

Development of a small scale burnthrough test equipment

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Abstract

Fire entering into the cabin by burning through the fuselage has been observed in some accidents of commercial aircraft. As a result, numerous research programs have been initiated by the CAA and FAA to study this issue. Full scale and medium scale tests have been conducted to investigate ways of improving the burnthrough resistance of aircraft fuselages. As a complement to full and medium scale tests, the need for a small scale test has been identified to evaluate materials themselves.

This paper describes the test equipment developed at the Centre d'Essais Aéronautique de Toulouse (CEAT). Developed in the same way as the cargo liner burnthrough test, it consists of a kerosene burner adjusted to deliver a flame of 20 W/cm² and 1100°C and a 1m² sample holder attached to a 1m³ smoke chamber. The first results and future developments will be presented.

Introduction

In survivable accidents of commercial aircraft, a significant number of deaths is caused by the effects of fire. The investigations conducted after the accident at Manchester Airport in 1985 show that the external fuel fire entered into the passenger cabin by burning through the fuselage skin(1).

As a result, numerous studies have been initiated on this subject in the UK and in the US. Series of large scale(2) and medium scale(3) tests, supported by the FAA and the CAA have been conducted to investigate the following issues :

- the delay for an external fuel fire to enter the cabin through the fuselage
- the most vulnerable areas of the fuselage
- the fire entry paths into the cabin
- the ways of improving the burnthrough resistance of fuselages.

As a complement to full scale and medium scale tests, the need for a small scale test has been identified(4) to be used as a screening device for evaluating aircraft materials themselves. This small scale test equipment should be developed in the same way as the FAR 25 burnthrough test method for cargo liners and should meet the following objectives :

- good correlation with medium and full scale test results
- easy to duplicate
- low cost of use and fabrication
- be applicable to a large range of materials and design features.

In this paper, the small scale test equipment developed at the Centre d'Essais Aéronautique de Toulouse will be described. Then, first results and future considerations will be presented and discussed.

General description of the small scale test rig

The small scale test equipment developed at CEAT takes inspiration from the design of the test equipment used to demonstrate the compliance of cargo liners with the FAR 25 fire containment requirements. It basically consists of (see figure 1) :

- the 2 gph oil burner modified to reach appropriate flame temperature and heat flux
- a specimen holder
- a smoke chamber

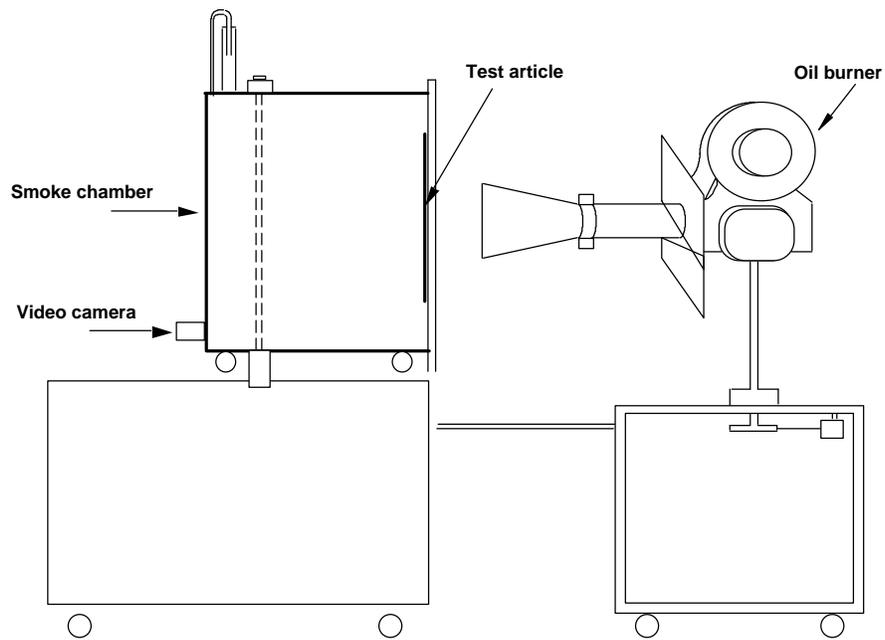


Figure 1 : Small scale burnthrough test rig

The detailed characteristics of each component are given below.

