Engine Bird Strike Tests at Cepr Saclay Test Methods Improvements

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ENGINE BIRD STRIKE TESTS AT CEPr SACLAY TESTS METHODS IMPROVEMENTS

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ABSTRACT

The CEPr SACLAY has developed for almost twenty years a full FOD test capacity, in order to offer at the french engine manufacturers a very high level FOD engine test rig, both for development and certification purposes.

Throughout those years, a large number of development tests was performed at CEPr SACLAY TX test rig in order to improve the french regulations and to decrease the costs of full size test on a real engine by testing components under different conditions.

Studies on the tests methods have been achieved to avoid the most severe cases of strikes, considered by the certification authorities as non representative of a real bird strike : those new technologies were applied to the HBPR engine CFM56-5 program.

As the engine and material technology is improving quite rapidly, CEPr SACLAY has to adapt his knowledge to the new engine concepts born a few years ago : in particular, CEPr SACLAY is developing new FOD test technology to face the challenge of firing nine to ten birds into an UHBPR* engine, as the actual regulations ask.

Two FOD campaigns were achieved on composite propellers : the results are very encouraging and CEPr SACLAY will be prepared to test the GE 36 UDF to bird strike hazards.

A video is presented to illustrate typical tests achieved on various kinds of engines.

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* UHBPR engine : Ultra High ByPass Ratio engine

I - GENERAL HISTORY

The CEPr SACLAY (Centre d'Essais des Propulseurs) is the French Ministry of Defence official test center. Although its main activities deal with the flight simulation tests on components and engines for the French Air Force main programs, it is also considered as a technical expert and support for the french civil aviation authority (DGAC). For those reasons, it has been involved very early in birds strike test on engine, both for military and civilian purposes.

The development of the FOD tests technics at CEPr SACLAY are directly related to the the CFM56 program. Before starting the program, french officials services (STPA and DGAC) and french main engine manufacturer SNECMA have launched studies on the bird strike effect on a large fan of an HBPR engine called M 45 : this led the CEPr SACLAY, whose speciality was also the so called "special tests", to develop a test rig capable of achieving those bird ingestion tests, the TA rig (fig 1).

This installation , created in 1975, was completed with a fixed target shoot stand to increase the capacity for development tests on manufacturers products as well as on our bird gun (fig 2).

The installation has performed nearly all the FOD certification tests on the CFM56 engine family (CFM56-2, CFM56-3 and CFM56-5) and was also implied in FOD tests on the Alpha Jet engine (LARZAC) and helicopter air intake for AEROSPATIALE (fig 3,4,5).

II - GENERAL DESCRIPTION OF THE COMMON TESTS TECHNICS BEING USED

2-1 Air guns

The FOD test technic consists in firing the foreign objects in an engine at a velocity which is representative of the aircraft velocity during the part of the flight considered by the authorities as the most critical for this kind of hazard.

Most of the tests centers have adopted the air gun technics to launch the projectile at the target. The projectile is put in a carrier which acts as a piston when the compressed air is suddenly released by a "fast opening valve" : the velocity is then a function of both the mass of the carrier plus projectile and the pressure of the compressed air, known by calibration tests.

The differences between the systems built in the world appear when considering the material employed for the carrier, the way the bird is put into the carrier, if the carrier is catched at the end of the tube and the way the "fast opening valve" is obtained. Some differences can also be noticed in the geometry of the guns.

CEPr has chosen for bird strike tests the following philosophy : being capable of firing with the lowest probability of failure and a great repetability one or two birds into an engine, without sending the carrier, which might affect the results of the test. This has led the CEPr engineers to develop a new kind of gun based on the following improvements :

- a "fast opening valve" based on a plastic sheet opened by a detonator
- a projectile carrier catch at the end of the tube, which is capable of retaining through mechanical shock absorbers a mass of 2 Kg launched at a velocity of 400 m/s
- a projectile carrier keeping its integrity during the shock of the catch in order to avoid parts of the carrier to be send in the engine
- a very well known material for the inside wall of the gun in order to improve the repetability of the gun
- a gun recoil absorber in order to improve the impact precision

The more recent air gun type developed by the CEPr SACLAY for the CFM56-5 certification is 5 meters long and has a 140 mm diameter : it can fire a large bird at 400 m/s to covered the military flight at low altitudes domain. Seven to nine of them can be put together on a special support for medium bird ingestion tests on HBPR (1) engine (fig 6).

All the CEPr guns are equiped with a "wire to wire" projectile velocity measurement based on the measurement of the time spend by the projectile between two well known positions inside the gun : the impact velocity is measured with high speed videos or calculated through mathematical models.

(1) HBPR engine : High ByPass Ratio engine

2-2 The sequence

The CEPr philosophy implies the use of a special automatic system capable of managing the whole firing sequence that is :

- the high speed cameras needed for the understanding of the test, and therefore the intensity of light put on the target
- the different electrical sources needed to feed the detonators
- the meteorological or engine parameters analysis
- etc...

As the good working of all servitudes put around the engine to measure or to analyze after the shot its behaviour is considered to be the most important thing to ensure before the test starts, the sequence automaton is also equiped with all the alarms needed to stop the firing sequence when things go wrong. Those alarms concern the behaviour of the engine before the test as well.

III - MULTIPLE STRIKES PROBLEM

CEPr tests engineers call multiple bird strikes the case of two or more birds impacting the same fan blade at quite the same height. During certification tests, the case seems to be more common than predictable as most of the engine manufacturers have faced the case of three birds impacting the same blade at the same height, with most of the time very bad results obtained due to the relative weakness of a blade which has been two times severely impacted.

