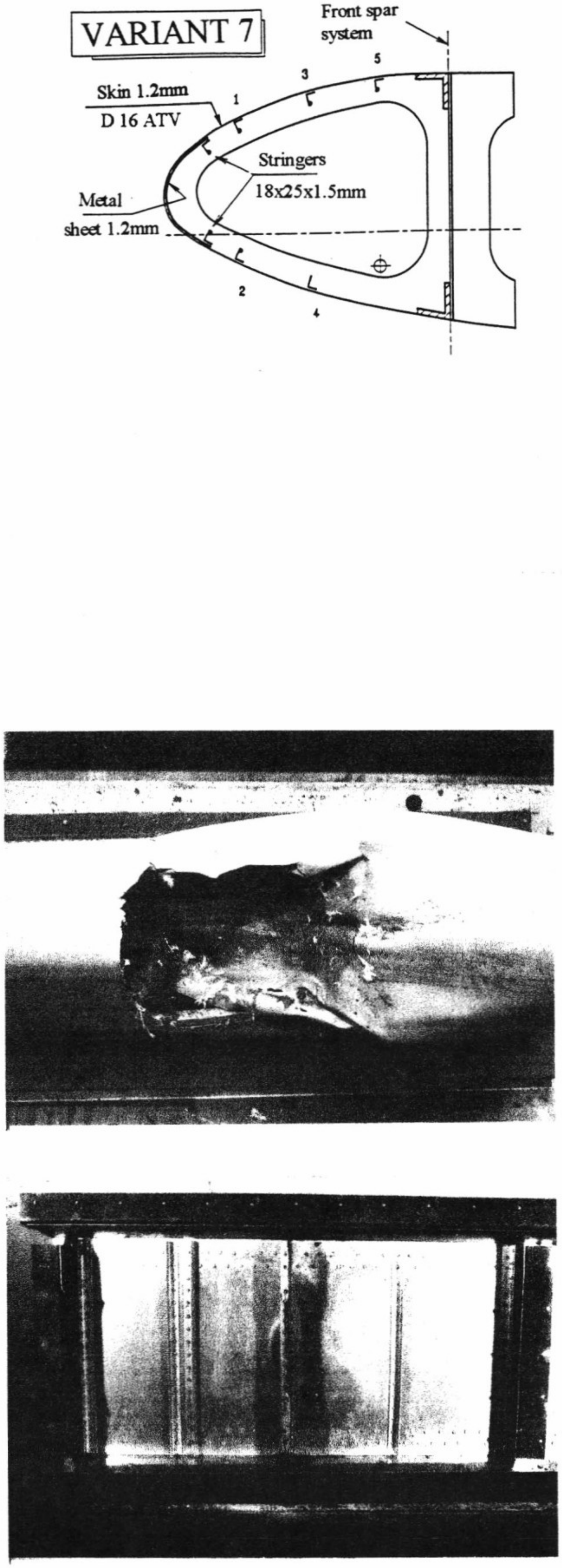


FIGURE 5 - Final Variant. The spar is without damage

