# INTERNATIONAL AIRCRAFT SYSTEMS FIRE PROTECTION WORKING GROUP

# INTERNATIONAL FIRE REPLACEMENT WORKING GROUP

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## PRESENTATION ON: FUEL TANK EXPLOSION PROTECTION

**Presented by:**

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## Abstract

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The paper describes an experimental work carried out in the crash test laboratory of the Aerospace Department of the Politecnico di Milano. Several crash tests have been performed to analyse the behaviour of helicopter fuel tanks when filled with water and expanded aluminum foils. Accelerations and pressures have been measured to compare the behaviour of the tanks with and without these particular filler. Results of the work show how the expanded aluminum foils (already known as efficient passive explosion suppression media for aeroplanes fuel tanks) greatly reduce the leakage of the fluid in case of impact and subsequent failure of the tanks; a reduction of the pressure increment, caused by the movement of the fluid towards the impact area, has been noticed too. The experimental data will be used in the future to validate a numerical model of the tank with the filler, to simulate different impact scenarios and further study the dynamic of both the fuel tanks and the filler when subjected to high decelerations or crashes.

## INTRODUCTION

Fuel tank explosion resulting from ignition of vapours by various means is a major cause of aircraft loss. Over the years, many concepts which seek to prevent or suppress such explosions have been explored. Among these a particular expanded aluminum foil has been investigated for several years by a performance and qualification test program to meet the Military Standard MIL-B-87162A (USAF).
The purpose of this research was to study the effect of the filler on the fuel tank in case of a crash event. Failure of the tank or leakage of the fuel resulting in explosion of an aircraft would vanish the great efforts that have been made, in recent years, in the design of more crashworthy aircraft systems, with an eye to reduction of fatalities and serious injuries in survivable accidents.

## EXPERIMENTAL TESTS

In the first phase of the research, two dropping tests on a small box filled with water were carried out, in accordance to the Aviation Regulations, using the dropping tower of the Aerospace Department of the Politecnico di Milano. These tests provided first information on the effectiveness of the filler showing less leakage when the box was filled with the expanded aluminum foil.
The next step was to perform crash tests on a real fuel helicopter tank. These tests were carried out using the *deceleration sled facility* (see Fig. 1) of the Aerospace Department of the "Politecnico di Milano".