CEPr SACLAY also had to face such a problem and has recently tried to find appropriate answers in order to avoid the case of three or more impacts on the same blade, as it is not considered as representative by the civil aviation authorities (2).

3-1 Studies

Two kind of studies have been launched by CEPr to understand the way such multiple impact could happen and try to estimate the risks for new certification tests.

(2) To our best knowledge, no case of medium size bird multiple impact on engine in service were noticed during the last ten years.

It was first necessary to understand how the performances of the firing system, sequence automaton included, could affect the arrivals of the birds on the fan. This has been done by analysing both the CFM56-2 and CFM56-3 bird certification tests and by analysing the performances of the former installation in order to have good mean characteristics of it. We noticed that whatever the firing sequence will be, a decelaration of the fan velocity occured approximatly when the first three bird strike hapenned (fig 7) ; then the mean decelaration rate is quite constant during the other strikes. Most of the time, when the test was successful, the decelaration ended before the last strike.

A current decelaration rate was included between 1500 and 3000 rpm/s/s, so that for an engine running at 4500 rpm, the difference between the estimated location of the impact through a simple calculation and the real location could easily be measurable in rounds : this led the CEPr to consider that the only way to avoid multiple bird strike was obviously to connect the automatic firing system to a fan velocity measurement and try to integrate this measure into the sequence, although it complicates the automaton quite a lot.

A second fact appears quite rapidly in our studies : the way of firing the birds was as so important as the knowledge of the most probable location of the impact. CEPr has never adhered to the philosophy consisting in firing all its birds at the same time (although its installation authorizes such a shot) considering that it is not representative of what can happen on an air field. CEPr engineers have tried to determine the real concentration of both little birds and medium birds when high concentration occurs : from there it was possible to estimate a majoration of it and translate that to the case of a test.

The results obtained shown that when all the birds were fired at the same time, the decelaration rate was more important and more hazardous than in the case when the birds were shot one after the other : this can be explained by a "recovery factor" of an impacted blade, which when hurt, bent and draw from itself up under the action of the centrifugal forces. If the blade is hurt, even by a very little part of a bird during this action, the dammages are often more severe and the abration more important.

All of this led the CEPr to choose a firing sequence which minimizes the risk of multiple strike by controling the way of arrival of the bird, within the regulation recommendations.(3)

(3) The FAR and JAR requirements authorize a one second firing sequence.

A mathematical simulation was developed to analyze the different possible behaviours of a sequence. The parameters considered were :

- the projectile repartition
- the firing sequence : this include the possibility of tie down the fire to the velocity of the fan
- the decelaration rate of the engine and the time when it occurs
- the parameters describing the repetability and the precision of the projectiles, of the guns and of the sequence automaton : all those parameters were calculated or estimated through calibration tests performed on all the implied elements of the installation

3-2 Applications

All the results obtained with the different studies show that the reliability and precision parameters were also very important : in fact they were the only non hazardous parameters on which important improvement could be made and tested before a big FOD campaign.

Conscious quite rapidly of this fact the CEPr has developed its new bird artillery with the purposes of minimizing the uncertainty on the following parameters :

- projectile velocity
- time spent between the authorization of fire and the strike
- localisation of the strike (3)

The uncertainty envelope was given by the models and checked by calibration which was the only way to show where an effort should be made to improve the system.

The results obtained were very satisfactory with a bird strike precision estimated +/- 30 degree on a rotating fan (4900 rpm). This technology was applied to the CFM56-5A program with a big success (fig 8).

(4) This test is realized without the engine running and therefore does not take in account the aerodynamical effects of the air intake on the bird.

IV - PROJECTILE CHOICE

One of the most exciting discussion most of the bird strike test engineers may have, consists in comparing the advantages and the disadvantages of all kind of birds they have to fire into an engine. CEPr is not an exception and this has been one of the most important activities of the bird strike team.

The CEPr unique bird was the common chicken : the reasons put forward by the center when someone asked why, were mostly political reasons :

- most of the birds concerned by the bird strike were protected in France, and therefore not available for test purposes.
- it was really difficult to find a dozain of real birds having the good weight when the poorest calibration campaign need quite a hundred of birds to be fired.
- even if it is authorized, finding and killing real birds without guns is quite impossible to do.

CEPr state of mind has changed after the discussions it had during the CFM56-3 bird tests with GENERAL ELECTRIC and SNECMA. The experience of GENERAL ELECTRIC shows that the chicken was not as so good as it seems for different technical reasons related to the fact that it is not a real bird as it not flies. In addition to that, the CEPr chickens were farm chickensraised to produce meat. All those elements led to have a bird projectile density too far from the reality.

Comparative tests were programed then to compare the damages done by different kind of birds : seagull and chicken were tested at SNECMA and at CEPr, as CEPr has the ability of using wild seagulls living in the south of FRANCE and provided by the DGAC. Both static and dynamical tests were performed : the results were very different, but the analysis of them lead to the conclusion that the seagull was a more representative bird for engine tests, when comparing them to the in flight bird strike data base.

The SNECMA tests were done on a whole rotating fan : a semi-dozain of birds were shot on the tip of the fan blades and compared to the dammages caused by chicken. The ladles obtained were less important when considering a single blade, but more in terms of number of blades hurt.

The CEPr tests were achieved on static blades grid under axial load : the dammages encountered when firing a seagull were more important as one blade supported the whole bird in this case and not when using chicken (fig 9). The CEPr tests have also proved that the seagull was a better projectile in term of strike precision, due to its flying capacity and morphology.