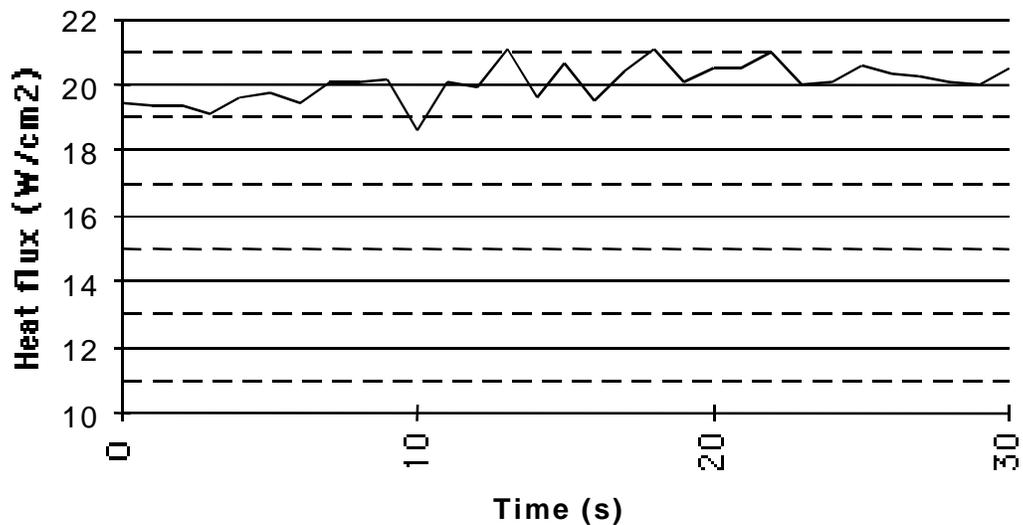
Characteristics

Fire source

Considering existing data on large external fuel fires, as reported by H. Webster(2), the kerosene burner was modified to deliver a flame at 1150°C and 200 kW/m². To reach these levels of temperature and heat flux the following modifications were undertaken :

- the existing nozzle was replaced with a 45° PLP 7 gph
- the air flow rate was adjusted to 10 m/s, measured with a vane air velocity sensor (diameter 90mm)
- the extension cone used in other FAA fire test standards was maintained

Flame calibration records are presented on figure 2.



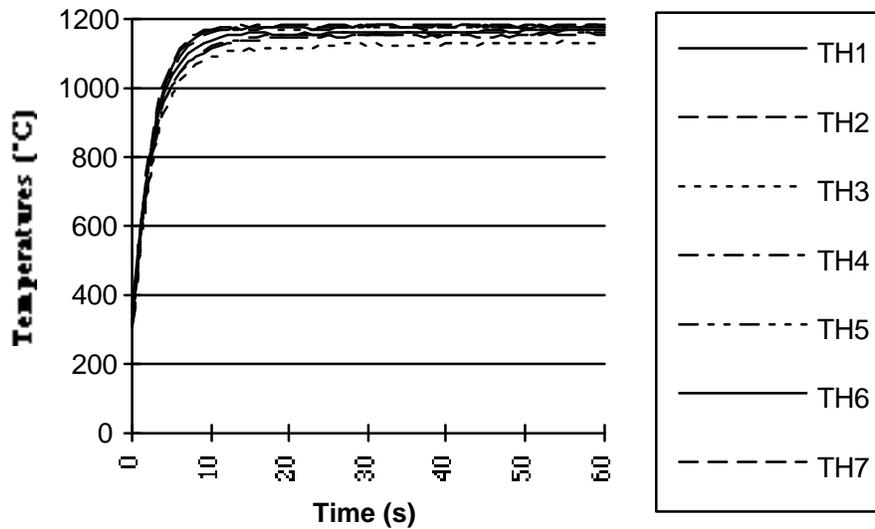


Figure 2 : flame calibration records

Specimen holder

The specimen is held in the vertical position. The specimen holder consists of a 1m x 1m steel frame in which the test article is attached to a metallic inner frame. The specimen dimensions can be adjusted from 400mm x 400mm up to 1m x 1m.

Smoke box

Previous experiments conducted at CEAT(5) and other published test data showed that flame penetration was not the only potential threat to be considered. Smoke and toxic gases released before the fire entry into the cabin had to be measured and data taken into account for the study of burnthrough. Thus, it was decided to equip the burnthrough test rig with a smoke box allowing smoke measurements and gas sampling.