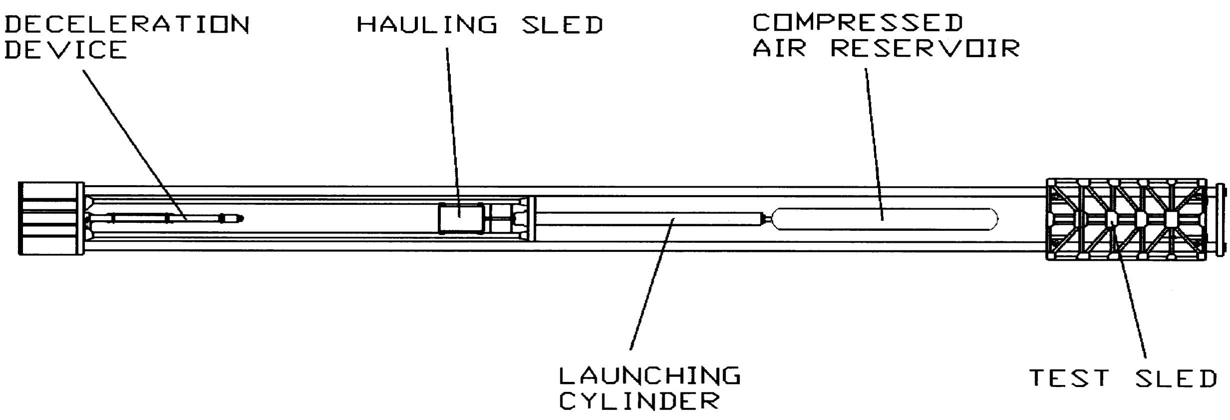


**Fig. 1 - Deceleration sled facility**

In this facility the items to be tested are mounted on a sled running on two horizontal rails. The initial velocity is reached by means of a compressed air piston that pushes the hauling sled which is connected to the test sled with a steel cable running over a series of pulleys. A rod under the test sled provides a mean for the braking phase. The coasting space is about 10 m and the initial acceleration is less than unity (in g's).
A test sequence can be divided in different phases. In the first phase the launching cylinder is prepared to give the required push to the hauling sled by compressing the air to the desired pressure. High values of kinetic energy can be accumulated without the piston moving from its start position. When the desired air pressure is reached in the reservoir, a set of valves, at the left side of the launching cylinder, are opened resulting in a pressure drop in the cylinder that moves the piston from its initial position. The braking phase is the most delicate phase in the whole sequence because the desired impact pulse shape must be set up. The braking system is comprised of a cylinder in which two moving plates are present. The first separates the cylinder in two chambers in which oil and nitrogen are let in respectively. The second plate prevents nitrogen from coming out. The chambers are in communication with an accumulator in which oil and nitrogen are separated by a membrane. Oil draws in the accumulator by means of a flow control valve . To obtain the desired deceleration pulse shape over time, adjustments of the plate position , the initial oil and nitrogen pressure and the head loss in the flow control valve can be made. At the beginning of the test, all the chambers and the accumulator are at the same pressure. When the penetrator enters the cylinder, passing through a ball bearing, the compression of the nitrogen in the chamber starts. The separation plate moves from its original position and the oil begins to flow into the accumulator. As soon as the rod reaches its final position, the ball bearing, being in a conic housing, prevents the rod from striking back.

To perform the tests on the fuel tanks two wooden plates were mounted, one on the sled and one at the impact area, to allow the movement of the fuel tank during the braking phase (see figures from 2,3 and 4). Two L shaped profiles were installed on both the plates to maintain the direction of the tank motion within a small angle. When the sled was at its final stop position, the distance between the two plates was less than 1 cm.
Three mutually perpendicular piezoresistive accelerometers on the top of the tank and two piezoresistive pressure transducers on the front left side and the back side of the tank were mounted (see figures 5,6 and 7)

**Fig. 2 - Test equipment: sled view.**

**Fig. 3 - Test equipment: sliding and impact surface view.**

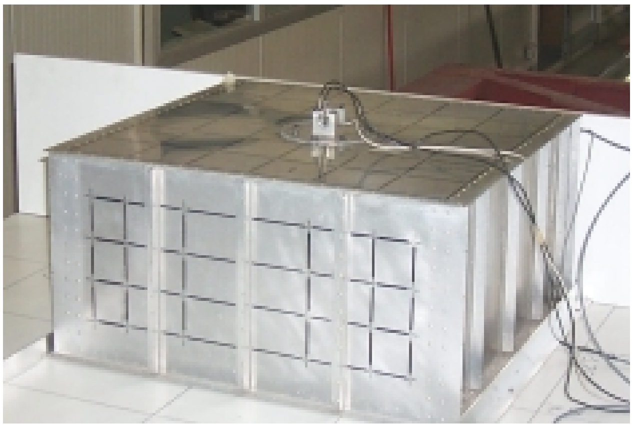

**Fig. 4 - Test equipment: global view.**

**Fig. 5 - Test equipment: top side acceleration transducer.**

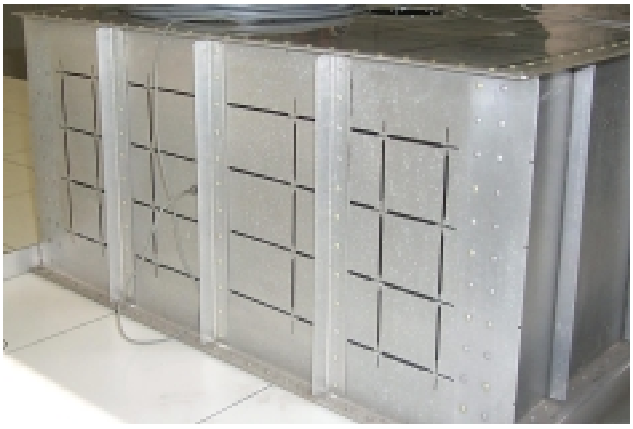

**Fig. 6 - Test equipment: right side pressure transducer.**

**Fig. 7 - Test equipment: back side pressure transducer.**

During the impact phase data acquisition systems and a STALEX high speed camera were running. The data, sampled at 12500 Hz and filtered during the test, were:

- sled position;
- sled velocity;
- sled acceleration;
- fuel tank velocity at impact;
- fuel tank accelerations;
- water pressure.

Data was digitally filtered after the test at the prescribed filter class.

## RESULTS

The following figures show the comparison of the accelerations curves of the fuel tank and the pressures curves of the water measured during two tests with and without the filler.