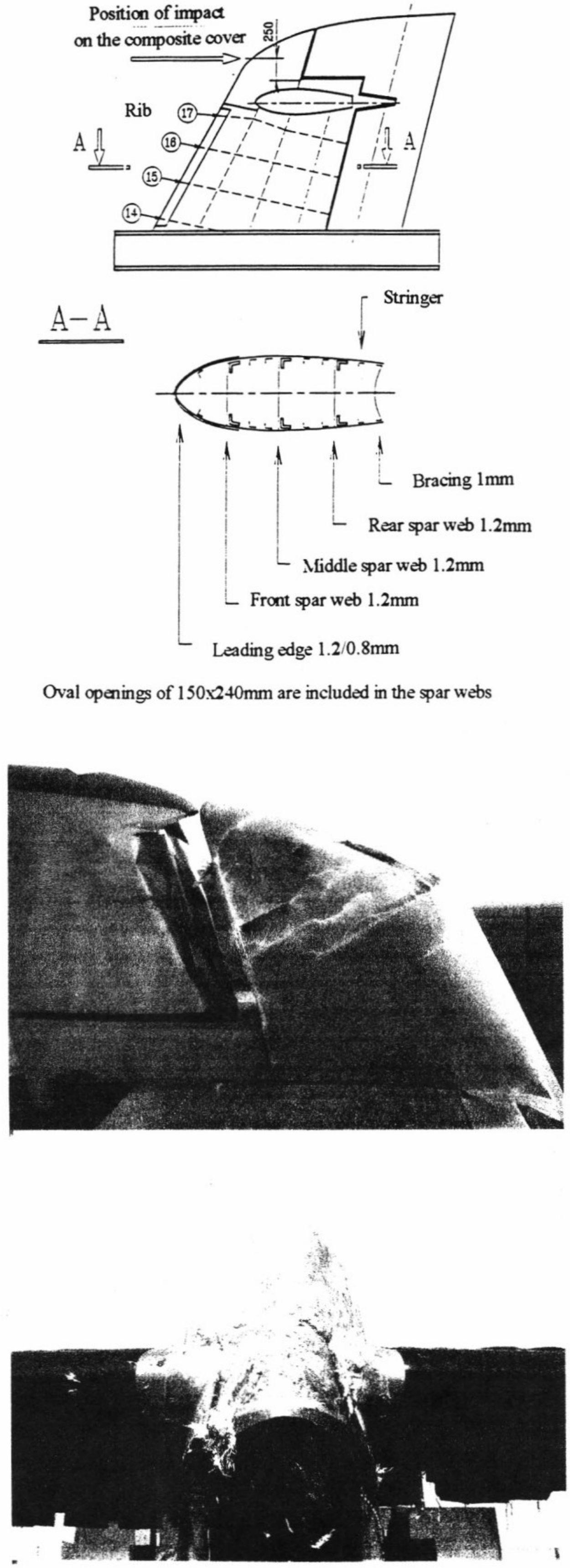
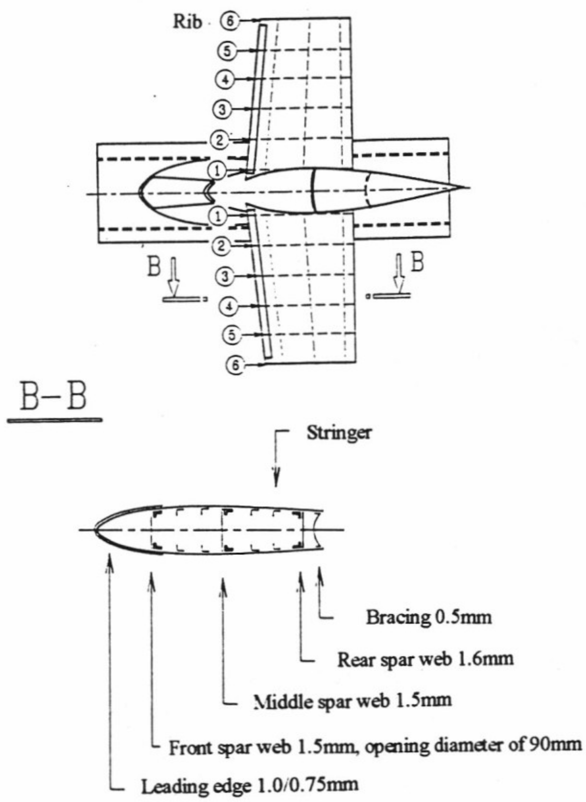