All those elements have decided the center to use natural seagulls for official tests as the most representative birds, even it is quite difficult to find a 1.5 lbs or a 4 lbs bird in a species where the average weight is 2 lbs.

Analysis are still continuing to analyze now how the way the birds are freezed or shot might influence the results of the tests. In particular, the influence of the gun diameter on the effects of a strike has to be studied a little bit more.

V - TESTS TECHNICS ENHANCEMENTS FOR PROPELLER BIRD INGESTION CERTIFICATION

The more recent developments in propulsion technology are for the five years to come a source of new development tests as there is no real regulation which can be exactly apply to the new UHBPR (5) engines : neither a turboprop engine, nor a turboreactor, the propfan is the next challenge to face for the bird tests certification.

For now two years, the CEPr is preparing all its installation to this new kind of problems. Two bird strike campaigns have now been realized first to check the effect of bird impact on rotational propeller blade in comparison with static test results and secondly to determine the nature of the problem to be solved when CEPr will have to test an UHBPR engine.

5-1 Analysis of the campaigns

The first campaign occured two years ago and the main aim of the tests was to analyze the behaviour of a composite propeller blade during a bird strike : the propeller was a three blades BASTAN propeller from RATIER. At first, static tests on a composite and a metallic blade were performed, then two propellers, one in composite material, the other in type design material were tested on the rotational test rig, without a turboshaft (fig 10).

The test installation was not precise enough to allow an axial shot on a blade, so that a new shot technic has to be found : the gun was put in the propeller plane and the propeller pitch was adjusted to zero. A dozain of shots were achieved without major troubles. However , this first test has shown that a new concept was now necessary to face the challenge.

The studies led from these results were concluded by the introduction of a "blade aimer" and an angle calculation module using the propeller velocity in the automaton : a first demonstrator of this technic has been built and tested for the qualification of the TRANSALL composite propeller to foreign object dammages. The propeller was propelled this time by a TYNE turboshaft engine in order to check the whole propulsion system (fig 11).

This new campaign of FOD tests performed on a four blade propeller is currently achieved at CEPr TRANSALL propeller test facility H0 rig : the FOD installation allows now an axial shot on a designated blade(6). The automaton and the gun being used were precise enough now to touch a rotating blade with a little stone of 30 gr.

This encouraging result shows the CEPr that the choosen concept seems to be the good one. Many studies should now be done to improve the reliability and the precision of this new system.

5-2 Application to the UHBPR engine testing

With the UDF GE 36 program, SNECMA and GE have launched now a new step in the propulsion evolution : this engine must be certified and there is no doubt that it will be necessary to check the compliance of this engine with the bird strike regulations although there is no one existing at the present time for this kind of engine.

Although it is not presently concerned by development or certification tests, CEPr SACLAY is presently studying the way FOD tests could be achieved on contrarotative propellers of an UDF engine, the main axis of thinking being the shots on the second propeller without hurting the first one and the aerodynamical effects around the nacelle.

Though there is no data base available to work, CEPr is also trying to analyze the problem of the multiple strikes during a medium bird ingestion test on an UHBPR engine to avoid such a problem if it has to realize such a test in the future. But, if some ideas can be extended from the HBPR engine testing without problem, other like the deceleration rate cannot be really analized without development test.

(6) both in terms of engine set up and bird velocity.

VI - CONCLUSION

The recent successes of the CEPr SACLAY in FOD testing are the direct consequences of four years of research on the test installation itself and the causes of the multiple strikes. It lead us to understand the necessity of developing high level technology for these kind of tests to get a high reliability in order to be more confident in the installation which must not be a source of problem when realizing such tests.

All the improvements presented above are not commonly used at the present time, but most of them will be employed in the next five years for the certification or the qualification of the french manufacturers propulsors.

Like the other centres we are facing the future to keep what we consider to be one of our major successfull activities during the past ten years and to participate to the challenge of the new regulation writing and testing for the UHBPR engines.

