AN INVESTIGATION INTO THE BURNTHROUGH RESISTANCE OF FUSELAGE AND CABIN STRUCTURES

Darren C Dodd
Darchem Flare
Stillington
Stockton-on-Tees
TS21 1LB
England

ABSTRACT

A major threat in survivable ground accidents is an external fuel fire, which may penetrate the fuselage and threaten the lives of cabin occupants. Following the accident at Manchester airport in 1985 the CAA and FAA, as part of their on going programme to improve cabin safety, embarked upon a joint research project. The aim of which was to look at ways of improving the burnthrough resistance of aircraft fuselages with a view to delaying the ingress of fire and toxic gases into the cabin, thus increasing survivability time.

The CAA commissioned Faverdale Technology Centre (now Darchem Flare) to design and construct a reproducible heat source facility and medium scale test to evaluate the fire resistance of various fuselage sub assemblies (skins, floors, windows, etc.). Numerous tests have been carried out on a wide range of materials and fuselage systems. The results of recent testwork involving insulation system materials have provided important information about material burnthrough characteristics, with some materials showing superior burnthrough resistance. However it was reasoned that if the potential of new materials are to be realised, then future testwork should not focus upon material characteristics in isolation, but should also consider insulation material attachment design and methodology. As a result Darchem Flare have developed a stylised aluminium skin and fuselage frame to test both insulation material and attachment system.

INTRODUCTION

The investigation into fuselage burnthrough as detailed in this paper is part of the CAA and FAA's on-going research programme into improving fire safety which has already resulted in several important regulatory changes over the last decade, as discussed by Hill and Povey (1993).

Most of these have been aimed at controlling the spread of fire through the cabin and reducing the harmful effects of flashover. This has been achieved primarily through the introduction of low heat release standards for cabin materials and fire blocking layers for seat cushions. Other changes that have been implemented help improve evacuation times by providing passengers with illuminated exit aisles in emergency situations and also by assuring that evacuation slides will not deflate when exposed to the high levels of radiant heat experienced during large ground fires.

An accident that highlights the significance of fuselage burnthrough resistance occurred in 1985 when a British Air Tours B737 was departing from Manchester International Airport in England. Just prior to take off, the Number 1 engine failed and ruptured the port wing fuel tank, igniting a large pool fire.

According to the Air Accident Investigation Branch (AAIB) report the extensive loss of life was attributed to a rapid fuselage burnthrough into the passenger cabin. Of the 131 passengers and 6 crew on board, 55 people lost their lives from rapid incapacitation due to inhalation of toxic emissions from the burning interior materials. One of the major contributory factors was the vulnerability of the aircraft hull to an external fire. The AAIB Report (1988) also speculates that the burnthrough occurred within 60 seconds of the aircraft coming to a stop. The catastrophic results of this accident are perplexing in that the fire was caused by an engine burner shell failure with no resulting loss of aircraft control or crash, the fuel involved in the fire was limited in amount, and the rescue and fire-fighting services responded rapidly.

In the wake of this incident and others the burnthrough resistance of fuselages is becoming increasingly more important especially within the context of future aircraft design and the advent of ultra-high capacity aircraft.

The complementary programme of study agreed between the CAA and FAA seeks to address two major concerns of structural fire safety:

1) The time taken for an external fuel fire to burnthrough the fuselage skin and insulation system and penetrate into the passenger cabin.

2) The increasing use of composite materials in the primary and secondary aircraft structure.

During the early phase of the joint research programme, it was determined that the development of a small or medium scale burnthrough test facility could be beneficial in investigating the issues surrounding fuselage burnthrough. A test facility that could replicate the full-scale conditions experienced in a post-crash fuel fire, would allow for quick and inexpensive testing of improved materials and/or systems, and also serve as a screening device for evaluating new materials under consideration.

The first stage of developing the burnthrough facility involved the definition of a heat source that was representative of real post crash fuel fire. This definition was based upon previous test work, accident data and theoretical calculations. The search for information to define the heat source was concentrated upon previous published test work. This published testwork was based upon previous studies of post crash fires and the study of general pool fires.

The values used were the average of the highest temperatures and heat fluxes taken from the previous experimental data and are given below.

Temperature	=	1150°C
Heat flux	=	160 kW/m^2
Gas velocity	=	2 m/s at 1150°C
Fire status	=	Fully developed
Profile of fire curve	=	Instantaneous rise to maximum level.

