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RAIN AND DEICING EXPERIMENTS IN A WIND TUNNEL

Guy Fasso

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16. Abstract

Comments on films of tests simulating rain and ice conditions in a wind-tunnel, with the aim of studying efficient methods of overcoming the adverse effects of rain and ice on aircraft. In the experiments, lifesize models and models of the Mirave IV aircraft were used. The equipment used to simulate rain and ice is described. Different configurations of landing and takeoff under conditions of moderate or heavy rain at variable angles of incidence and of skipping and at velocities varying from 30 to 130 m/sec are reproduced in the wind-tunnel of Modane. The risks of erosion of supersonic aircraft by the rain during the loitering and approach phases are discussed.

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RAIN AND DEICING EXPERIMENTS IN A WIND TUNNEL[1] */1

Guy Fasso

INTRODUCTION

The effectiveness of equipment for combatting rain and ice on aircraft is an important factor for safety during low velocity flight and low altitude of zero altitude flight. These flight phases can become critical because of bad weather. Flight tests which involve deliberate involvement of difficult conditions imply certain risks. If these tests constitute the final proof for performance quality, they cannot be conveniently used for testing equipment, for comparing various solutions or variations and for developing specifications for use. On the other hand, phenomena related to flight under poor conditions are not well suited for simulation on a small scale, and special equipment can never be modeled by valid small scale models.

Therefore, it is useful to perform wind tunnel tests on real aircraft equipment or large scale equipment. This equipment will have anti-icing and anti-rain equipment. Simulated flight conditions will be used which are as realistic as possible. There will be facilities for reproducing or varying these conditions and the tests are of course completely safe.

The films which we will now demonstrate the possibilities offered by ONERA at the large wind tunnel of the Modane-Avrieux

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[1] ONERA. (National Aerospace Research and Study Office). AFITAE (French Assn. of Aeronautics and Space Engineers and Technicians) Paris, May 29-31, 1967. 8th International Aeronautical Congress. Film Presentation.

*Numbers in margin indicate pagination of foreign text.

Test Center for simulated icing and rain tests.

ICING TESTS ON FULL SCALE AIRCRAFT COMPONENTS

Comment

Winter is particularly severe in the high valleys of the Maurienne region, where the Modane-Avrieux ONERA Test Center is located.

These severe climate conditions have been used to advantage for icing tests of large scale aircraft components in the large S1.MA wind tunnel.

Special equipment was developed for producing artificial clouds in a flow which surrounds the model.

The pulverization grid had profile bars and carries 90 NAPIER injectors which are supplied with water and compressed air.

The annular air inlet pulverizes the water jet coming from the central drop distributor. The drops are 15-25 microns in diameter.

In the measurement chamber of the test section, the test director controls the maneuvers of the installation and follows the recording of measurements. While he is doing this, he can observe the icing process through portholes.

There are control and command units installed for controlling icing and deicing.

The generator for the icing fog consists of a water circuit and a compressed air circuit.

The water is filtered and decarbonized. It is heated to an appropriate temperature. Flow meters control the distribution of the water in channels which supply the various parts of the pulverization grid.

The compressed air is compressed to 9 bars and is supplied from the general supply center. It is expanded to the desired pressure and electrically heated.

Then it travels to the injectors where it pulverizes the water to make up a cloud. The fineness and the density of the cloud are regulated by the air pressure and the water flow rate.

If the model to be tested has hot air deicers, they are supplied from the same general 9 bar circuit.

The deicing air flow rate which can reach 500 g/sec, is controlled by a manometer and a branched U tube which branches to a Venturi tube. An electrical controlled panel controls an 85 kW heater which can heat this air to 200°C. This air then reaches the deicing circuits of the test wing.

The installation also allows testing of any other kind of deicing equipment.

In the case of a pneumatic deicer, a pressure modulater controls the arrival of the air at the deicing chambers. This air can then be reheated when passing through, if the "aircraft" conditions require this.

The electrical deicers can be supplied from the present electrical panels by using transformers and electrical converters.

A multitrack recorder indicates the deicing and pulverization air temperatures which are separately controlled by twin electrical panels. In order to avoid the freezing of the water in the grid, the pulverization air is heated to close to 100° at the beginning.