FIGURE 6 - Fin Speciment and its State Following the Tests



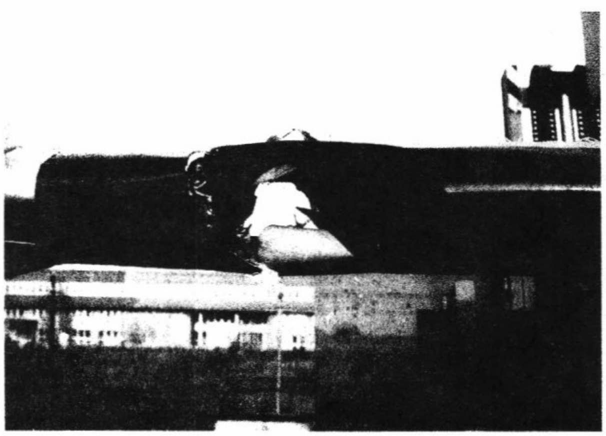
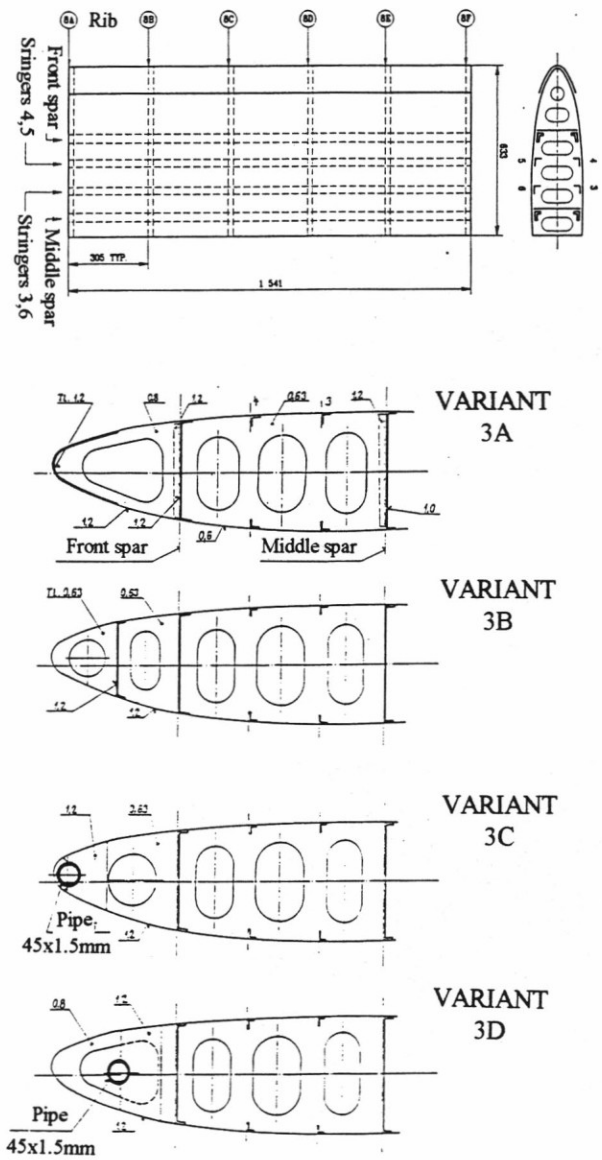


FIGURE 7 - Original Structure of a Stabilizer and its State Following the Test



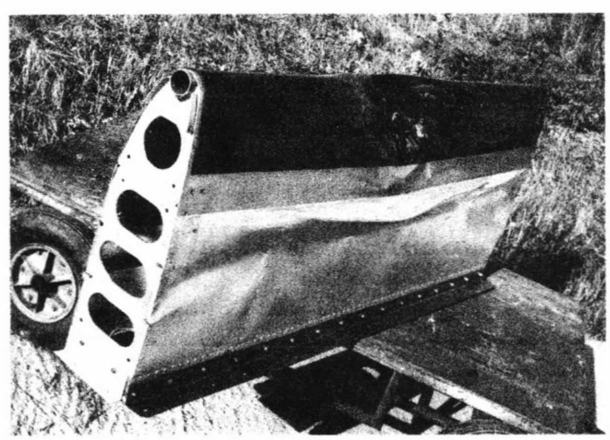


FIGURE 8 - Stabilizer Specimen for Testing of Structure Variants A,B,C,D. Final Variant C and its State Following the Test