These parameters were then used as the basis for specifying the factors needed in designing a test facility to study the issues surrounding the burnthrough of aircraft fuselages. Whilst defining the heat source an opportunity arose to conduct an indicative test on a commercial aluminium panel. The panel started to burn through after 80 seconds with a furnace temperature of 950^{o}C, demonstrating that the basic principle of using a furnace to simulate a pool fire scenario was a sound one.

At this stage of developing the burnthrough facility the choice was one of scale. The history of small scale testing is such that it has evolved into a useful means of comparing physical properties such as flammability and ignitability. The tests are inexpensive and usually very repeatable. However it was considered that in order to encompass all the important factors desirable in a realistic burnthrough test, a new type of testing method would have to be developed. After considering the published test data as well as previous testing experience, it was decided that the best method of producing a controlled and repeatable heat source was to design and build a dedicated gas fired test unit. This led to the design and development of the medium scale burnthrough facility.

This paper documents some of the most recent burnthrough investigation testwork. Full details of previous medium scale burnthrough testwork can be found in Dodd et al (1994) and Dodd et al (1995). A discussion document by Dodd et al (1996) is also a source of useful information and seeks to focus the efforts of fuselage burnthrough research.

MEDIUM SCALE BURNTHROUGH FACILITY

Burnthrough Facility

The burnthrough facility, as shown in Figure 4, is a dedicated test furnace consisting of a mild steel frame and shell clad internally with 150mm thick ceramic fibre insulation. Its internal dimensions are 2m x 2m x 1.5m high. The furnace is powered by four 300 kW propane burners which fire tangentially to ensure that energy is transferred efficiently to the furnace wall. The floor of the furnace is brick-lined to provide the required heat energy, both convective and radiative, in the correct proportions. The air and propane gas supplies are driven to the furnace by a fan and a pressurised gas supply, respectively.

The roof of the furnace incorporates a manually operated sliding lid which when rolled back reveals a 1 metre square aperture on the top of the furnace. The sliding lid section has a plug type sealing action onto a 25 mm ceramic fibre gasket to ensure that no hot gases leak out during the furnace warm up period. The test piece is held in a frame 250 mm above this aperture and sliding lid. When the furnace is heated up to temperature and soaked, the insulated lid is rolled back, allowing instantaneous thermal assault to the test sample for the duration of the test. The results show that this method of storing energy and then releasing it provides the rise in a repeatable form.

Cold Sooting Facility

The burnthrough facility described above is a gas fired facility and burns with a relatively clean flame. In a real pool fire the presence of soot particles play an important role in the burnthrough process, altering the emissivity of the test sample. So in an attempt to replicate the conditions of a post crash fuel pool fire as closely as possible a method was devised to allow samples for burnthrough testing to be conditioned with soot. In order not to affect the burnthrough test itself a method had to be devised which was sufficiently gentle not to heat damage the sample. A ‘cold sooting’ procedure was devised.

The cold sooting facility comprises a modular racking system and is shown in Figure 5. A frame, into which the sample is placed, is laid across it. The sample frame has a runner at each corner that enables the frame to traverse smoothly along the racking system. A wire and pulley arrangement allows the sample frame to be moved along the length of the rig. The movement of the sample is controlled from outside the enclosure.

A tray is positioned centrally underneath the rig. The tray contains a strip of ceramic fibre material soaked in kerosene. A cover is positioned over the tray so that only a narrow strip of material protrudes. With the development of this cold sooting technique, materials can now be pre-conditioned to an appropriate emissivity representative of a large scale pool fire, before testing in the small scale facility.

Smoke Measurement

To quantify the smoke release from a particular sample tested in the burnthrough facility, the following arrangement exists. On one side of the central flue a light source is positioned and on the opposite side of the flue there is a photoelectric cell. The amount of light detected by the cell is represented as a voltage, the voltage being directly proportional to the light intensity. The amount of smoke released is then measured as the percentage reduction in light transmission.

PLAIN PANEL TESTING

Introduction

Results from both full and medium scale tests had shown that the aluminium skin could consistently provide at least 30 seconds of protection prior to melting. Once the aluminium melts this allows flame impingement upon the insulation system. It was reasoned that the material types and thicknesses of aluminium skin currently in use will, in all probability, continue to be used even in the next generation of aircraft. Therefore the focus of this phase of the investigation on burnthrough was on extending the time from when the aluminium skin melts until the time when fire enters the cabin. Specifically, attention was focused on thermal-acoustic insulation which testwork had demonstrated could be an effective fire barrier so long as it remains in place. For this reason, it was the intention to study both the methods of attachment and the flame resistance characteristics of the insulation.