From the control panel, the air in the water is directed to the carriage which supports the test section using heated tubes.

The air heater for deicing is installed in a caisson below the test section in order to avoid heat losses.

Before entering the wing, the circuit is divided and the butterfly valves control the distribution of the flow.

Because of its structure, the leading edge of the wing in effect has three deicers which are each supplied by a perforated tube.

The first one is installed in the root of the wing. The second is installed in the mobile tip and the third is installed in the fixed part of the leading edge located behind this tip. The warm air arrives in each zone below the forward heated part, and leaves through the rear.

A test starts. The test director is in contact with the control panel team.

The pulverization circuits are open and the water arrives at the injectors.

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Several operators are required in order to provide rapid variations of the fog concentration which simulates the passage of freezing clouds with greater or lesser density.

These conditions vary according to a carefully timed program.

The deicing air flow rate is adjusted to the required value. It is variable according to the test case study. The air pressure for pulverization and the water flow rate are changed for each "cloud change".

From the measurement chamber, the projectors are illuminated for taking photographic pictures.

When the deicing flow rate is reduced, the frost appears gradually.

The frost will now cover a large part of the wing which will modify the shape of the articulations and the profile of the tip.

The test director announces the measurement point. The photographic apparatus fixes the appearance of the frost. The temperatures at various points of the wing and the circuits are recorded automatically.

The operators of the command block perform different regulation functions.

The frost deposition will slightly modify the aerodynamic forces applied to the wing; their value is measured by the wall balance.

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Soon, an automatic apparatus which is more complex will replace the manual command now given by the operator for this first series of tests.

The ice crystals melt under the effect of the air which arrives at 200° in the deicing units.

The frost which occurs on unprotected parts is eliminated in a few seconds from the leading edge of the wing.

The record of the test collects results obtained and then determines the efficiency of the deicing unit tested.

In this new test, the pneumatic deicing unit eliminates the ice formed at the leading edge of the empennage by a purely mechanical action and not by thermal action as in the previous test.

The components of the aerodynamic forces are always measured and recorded automatically, but there is no longer any room for measuring the temperatures of the cover.

The operation is cyclical. The frost is deposited over a predetermined time, then the deicer inflates and breaks up the ice formed.

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The cycle is repeated by varying the rhythm of operation or by changing the deicing units according to the program.

Using these installations, which have now been thoroughly tested, the ONERA now has available for designers at the Modane Test Center, a certain and convenient test facility for deicing systems. This will allow aircraft to perform their mission no matter what the weather is.

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Since this film was made, several tests have been performed and among them icing and anti-icing tests of a radome with large dimensions. The present installation, not as beautiful as the one you will see, requires less personnel but provides greater control in the sequences of flight under various icing conditions. In spite of the limitations of use imposed by nature, considering that favorable conditions for icing tests only occur during 30-40 days during winter, and for a few hours over each one of these days, the information provided by these tests has been found to be very useful. It has allowed one to avoid performing many hours of flight tests.

We believe that the same ~~is true~~ for the installation which simulates rain which will be discussed in the following film.

RAIN TESTS ON A LARGE MODEL OF THE "MIRAGE IV" AIRCRAFT

In the large Modane-Avrieux wind tunnel, a device allows one to study the problems of visibility which occur for the pilot of an aircraft due to rain. It has been established in one of the test sections.

The model is installed behind the system and it reproduces the forward part of the fuselage of the Mirage IV aircraft at full scale.

For certain tests, the model can be placed in a sideslip condition by displacing the extremities of the large tube on its support, which is the main fixation axis.

The pilot is enclosed in his cockpit and can observe visibility through the windshield for the various flight cases, especially for takeoff and landing.

The corresponding configurations are simulated by controlling the incidence angle between 2.5 and 14° and by controlling the wind tunnel speed.

The test director gives his orders to the operators in charge of controlling the rain device from a measurement chamber close to the test section.