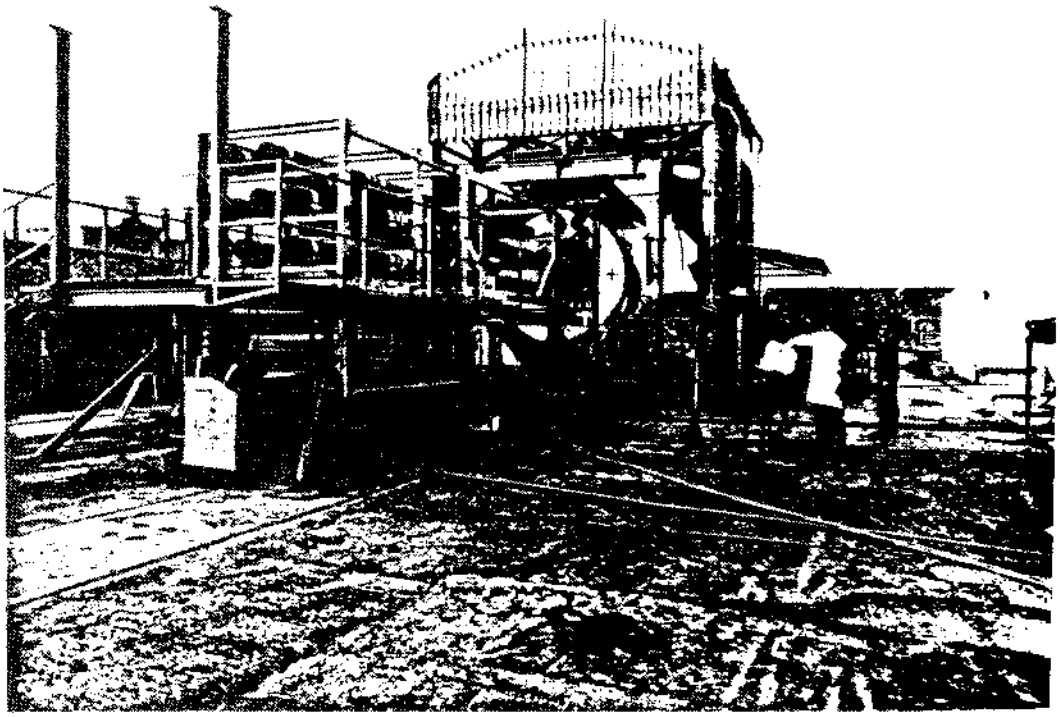

Figure 1

TX rig engine test facilities
(Photo CEPr 87 280)

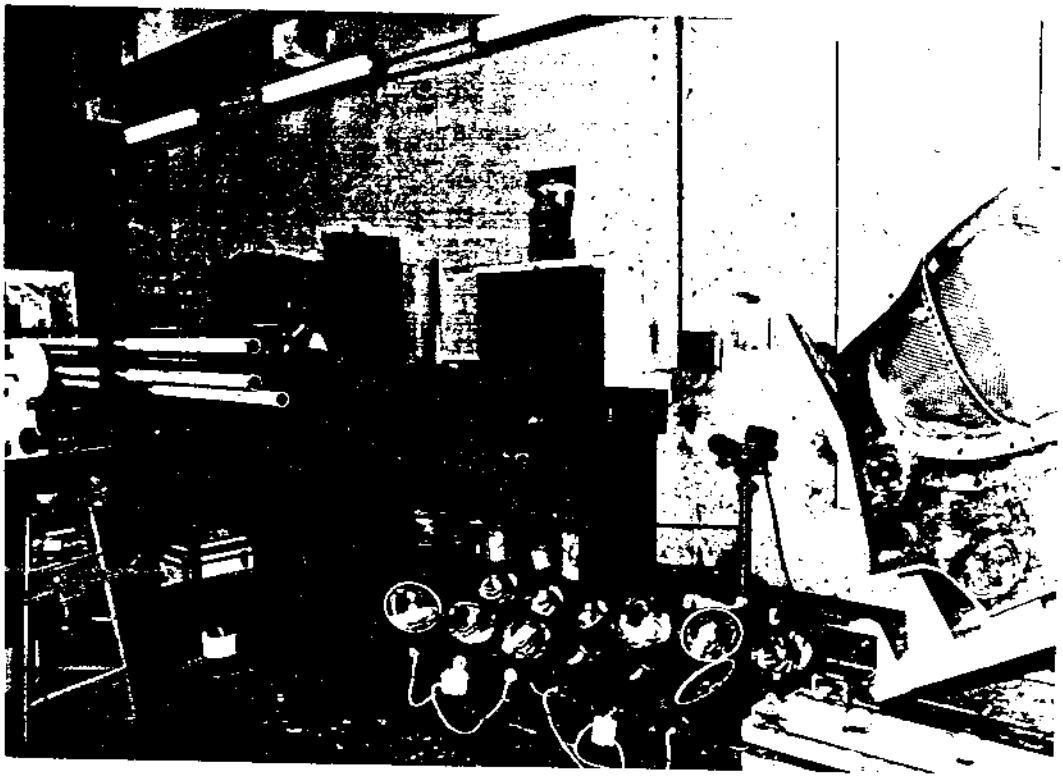

Figure 2

TX rig fixed target test facilities
(Photo CEPr 87 2143)