Test Set Up

All the test pieces were made up of two components, an aluminium panel and an insulation blanket. The aluminium was 1.6mm thick to the specification; alclad 2024-T3. All the aluminium panels were preconditioned to an appropriate surface emissivity using the cold sooting facility and procedure as previously described. For each test five thermocouples were positioned on the back face of the aluminium.

The insulation material tested comprised two types and three thicknesses. The two types of material tested were Microlite AA and Orcobloc®. Microlite AA is a fibre glass material with a density of 6.7 kg/m^3. This insulation was tested at both 50.8mm and 76.2mm thicknesses. Orcobloc® is an Orcon product designation for insulation batting made using RK Carbon Fibre Curlon® Fibres. Curlon® is comprised of heat treated oxidised polyacrylonitrile fibre and is similar in appearance to fibre glass but black in colour. The density of the material tested was 5.5 kg/m^3 and it was tested at 63.5mm thickness.

All the insulation materials tested were sealed in water resistant polymer bags manufactured by the Orcon Corporation. The coverings used were Orcofilm® AN-18R, which is a metallized polyvinyl fluoride film, reinforced on one side with polyester yarns and Orcofilm® KN-80 Kapton which is a polyimide film, reinforced on one side with nylon yarns.

For the tests the insulation blankets were positioned on the back face of the aluminium panel and five thermocouples were positioned on the back face of the insulation blanket. In addition a thermocouple was positioned 100mm above the centre of the insulation blanket to provide a cold side temperature measurement.

Results and Discussion

A summary of the test results is provided in Table 1.

Aluminium

As can be seen from the test results the burnthrough time for the aluminium tested is consistently in the region of 35 seconds with the exception of two tests. This burnthrough time is as expected and correlates well with earlier test work as described in Dodd et al (1994) and Dodd et al (1995).

Insulation

The results from the tests on fibre glass insulation similarly correlated with previous test work results. At 50.8mm thickness the fibre glass encased in polyvinyl fluoride film provided on average an additional 19 seconds protection following the burnthrough of the aluminium, giving a burnthrough time for the system of 55-56 seconds.

At 76.2mm thickness when again encased in polyvinyl fluoride film the protection afforded was an additional 18-21 seconds, giving a burnthrough time for the system of 55-60 seconds. It's also worth noting that once burnthrough had occurred the 76.2mm fibre glass lasted longer than the 50.8mm before collapsing completely. At 76.2mm thickness when encased in polyimide film the insulation provided an additional 40 and 43 seconds protection, giving system burnthrough times of 75 and 78 seconds respectively.

For the tests involving fibre glass the insulation was laid across the aluminium and weighted down at all four sides with mild steel angle. After preliminary testwork on other insulation materials where burnthrough times were greatly increased, it was concluded that this method of fixing, while suitable for tests of short duration, was unsuitable for tests involving insulation that survived for a number of minutes.

After discussions with the FAA on their large scale testwork it was decided that in order to keep the insulation in place, spring steel locking jaw clips would be used along the perimeter of the test sample. In this way provided the insulation test piece is large enough to overlap the test frame the test piece will remain in place for the duration of the test. The positioning of the jaw clips is such that they do not interfere with the test itself.

The subsequent burnthrough tests on the Orcobloc® insulation material produced impressive results. At 63.5mm thickness Orcobloc® encased in polyvinyl fluoride film resisted burnthrough for an additional 240 seconds following burnthrough of the aluminium, giving a system burnthrough time of approximately 270 seconds. When encased in polyimide film the insulation provided an additional 510 seconds protection giving a system burnthrough time of approximately 540 seconds.

Bagging Film
For the tests using polyvinyl fluoride film as the bag material for both the fibre glass and Orcobloc® insulation the results for burnthrough times were inferior to those using polyimide film.

Considering first the fibre glass insulation, with polyvinyl fluoride film 76.2mm fibre glass provided an additional burnthrough time of 19 seconds with polyimide film the time was 43 seconds, more than double.

Equally impressive results were obtained with Orcobloc® insulation. With polyvinyl fluoride film 63.5mm Orcobloc® provided 240 seconds additional protection and with polyimide film 510 seconds, again more than double.