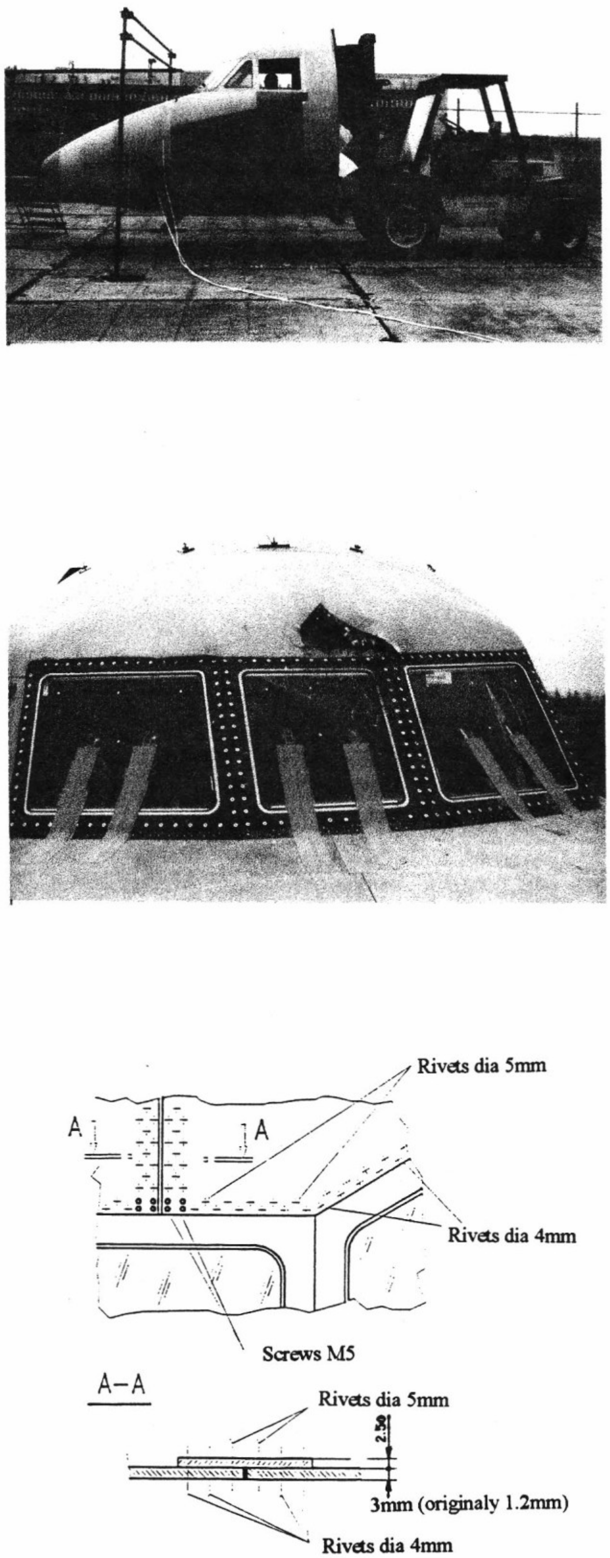


FIGURE 9 - Fuselage Specimen with a Pilote Dummy
Repair of Skin Damage

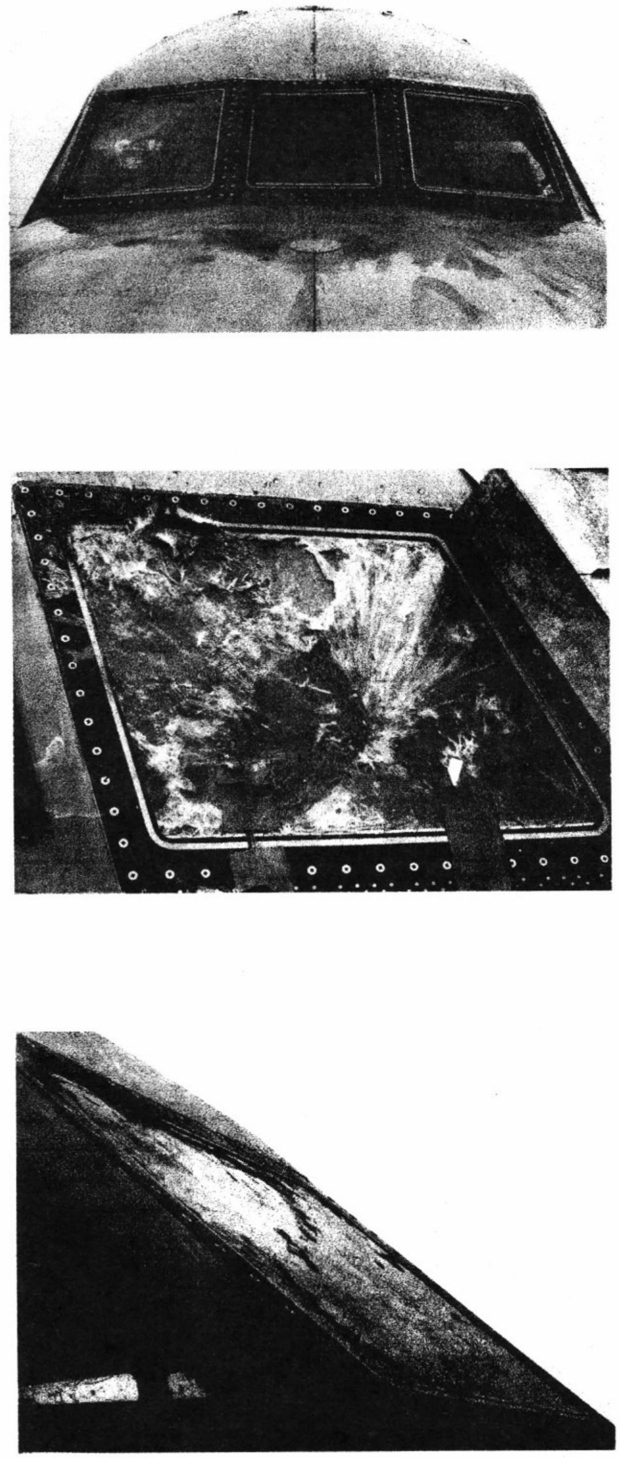


FIGURE 10 - Cockpit Windows and their State Following the Tests. The most Damaged Right Side Window