The smoke box has a volume of 1m³ and is fitted to the back side of the specimen holder. It is equipped with :

- a smoke measurement device adapted from a NBS smoke chamber system
- a sampling device for gas analysis
- a video camera positioned behind a protection window to observe the degradation on the back side of the specimen.

A sketch of the smoke chamber is presented on figure 3.

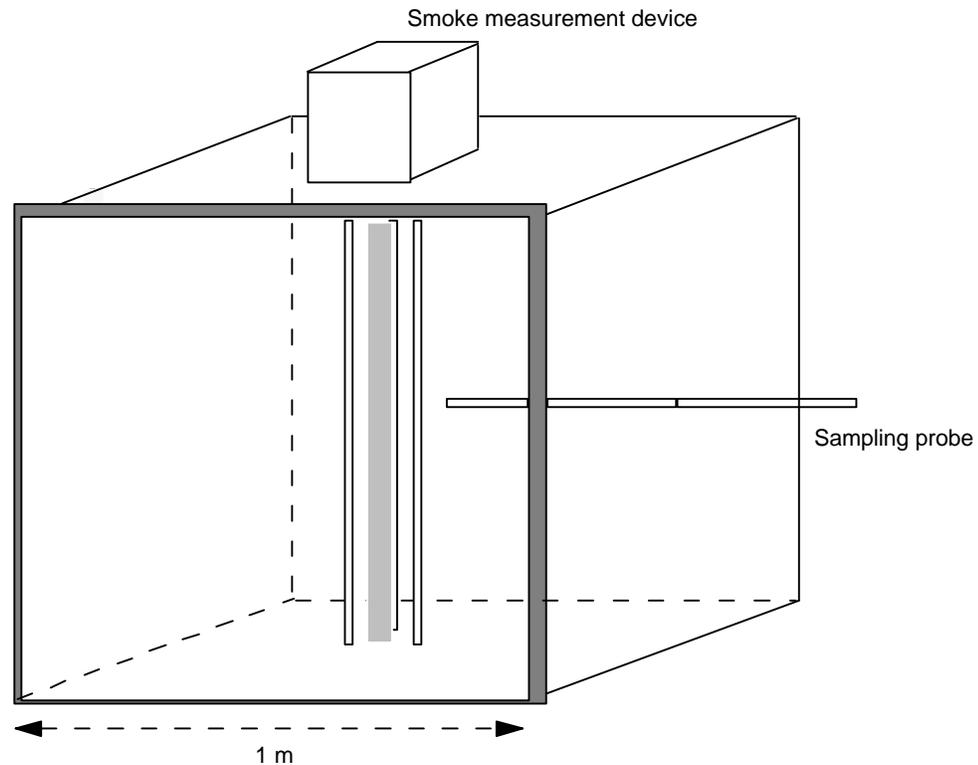


Figure 3 : 1m3 Smoke chamber

Test procedure and definitions

For each test, the oil burner flame is applied to the specimen after a warm-up period of 2 minutes. Burnthrough time is defined as the time when the oil burner flame itself penetrates the specimen.

Tests on aluminum sheets

In a first attempt, series of tests have been carried out on 2 millimeter thick aluminum sheets in order to compare measured burnthrough times with published tests or accident data. Burnthrough of the aluminum skin itself was observed after 30 to 60 seconds as reported by H. Webster(2) during large external fuel fire tests on aircraft fuselages. At the FAA TC, full scale burnthrough tests on fuselage materials showed that the fire burnt through the aluminum skin within 30 seconds(6). In the same way, medium scale tests conducted at Faverdale on a 2.0mm aluminum panel gave a burnthrough time of 43 seconds(6).

Tests conducted on 2.0mm aluminum sheets using the small scale burnthrough test rig developed at CEAT showed burnthrough times ranging from 30 to 40 seconds.

Other tests were conducted on different grades and thicknesses of aluminum. As shown on figure 4, burnthrough times measured on 2.5 and 4.0mm thick Al 2017A (close to 2024 alloy) correlates well with results obtained on Al 5053 sheets in 1.0, 2.0 and 5.0mm thick. As already observed at Faverdale(6), burnthrough time increases as material thickness increases.