Once burnthrough of the aluminium had occurred the polyvinyl fluoride film set alight allowing flame propagation to the cold side and was quickly consumed. In contrast the polyimide film displayed excellent fire resistance. No flaming occurred and the film remained in place on the cold side for the duration of the tests.

Considerations
This series of tests demonstrated that in changing from an aluminium skin insulated with polyvinyl fluoride encapsulated fibre glass to an Orcobloc® encapsulated in a polyimide film an improvement in burnthrough time from 55 to 540 seconds was potentially possible.

However there are many other factors to consider. Up to this point the testwork had focused on flat aluminium panels 1200 x 1200mm and insulation blankets of a similar size. The test results provided a very good indication of the material burnthrough characteristics. In the burnthrough tests the insulation material was secured in place around the perimeter using mechanical spring steel clips. Obviously such clips are not used on board an aircraft and so can not be used in system tests. By way of illustration, an insulation blanket in material tests may appear to delay burnthrough by 5 minutes however in reality after such exposure to a fuel fire the aluminium fuselage structure itself may well have collapsed reducing the effectiveness of any insulation system. Even if the fuselage shell remains intact the method of attachment of the insulation blankets to the fuselage frame is critical. The insulation can not provide a barrier to burnthrough if it is no longer there.

At this point of the investigation it was reasoned that attention must be focused on the development of the necessary mechanical attachments and insulation design if the potential of new materials was to be realised in improved burnthrough resistance of an aircraft.

Table 1
Medium Scale, Plain Panel + Insulation Material Burnthrough Results

Insulation Material	*Insulation Thickness (mm)*	*Insulation Density (kg/m^3)*	*Film Material*	*Burnthrough Time Aluminium (sec)*	*Burnthrough Time System (sec)*
Microlite AA	50.8	6.7	AN-18R	37	56
Microlite AA	50.8	6.7	AN-18R	36	55
Microlite AA	76.2	6.7	AN-18R	34	55
Microlite AA	76.2	6.7	AN-18R	42	60
Microlite AA	76.2	6.7	KN-80	35	78
Microlite AA	76.2	6.7	KN-80	35	75
Orcobloc®	63.5	5.5	AN-18R	35	≈270
Orcobloc®	63.5	5.5	KN-80	35	≈540

STYLISED FUSELAGE PANEL TESTING

Introduction

As described in the previous section the focus of the work on fuselage burnthrough to date has been on the flame resistance characteristics of the insulation and bagging film materials. The medium scale tests conducted involved flat aluminium panels and insulation blankets. The results from these tests provided a very good indication of the material burnthrough characteristics and suggested that combinations of certain insulation and bagging film materials may delay burnthrough by as long as 10 minutes. However if the potential of the material is to be realised, in improved burnthrough resistance of an aircraft, then attention must be focused on the development of the necessary mechanical attachments and on the insulation system design.

With this in mind and to progress the investigation into fuselage burnthrough further the CAA commissioned Darchem Flare to develop a stylised aluminium skin and fuselage frame. With the development of this stylised fuselage panel it was envisaged that it would be possible to test representative sizes of insulation blankets and also the method by which insulation blankets are attached to one another and to the fuselage skin.

The Stylised Fuselage Panel

From studies of aircraft fuselages and as a result of discussions with the CAA and airframe manufacturers a stylised fuselage panel was constructed as shown in Figure 6. Riveted onto a plain aluminium panel are a number of structural features typical of those employed in fuselage construction. These features comprise two airframe members and a number of ‘z’ section and top hat stringers running perpendicular to the frames. The size and positioning of these features are typical of those used on an aircraft.

No curvature was manufactured into the panel. Although there would be some curvature on an actual fuselage skin it was reasoned that given the size of the stylised panel any degree of curvature that was introduced to more closely represent an actual fuselage would be small enough that its omittance would have no effect on the test.

As with previous testwork the majority of the aluminium used in the construction of the stylised fuselage panel was typical aircraft grade aluminium, 2024-T3 1.6mm thick. This was used in the plain aluminium sheet and the stylised frame members. The stylised stringers were constructed of commercial grade aluminium 0.8mm thick.

Test Set Up

All the stylised aluminium fuselage panels tested were preconditioned to an appropriate surface emissivity using the cold sooting facility as previously described. For each test five thermocouples were positioned on the back face of the stylised aluminium panel.