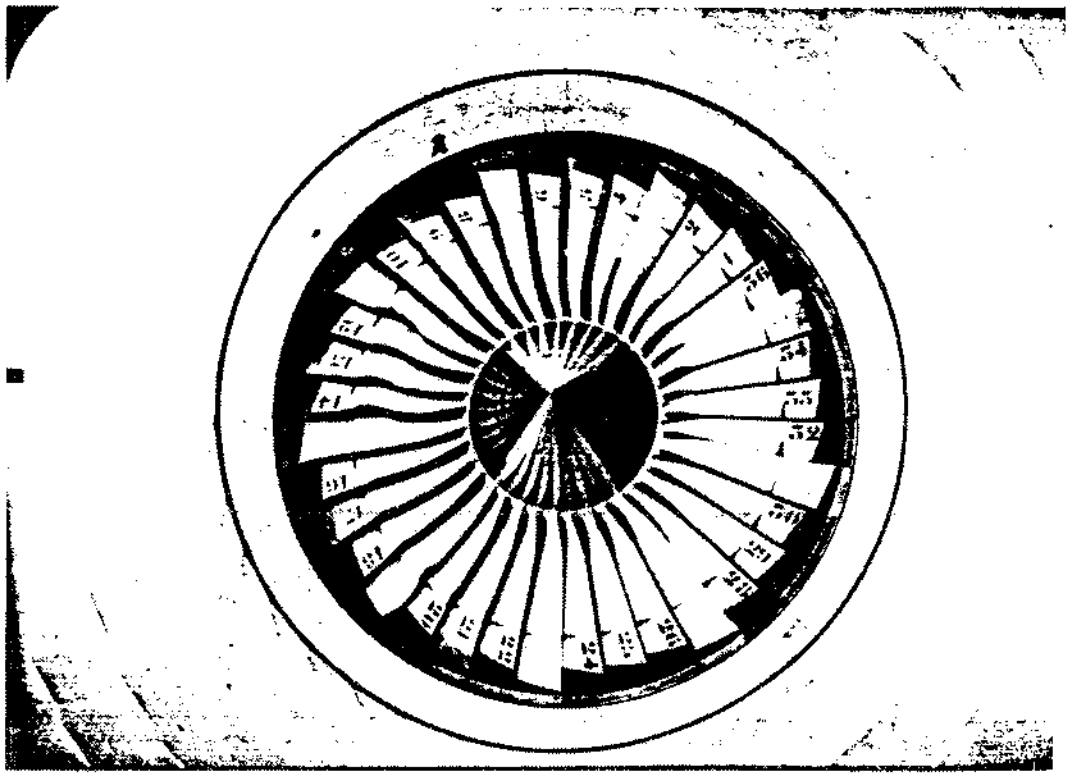

Figure 3

Medium bird certification test on the CFM56-5A1
Dammages encountered
(Photo CEPr 87 1061)

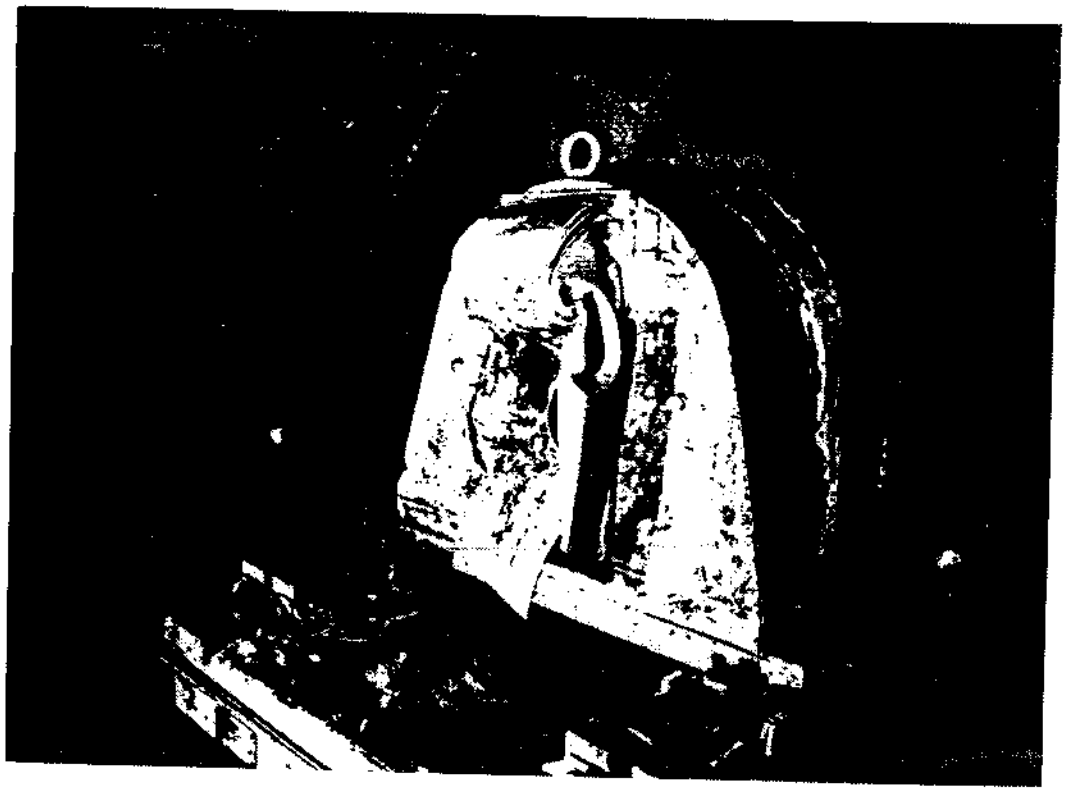

Figure 4

Medium bird qualification test on an airborne equipment
(Photo CEPr 87 1460)