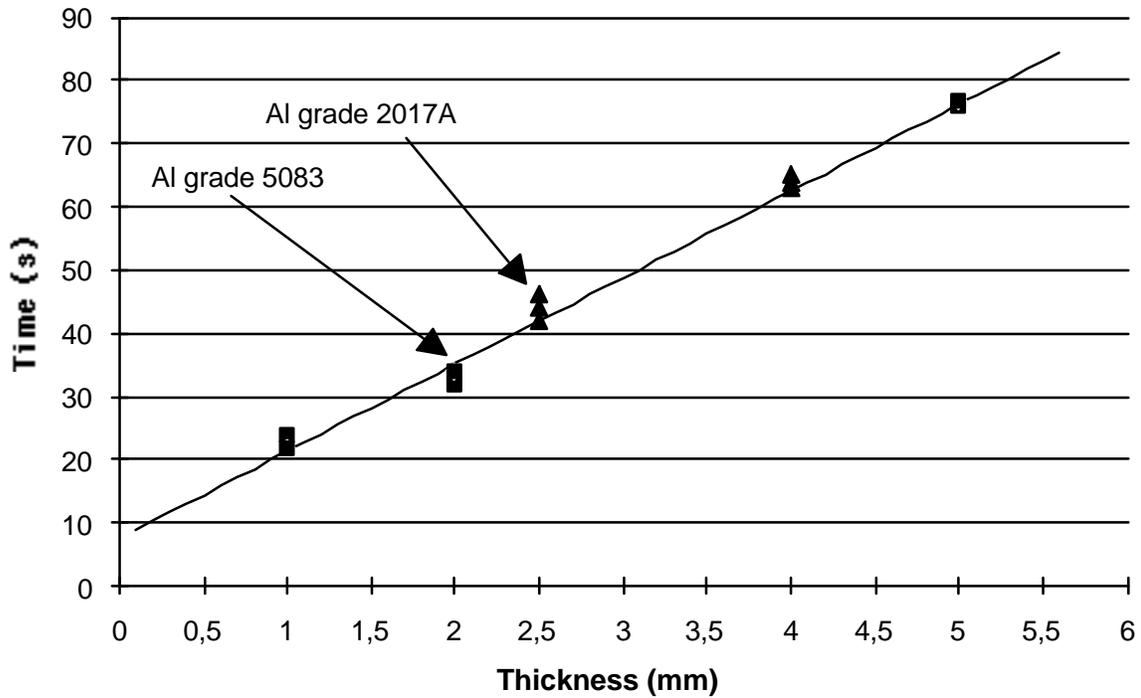


Figure 4 : Burnthrough time vs. Al thickness

Tests on current insulation materials

The performance of these tests led us to define a specific configuration of the test specimen. It was decided to associate the thermal acoustical insulation material with a 2.0mm thick aluminum skin (see figure 5). The aluminum skin is attached to the specimen holder, on the face inside the smoke chamber, with four steel fixtures. Each fixture is equipped with 2 pointed bolts to hold the insulation material. The dimensions of the aluminum skin are 600mm x 600mm and the overall dimensions of the test article are 700mm x 700mm including 50mm wide sealed edges.

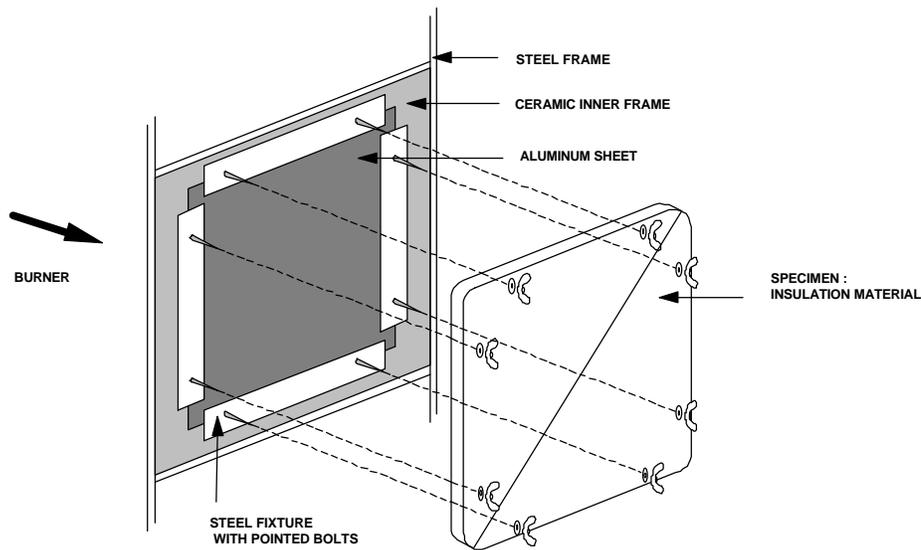


Figure 6 : Specimen holder for insulation materials

In a first attempt, a series of three tests were performed on a thermal acoustical system which consisted of 1 inch thick MICROLITE[®] encapsulated in TERIL[®] 34 polyester film, in association with a 2.0mm Al skin. Results were remarkably repeatable, see table 1.