The insulation materials used in the burnthrough tests were Microlite AA of 76.2mm thickness described previously and Orcobloc® of 76.2 and 38.1mm thickness also described previously.

All the insulation materials tested were sealed in water-resistant polymer bags manufactured by the Orcon Corporation. The coverings used were Orcofilm® AN-18R, which is a metallized polyvinyl fluoride film, reinforced on one side with polyester yarns and Orcofilm® KN-80 Kapton which is a polyimide film, reinforced on one side with nylon yarns.

It was the intention to attach the insulation blankets to the fuselage panel using fastening devices and methods that are currently used by the aircraft industry. It was not possible to obtain actual fastening devices but an attempt was made to recreate the way in which the blankets are typically attached. Four holes were made in each of the two frames on the panel at approximately 350mm pitch and at a height of 50mm from the base of the frame. Insulation fixing pins made of mild steel and 1.6mm in diameter were put through these holes and through the insulation blankets. Each pin went through the two insulation blankets adjacent to the frame and the cap strip covering the frame. This arrangement was held in position using metallic push fit washers.

For each test the insulation blankets were positioned on the back face of the aluminium panel and five thermocouples were positioned on the back face of the insulation blankets. In addition a thermocouple was positioned 100mm above the centre of the insulation blankets to provide a cold side temperature measurement.

Results and Discussion

A summary of the test results is provided in Tables 2 and 3

Stylised Fuselage Panel

As can be seen from the test results the burnthrough times for the stylised aluminium fuselage panels were in the range 30-39 seconds. The burnthrough times are comparable with previous testwork on plain aluminium panels. This suggests that there is no appreciable difference in burnthrough times between plain aluminium panels and the new stylised aluminium fuselage panels.

Insulation
The results of the tests on fibre glass insulation demonstrated similarity to previous test work.

Looking first at the tests involving fibre glass encased in polyvinyl fluoride film, a wide range of results occurred. The burnthrough times for the system ranged from 38 to 60 seconds. The burnthrough times for the aluminium were in the range 30 - 39 seconds. The additional protection provided by the insulation system was between 1 and 25 seconds. Excluding the two tests where burnthrough of the insulation occurred very quickly, the average additional protection provided by the insulation system was 21 seconds. This value is comparable with previous testwork on plain aluminium panels.

However in the two other tests involving fibre glass encased in polyvinyl fluoride film, the additional protection provided by the insulation was between 1 and 8 seconds. This rapid burnthrough can be attributed to the area of the panel at which the failure of the aluminium occurred. The panel failed at a point along one of the stylised frame members. In this region there is an overlapping of insulation blankets, it is therefore possible depending on the way in which the insulation blankets are attached to the stylised frame, that flames can navigate their way through the insulation system without destroying it in the process.

The probability of this occurring is difficult to predict but certain considerations point to how effective an insulation system might be to resisting fire penetration. The method and materials used to attach the insulation to the frame appear critical as does the insulation and bagging film material used. The way in which the individual blankets are attached to one another to form a cohesive system also appears important, a large degree of overlapping is likely to delay flame penetration. It also appears that the insulation materials themselves should display some degree of rigidity, this being the case it seems more likely they will remain in place following burnthrough of the aluminium.

In the tests using fibre glass encased in polyimide film the insulation blankets provided an additional 34, 40 and 46 seconds protection, giving a system burnthrough times of 72, 72 and 80 seconds respectively. Therefore the average additional protection provided by the insulation system was 40 seconds. This correlates well with previous testwork where the additional protection provided by the insulation system was in the region of 40 seconds.

The results from the tests using Orcobloc® as the insulation material showed a marked difference from the tests carried out using plain aluminium panels. In the plain panel tests system burnthrough times were 270 seconds for the test using AN-18R as the bagging film material and 540 seconds for the test using KN-80 as the bagging film. In the stylised panel tests the system burnthrough times for almost identical configurations of insulation material and bagging film (the only difference being 76.2mm insulation was used for the stylised panel testwork compared with 63.5mm of insulation for the plain panel testwork) were 54 seconds and 90 seconds respectively.

The explanation of these results is similar to that of the rapid burnthrough for the fibre glass results. In all stylised panel tests involving Orcobloc® the mode of failure was not due to material failure. Plain panel testwork had demonstrated the ability of Orcobloc® insulation blankets to resist flame penetration for a number of minutes. The mode of failure for the stylised panel tests was system integrity. Contributory factors to this failure include the initial area of the panel at which the failure of the aluminium occurred, the rigidity of the insulation material and the jointing arrangements for the insulation blankets.