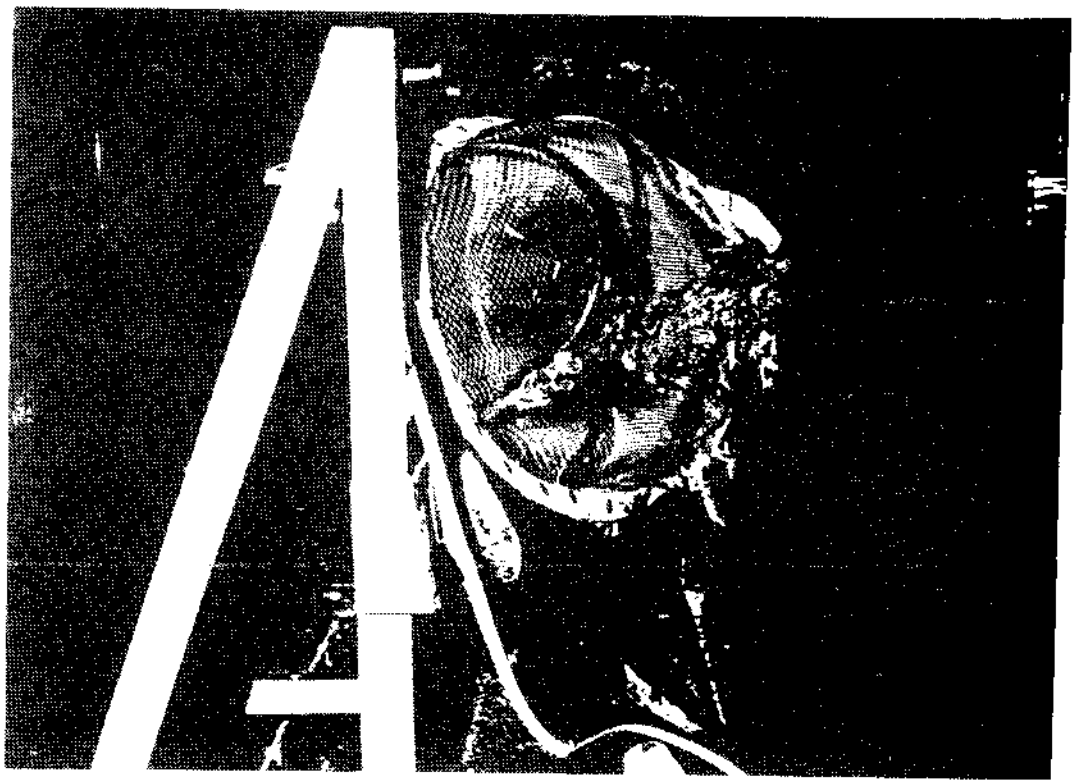

Figure 1

Heavy bird certification test on an helicopter air intake
(Photo Credit AFRL)

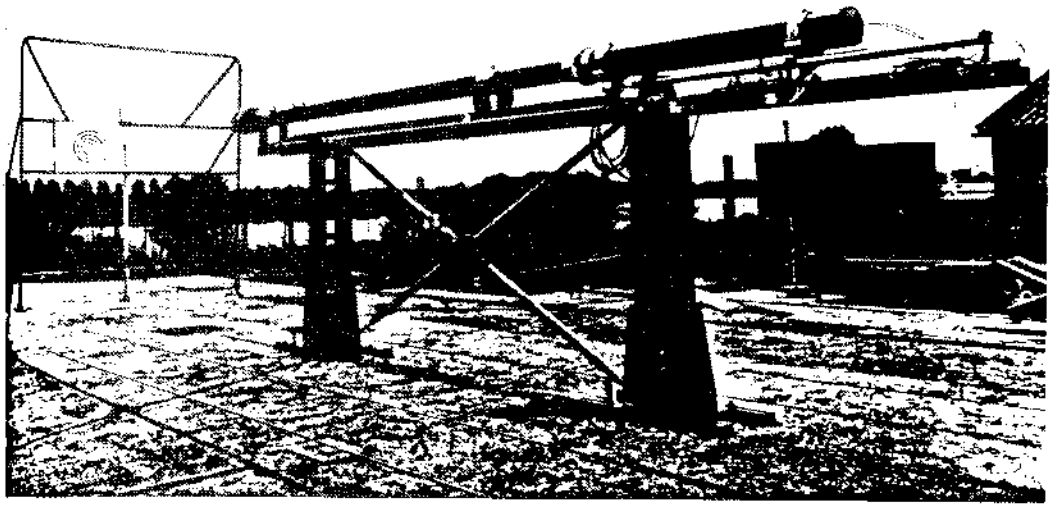

Figure 6

Typical CEPr air gun
(Photo CEPr 87 3485)