Approximately five meters upstream from the control station, the ejection grid distributes the rain over the front surface of the model. The water emerges from 7 interchangable injectors and flows through the central installation through a canalisation pipe inside the mast. The transmission of the command for cyclical orientation of the injectors also passes through the mast. A motorised system allows control of the height of the grid. A motor drives the animation cam and the command arm which communicate their spiral motion to the injectors.

A pump delivers the pressure and the flow rate required for the rain intensity under study, and is connected to a reservoir.

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A rain analyzer at the level of the windshield of the model allows calibration of the three rain intensity ranges considered for the test:

- moderate
- strong
- and violent.

This recorder essentially consists of an obturator and a striated drum, over which an aluminum ribbon passes. When the obturator is opened, the raindrops impact on the thin aluminum film and leave their impression there.

This recorder allows one to define the type of rain obtained as a function of number and diameter of the impacts: density and drop size.

For large incidence angle configurations of the model, the ejection grid is set in a frame.

The wind tunnel reaches the desired condition. The test section orders the start-up of the water pump.

In order to form drops without pulverization, the pressure has to be strictly related to the wind tunnel speed, a maximum of 140 bars at 130 meters/sec.

An operator starts up the animation system of the ejection grid.

Driven by an electrical motor, the pilot mechanism makes a command arm carry out a conical spiral motion with return to the center within two seconds. It is supported by a cam.

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A double articulated system provides transmission of the two components of this motion, incidence and separation, to each of the injectors with adjustable angular amplification ratio.

As we will see, the real cam turns around its axis at 4 rpm. For each pass, the rain body never covers the trace of its predecessor. Each injector provides uniform distribution of the drop over a surface of 0.25 m2 at the height of the windshield.

Depending on the type of rain simulated, the drop diameter varies between 0.8 to 2 mm and ejects the water through orifices with a diameter of 1/2 of that of the drops.

The water content varies between 0.3 to 3 grams per m3 of air.

A magnetophone records the comments of the pilot. Using a previously established code, the pilot reports the visibility conditions in various directions on a diagram which shows the contours of the windshield.

As a basis of these observations, the pilot has a certain number of references upstream of the model. At about 65 meters, there are white bands drawn on the blading of the wind tunnel angle. Somewhat farther away, incandescent lamps simulate the runway beacons. Finally, the ejection root itself is painted in white.

The pilot sits back in his seat and completes his observations using cinematographic recording.

A 35-mm camera having a wide angle lens takes the place of the head of the pilot and films the entire windshield at a frequency of 24 images per second.

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The observations and drawings of the pilot, the cinematographic pictures and magnetic recordings are repeated for each measurement point.

The various landing and takeoff configurations under moderate, strong and violent rain conditions with incidence angles or side-slip angles which vary and velocities between 30 to 130 meters per second can be reproduced as requested in the large Modane wind tunnel, depending on the requirements of the designers:

- moderate rain, taxiing on the ground
- same conditions, violent rain
- maximum incidence, higher velocity, landing through moderate rain
- and under the same conditions, with violent rain
- for strong rain, taxiing on the ground with increasing velocity: 31 to 75 meters per second,
- effect of strong side slip.

For all these critical cases, the pilot knows in advance what he will see during flight.

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CONCLUSION

It is certain that the installation which has just been presented can be improved, in particular by increasing the distance between the ejection grid and the tested windshield. However, it has already allowed test pilots at the flight test center to obtain precise information about visibility through windshields during rain. These pilots have actually made observations in the cockpit seat. It would not be possible to simulate other bad weather conditions, such as snow or hail, if designers had to resolve problems in these areas.

Before finishing my discussion, I would like to mention the erosion risks of super-sonic aircraft due to rain during holding an approach, that is, at relatively low Mach numbers. Severe damage can be caused by the rain to the sensitive parts of the leading edge in only a few minutes of flight under these conditions. This has been noted by designers. We believe that we are now able to help them using an installation which has been in operation for some time in another Modane wind tunnel: the blowdown wind tunnel S3.MA. There the rain is simulated at Mach numbers between 0.6 and 0.8. The drop diameter corresponds to moderate to strong rain, the water content is substantially higher than in natural rain. This means that the same erosion effects can be obtained over shorter times, that is, accelerated erosion tests can be performed.