The area of the stylised panel on which the stylised frame members are situated corresponds to a region of overlapping insulation blankets, therefore in the situation where the stylised panel fails at a point along one of the stylised frame members, the important failure mechanism for consideration is the ability of the jointing system and material to resist burnthrough and not solely the material. This highlights the importance of considering other factors other than purely material performance when attempting to put forward proposals for improved burnthrough resistance.

The methods used to attach the insulation system to the frame can be as critical as the type of insulation and bagging film materials used. The way in which the individual blankets are attached to one another to form a cohesive system is also an important consideration. A large degree of overlapping would be beneficial in delaying flame penetration. In addition if the insulation materials themselves displayed some degree of rigidity then it is more likely they will remain in place following burnthrough of the aluminium.

Bagging Film

As expected the results of the tests involving polyimide film exhibited longer burnthrough times than those of the polyvinyl fluoride film.

Considering the test in which the fibre glass and PVF film performed best, the additional burnthrough time provided was 25 seconds. Comparing this to the test in which the fibre glass and polyimide film insulation performed best, the additional protection provided was 46 seconds, almost double.

The tests involving Orcobloc® showed similar results. For tests using polyvinyl fluoride as the bagging film the additional protection provided averaged 18 seconds, for polyimide film the value was 51 seconds more than double.

Once burnthrough of the aluminium had occurred the polyvinyl fluoride film set alight allowing flame propagation to the cold side and was quickly consumed. In contrast the polyimide film displayed excellent fire resistance. No flaming occurred and the film remained in place on the cold side for the duration of the tests.

Method of Attachment

The method of attaching the insulation blankets to the fuselage frame could be considered as reasonably representative of the methods employed by the aircraft industry, however the materials of construction could not. Its difficult to assess the impact if any of using the mild steel fixing pins previously described on the test results. These fixings would certainly withstand extremes of temperature that typical aircraft nylon fastening systems would not. It is therefore possible although not certain that the performance of the insulation systems would have been marginally poorer if actual aircraft fastenings had been used.

Table 2
Medium Scale, Stylised Aluminium Fuselage Panel Only, Burnthrough Results

Insulation Material	*Aluminium Thickness (mm)*	*Aluminium Grade*	*Burnthrough Time Aluminium (sec)*
None	1.6mm	2024	30
None	1.6mm	2024	31

Table 3
Medium Scale, Stylised Aluminium Fuselage Panel + Insulation Material, Burnthrough Test Results

Insulation Material	*Insulation Thickness (mm)*	*Insulation Density (kg/m^3)*	*Film Material*	*Burnthrough Time Aluminium (sec)*	*Burnthrough Time System (sec)*
Microlite AA	76.2	6.7	AN-18R	35	60
Microlite AA	76.2	6.7	AN-18R	30	38
Microlite AA	76.2	6.7	KN-80	32	72
Microlite AA	76.2	6.7	KN-80	34	80
Microlite AA	76.2	9.6	AN-18R	37	54
Microlite AA	76.2	9.6	KN-80	38	72
Microlite AA	50.8	9.6	AN-18R	39	40
Orcobloc®	76.2	5.5	AN-18R	35	54
Orcobloc®	76.2	5.5	KN-80	39	90
Orcobloc®	38.1	5.5	AN-18R	37	54

CONCLUSIONS

Results from both full and medium scale burnthrough tests have shown that aluminium fuselage skins can consistently provide at least 30 seconds of protection prior to melting.

Once the aluminium fuselage melts this allows flame impingement upon the insulation system. The results of the recent medium scale tests conducted involving flat aluminium panels and insulation blankets, as described in this paper, have provided a very good indication of the material burnthrough characteristics and suggest that combinations of certain insulation and bagging film materials may delay burnthrough by as long as 10 minutes. In particular, the flat panel testing demonstrated that in changing from an aluminium skin insulated with polyvinyl fluoride encapsulated fibre glass to a polyimide film encapsulated Orcobloc® an improvement in burnthrough time from 55 to 540 seconds is potentially possible.