Test n°	1	2	3
Mass before test*	100	116	100
Mass after test*	89	103	88
Mass loss (%)	11,0	11,2	12,0
Burn through time (s)	58	63	59
% light transmission at 90s	3	3	4

* : for insulation material only (batting material + film)

Table 1

Burnthrough times were close to 1 minute, which represents almost 30 seconds more than the aluminum skin alone. The measured optical density was close to 1.5, which also means about 3% in light transmission. Figure 7 shows graphs of optical density recorded for each test, curves are in very good correlation. This indicates that it is possible to include optical density data to the criteria used to evaluate the burnthrough resistance of fuselage materials.

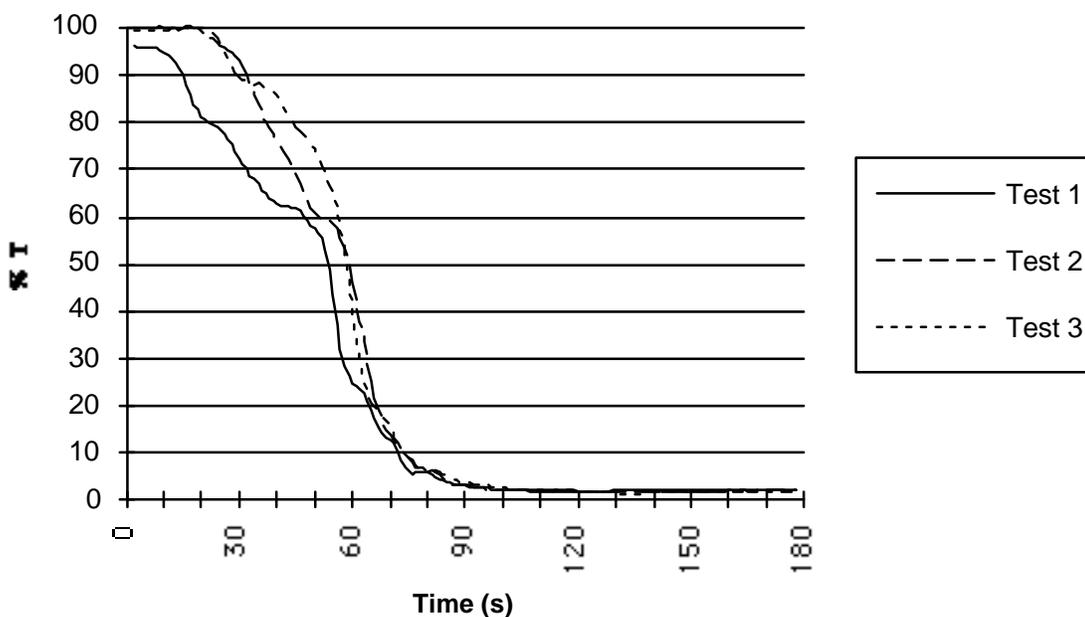


Figure 7 : Optical density records

Tests on other insulation systems

Tests were conducted using the test method described previously. Insulation systems were tested in association with a 2.0mm aluminum skin and mounted on our specific specimen holder. These experiments were conducted on eight insulation systems supplied by Orcon corp. These systems consisted of two types of insulation materials, MICROLITE[®] BMS 8-48R and ORCOBLOC[®] 302 in two different thicknesses, encapsulated in two different bagging films KN 80 and AN 18-R. Five specimens were tested for each insulation system.

Test procedure :

- the flame was applied to the aluminum skin after a warm-up period of two minutes
- the burnthrough time was determined using the video monitoring and a direct observation
- smoke density is recorded all along the test sequence
- sampling for gas analysis is started at burnthrough time or after 90 seconds if burnthrough exceeds 90 seconds.

Test results :

Results obtained on MICROLITE[®] and ORCOBLOC[®] 302 are presented in tables 2 and 3.