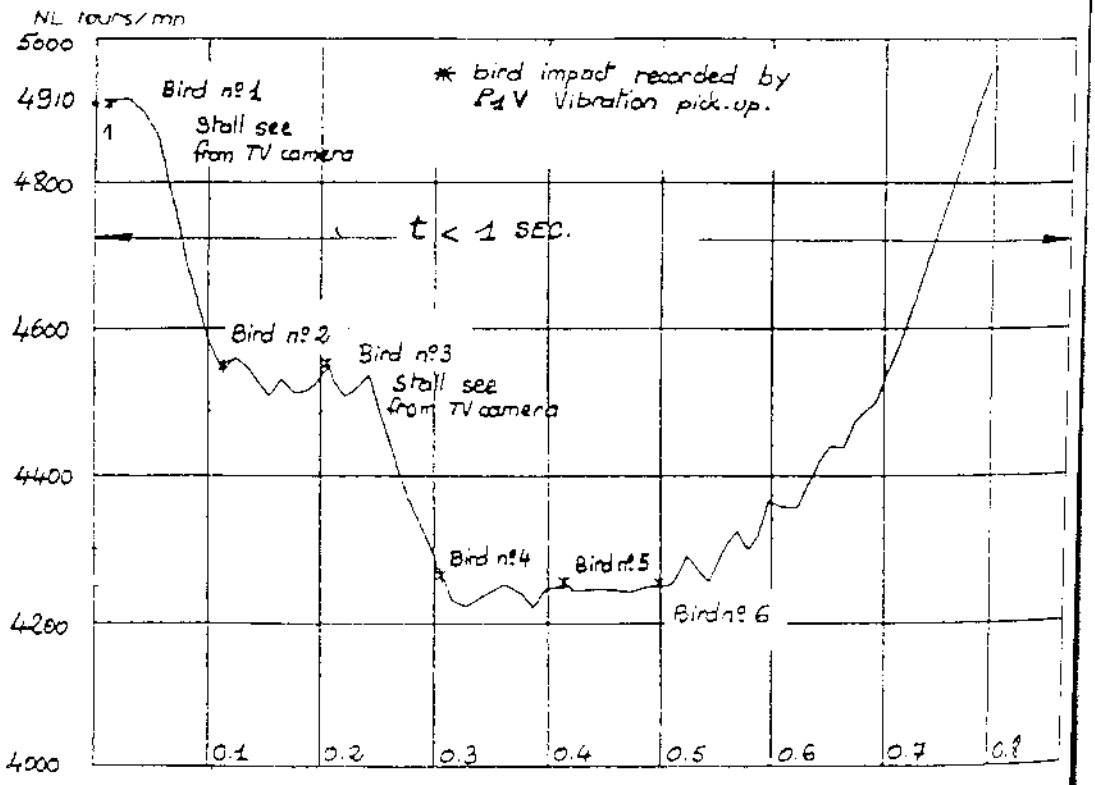

Figure 7

Fan speed during a medium bird test

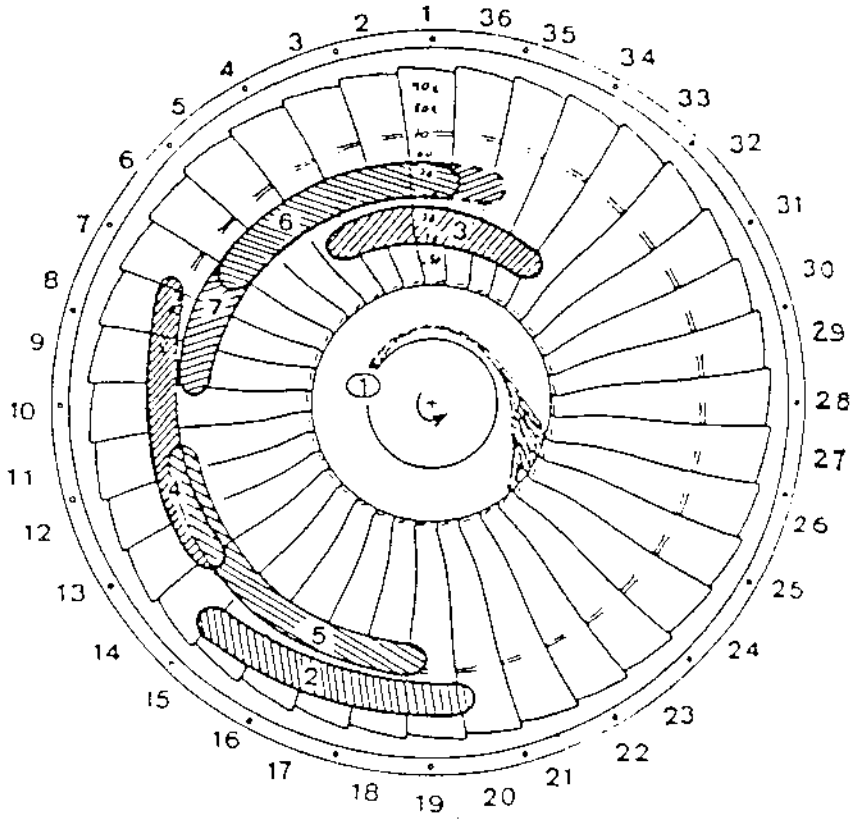

Figure 8

Medium bird certification test on the CFM56-5A1
Impacts location on the fan

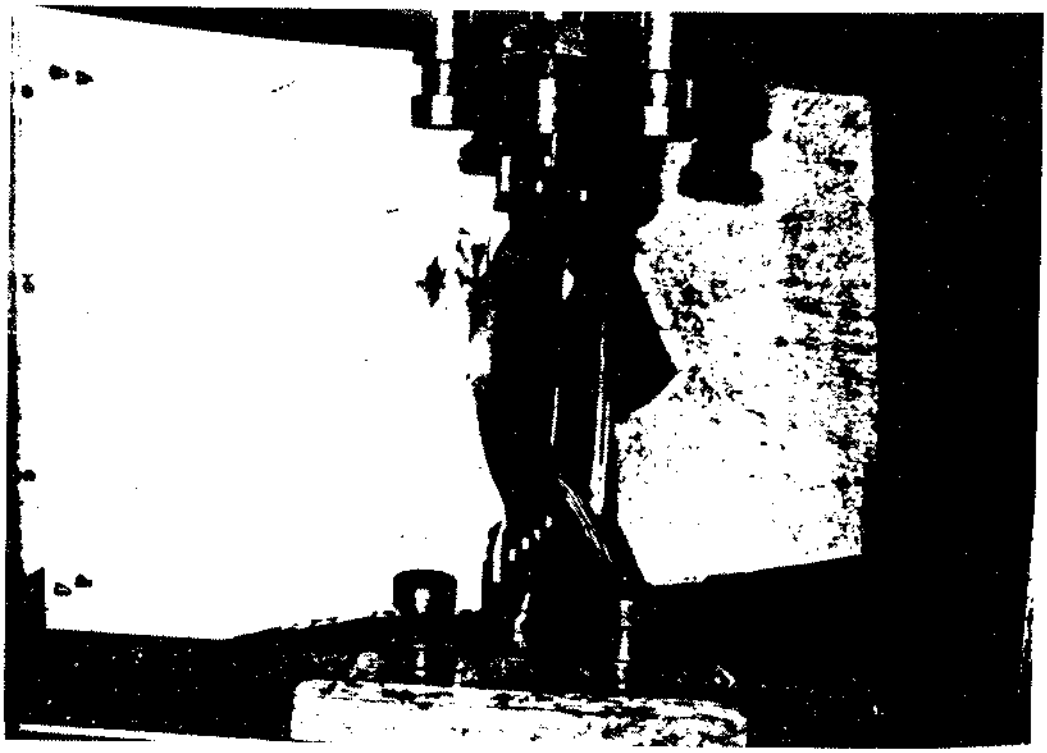

Figure 9

Static blades under load installation
Dammages encountered
(Photo CEPr 86 ...)