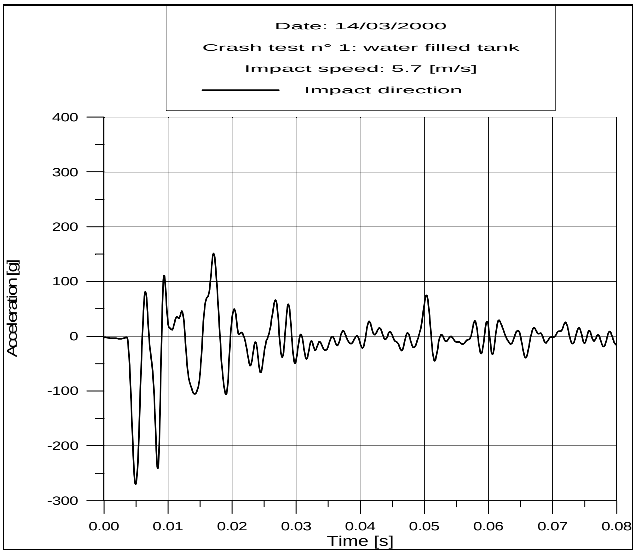


**Fig. 8**

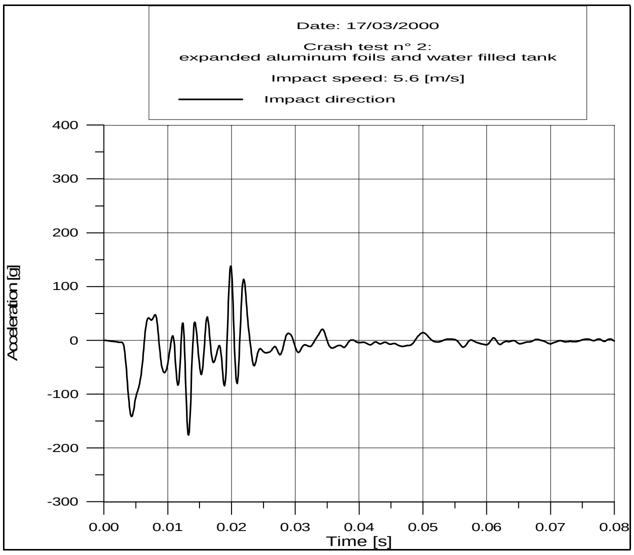


**Fig. 9**

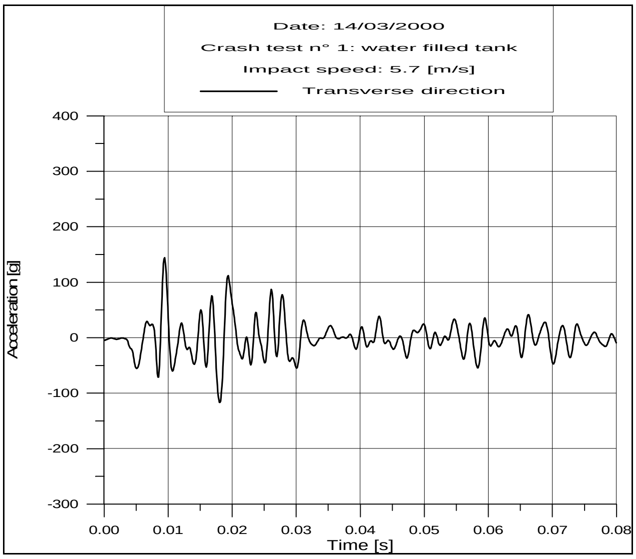


**Fig. 10**

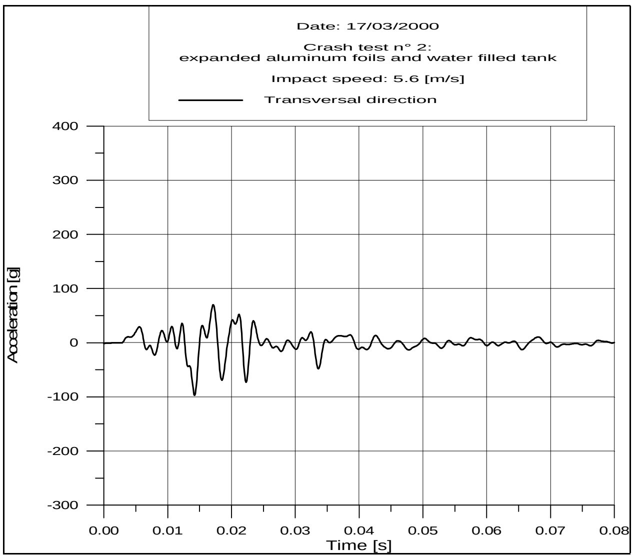


**Fig. 11**

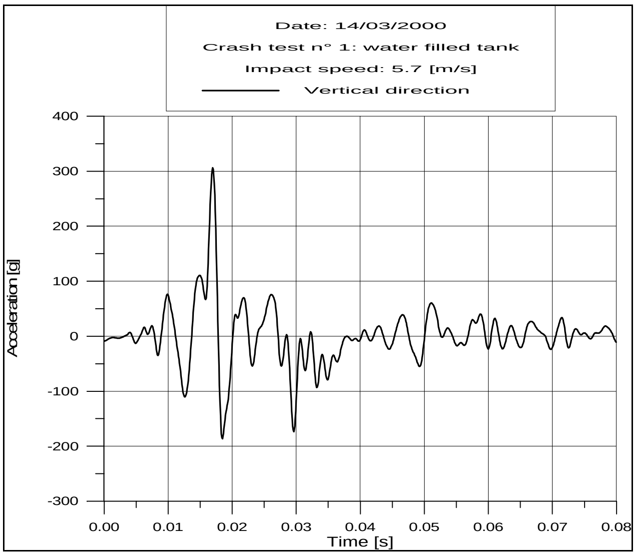


**Fig. 12**

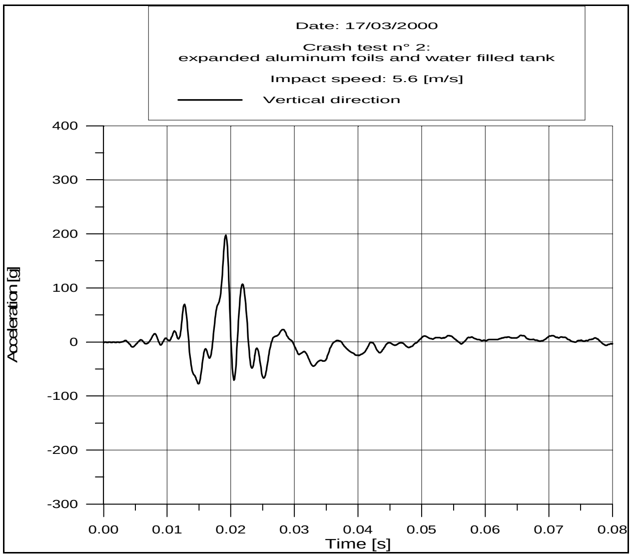


**Fig. 13**

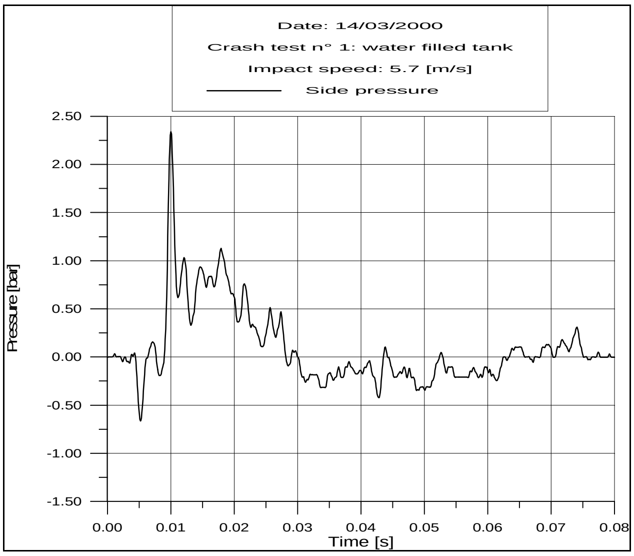


**Fig. 14**

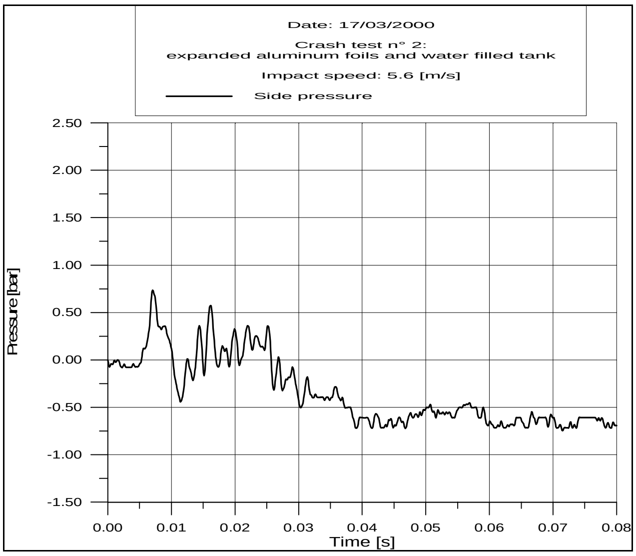


**Fig. 15**

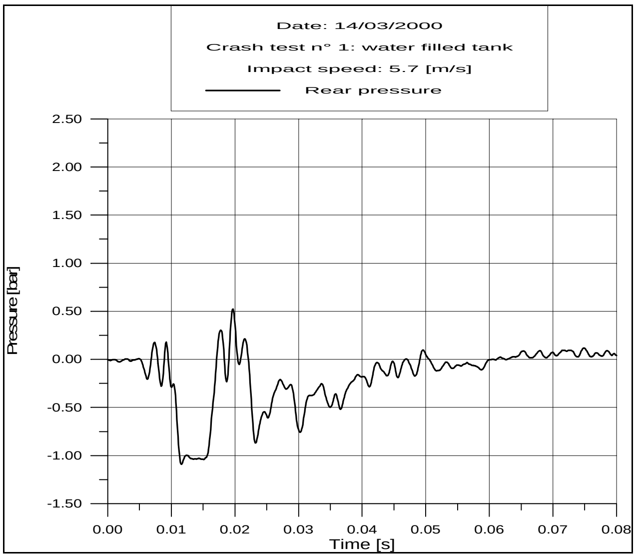


**Fig. 16**

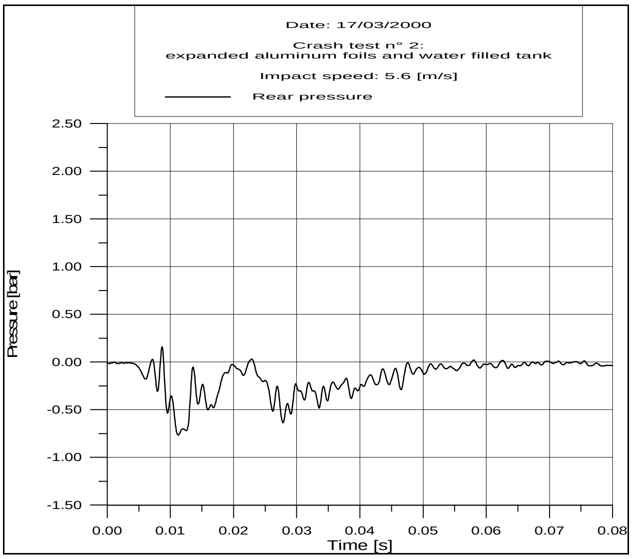