MICROLITE BMS 8-48 R	Thickness 20 mm		Thickness 70 mm	
Film	KN 80	AN 18-R	KN 80	AN 18-R
Average Burnthrough time (s)	50	52	75	80
Range (s)	48 to 52	51 to 56	66 to 81	73 to 92
Average Mass loss (g)	15	12	37	38
HCN (ppm) at burnthrough time	60 to 100	50 to 90	30 to 80	30 to 60
HF (ppm) at burnthrough time	No	60	Traces	20
HCl (ppm) at burnthrough time	No	No	No	No
Smoke release (% light trans.)	13	13	50	4
at time (s)	50	52	75	80

Table 2

ORCOBLOC 302	Thickness 20 mm		Thickness 30 mm	
Film	KN 80	AN 18-R	KN 80	AN 18-R
Average Burnthrough time (s)	80	250	123	> 300
Range (s)	73 to 105	236 to 264	107 to 137	stop at 300 s
Average Mass loss (g)	35	72	63	120 at 300 s
HCN (ppm) at burnt. time or 90s	100 to 200	190 to 220	150 to 200	110 to 200
HF (ppm) at burnt. time or 90s	25	-	Traces	35
HCl (ppm) at burnt. time or 90s	No	-	No	No
Smoke release (% light trans.)	< 0,1	< 0,1	< 0,1	0,1
at time (s)	80	65	85	90

Table 3

Discussion

Burnthrough times measured on each configuration of both insulation materials were remarkably repeatable. It was observed that burnthrough time increased as insulation materials thickness increased. The influence of bagging film was not clearly determined for the MICROLITE[®] but for the ORCOBLOC[®] 302, burnthrough time was significantly higher for the polyvinyl fluoride than for the polyimide bagging film. However, full scale tests conducted at the FAA T.C.(7) showed opposite results.

Mass loss is directly related to burnthrough time, thus to the insulation material thickness.

Toxic gases : HCN presents the major potential threat. Even if further works have to be done for a better understanding of HCN production and its quantification, it was clearly determined, throughout these experiments, that ORCOBLOC[®] 302 released significantly higher levels of HCN than MICROLITE[®] insulation systems.

Smoke emission was measured at burnthrough time. One remarkable point was the low smoke emission of MICROLITE[®] encapsulated in polyimide in the 70mm thickness. It could be explained as follows : the polyimide film, as opposed to the polyvinyl fluoride film, does not melt until the flame impinges directly on it, so, less smoke is released before burnthrough. This phenomenon is not observed for the 20mm thickness. Smoke emission of ORCOBLOC[®] 302 is significantly higher compared to the MICROLITE[®] insulation since burnthrough time is longer. In some cases, complete obscurity (<0,1% of light transmission) is obtained before burnthrough. For example at 65 seconds for a 20mm thickness insulation material encapsulated in polyvinyl fluoride film.

Conclusion

As a complement to full scale and medium scale burnthrough test facilities, a small scale test equipment has been developed to be used as a screening device for evaluating materials themselves. Data on aluminum panels have shown that it correlates with medium and full scale test results. Considering its fabrication and the choice of its fire source, the assigned objectives have been met : correlation with large scale tests, easy to duplicate and low cost of use. Other labs have shown interest for this type of test equipment and the FAA Technical Center is already developing the same kind of apparatus.

Future developments

Regarding the test rig itself, it has been decided to tilt the existing vertical specimen holder at a 30° angle. This modification aims at producing a more realistic representation of the effects of a fire impinging the lower part of an aircraft fuselage.

Further test works are already planned to continue evaluating the resistance to burnthrough of aircraft fuselage materials such as advanced thermal acoustical insulation blankets or newly developed skin materials like composites. A large part of these investigations will be conducted in the scope of a research program led by Airbus Industrie. Furthermore, co-operation works with the FAA T.C. have been undertaken, they aim at defining common characteristics for a small scale burnthrough test device.

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- (4)- " Improved Fuselage Burnthrough Resistance during a Post Crash Fuel Fire " Document Fire Safety Section, AAR-422 FAA TC Feb. 22, 1996
- (5) - " Cabin Material Burnthrough " Test Reports N° S-90 4550/01 and S-90 4550/02 DGA/CEAT 1994

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(7) - “ Full Scale Test Evaluation of Aircraft fuel Fire Burn-Through Resistance Improvements ” - Timothy R. Marker and Constantin P. Sarkos F.A.A, William J.Hugues Technical Center. SAMPE Journal, vol. 33, N° 4, July/August 1997.