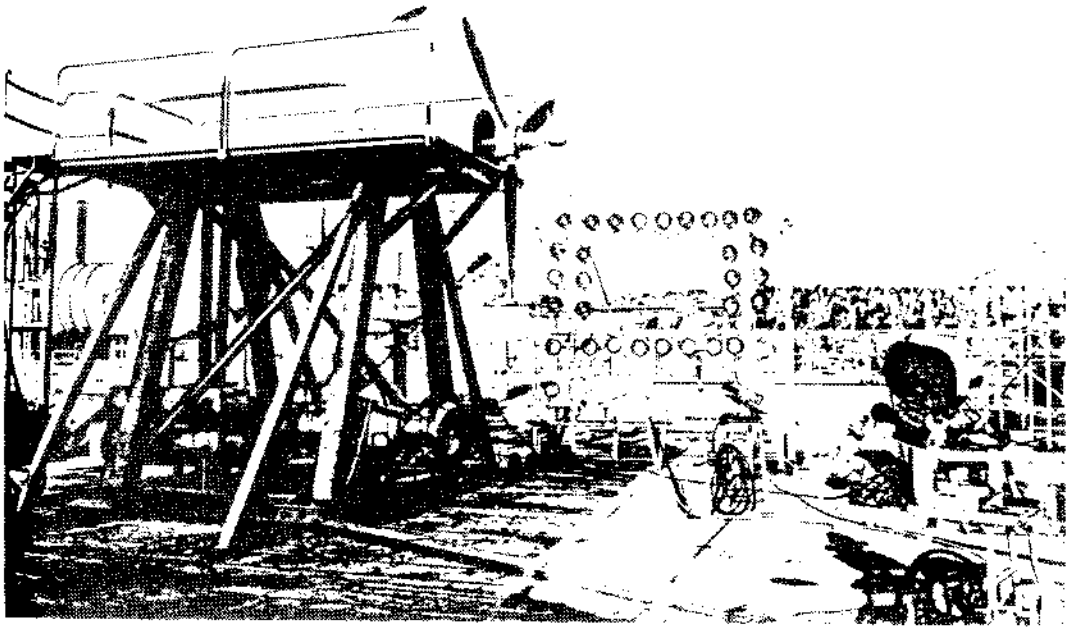

Figure 10

TX rig Propeller test installation
BASTAN Propeller campaign
(Photo CEPr 85 211)

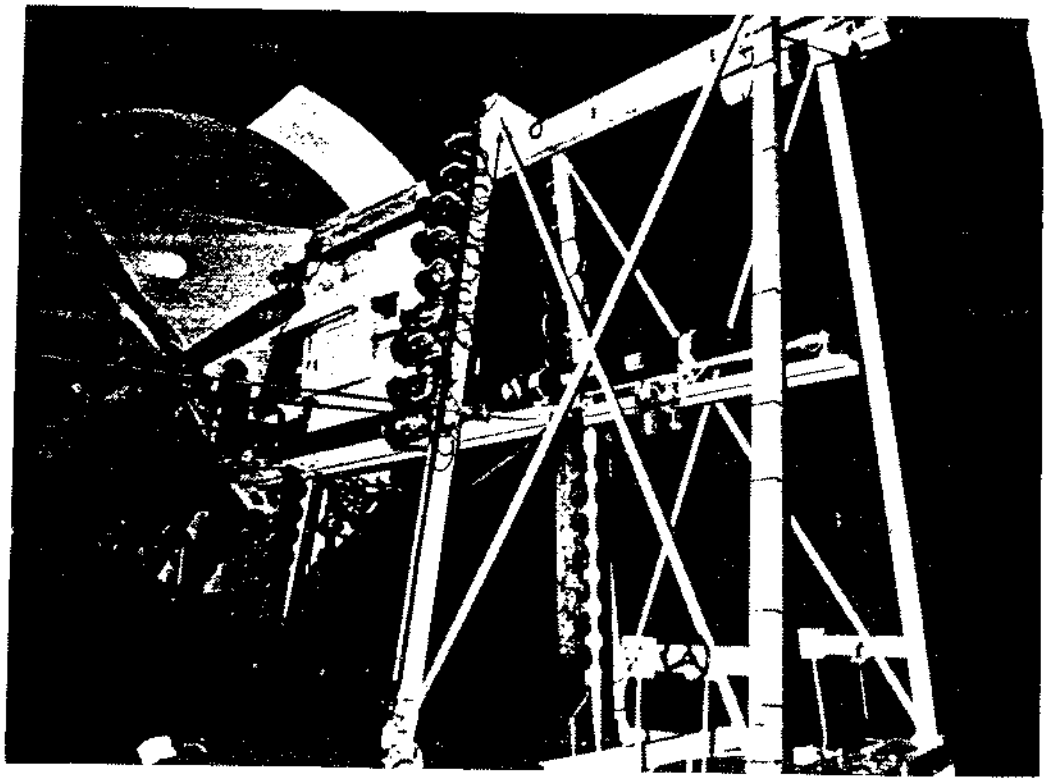

Figure 11

H0 rig Propeller test installation
TRANSALL Propeller qualification campaign
(Photo CEPr 88 5566)

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