**Fig. 17**

The following pictures show the item tested after the tests.

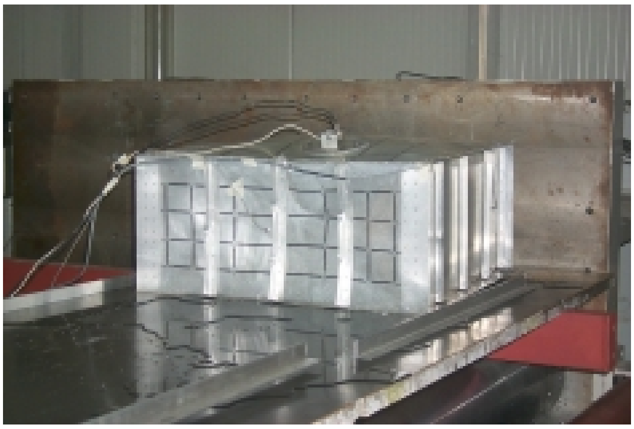

**Fig. 18 - Without filler rear view.**

**Fig. 19 - With filler rear view.**

**Fig. 20 - Without filler top view.**

**Fig. 21 - With filler top view.**

**Fig. 22 - Without filler side view.**

**Fig. 23 - With filler side view.**

## CONCLUSIONS

An extensive experimental investigation on the effect of expanded aluminum foils in case of fuel tank crash was performed. Results clearly show a reduction in acceleration peaks, pressure peaks, deformations of all the faces of the tank and leakage of the fuel levels when the expanded aluminum foils were used.
In the future, dynamic (high decelerations) and crash tests will be carried out on different tanks. Different fillers should also be used to have a better comparison between them.
All the data from the tests will be used to validate a numerical model of the tanks with the filler to better analyse their behaviour in different impact scenarios.

## ACKNOWLEDGEMENTS

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