However the results of the stylised panel testwork have demonstrated that there are a number of considerations that have to be taken into account when attempting to improve fuselage burnthrough resistance. Some of the key factors highlighted by the stylised aluminium fuselage panel testwork to be important are: -

- Fire resistance characteristics of insulation material
- Fire resistance characteristics of bagging film material
- Method of attachment of insulation system to fuselage
- Method of attachment of insulation blankets to one another
- Rigidity of insulation material

Therefore the conclusions of the medium scale burnthrough testwork to date are that it is only by having a complete system approach to insulation blanket design and material specification that the potential of new materials can be realised, and the aim of improving the fuselage burnthrough resistance of an aircraft can be achieved.

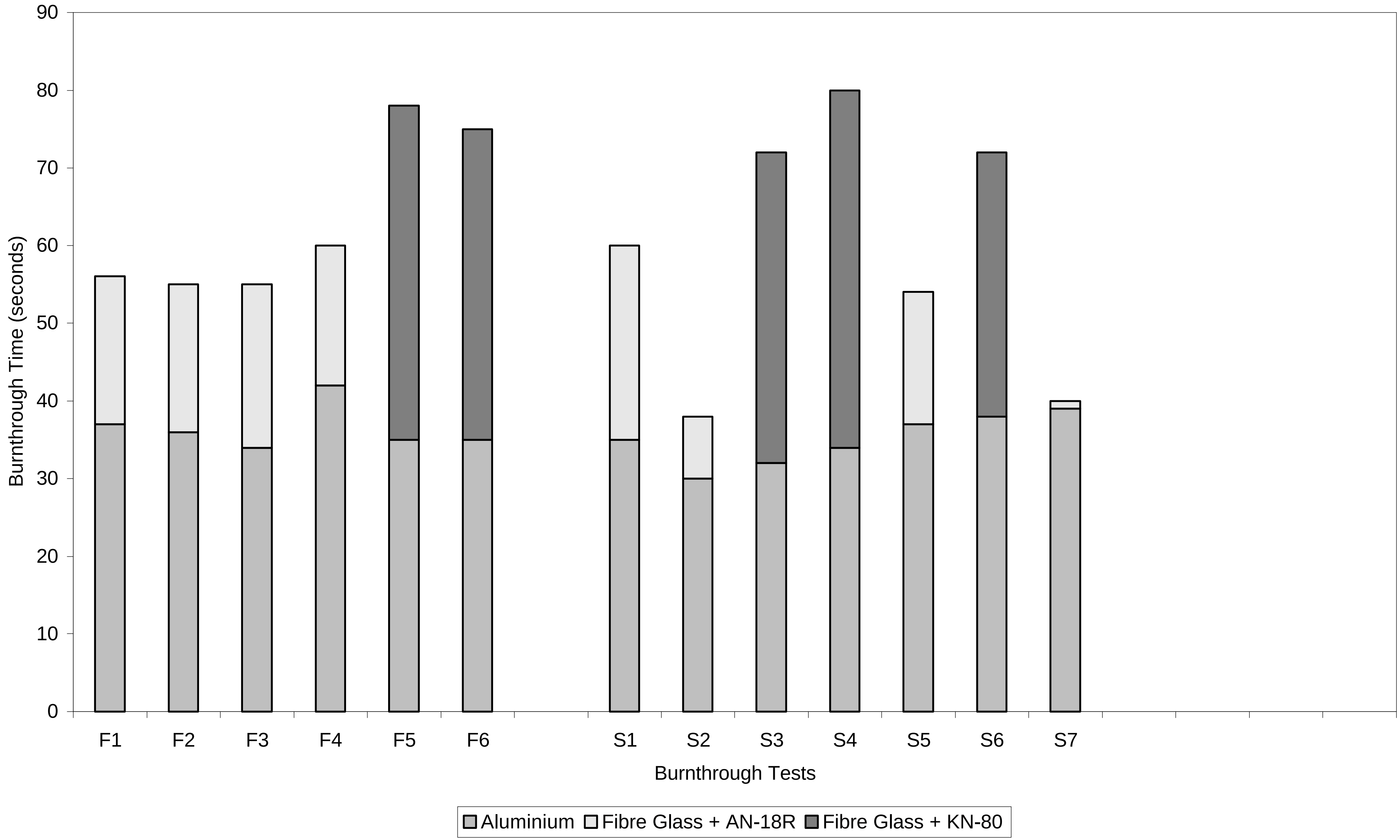


Figure 1 Medium Scale Burnthrough Test Results for Aluminium Panels and Fibre Glass Insulation

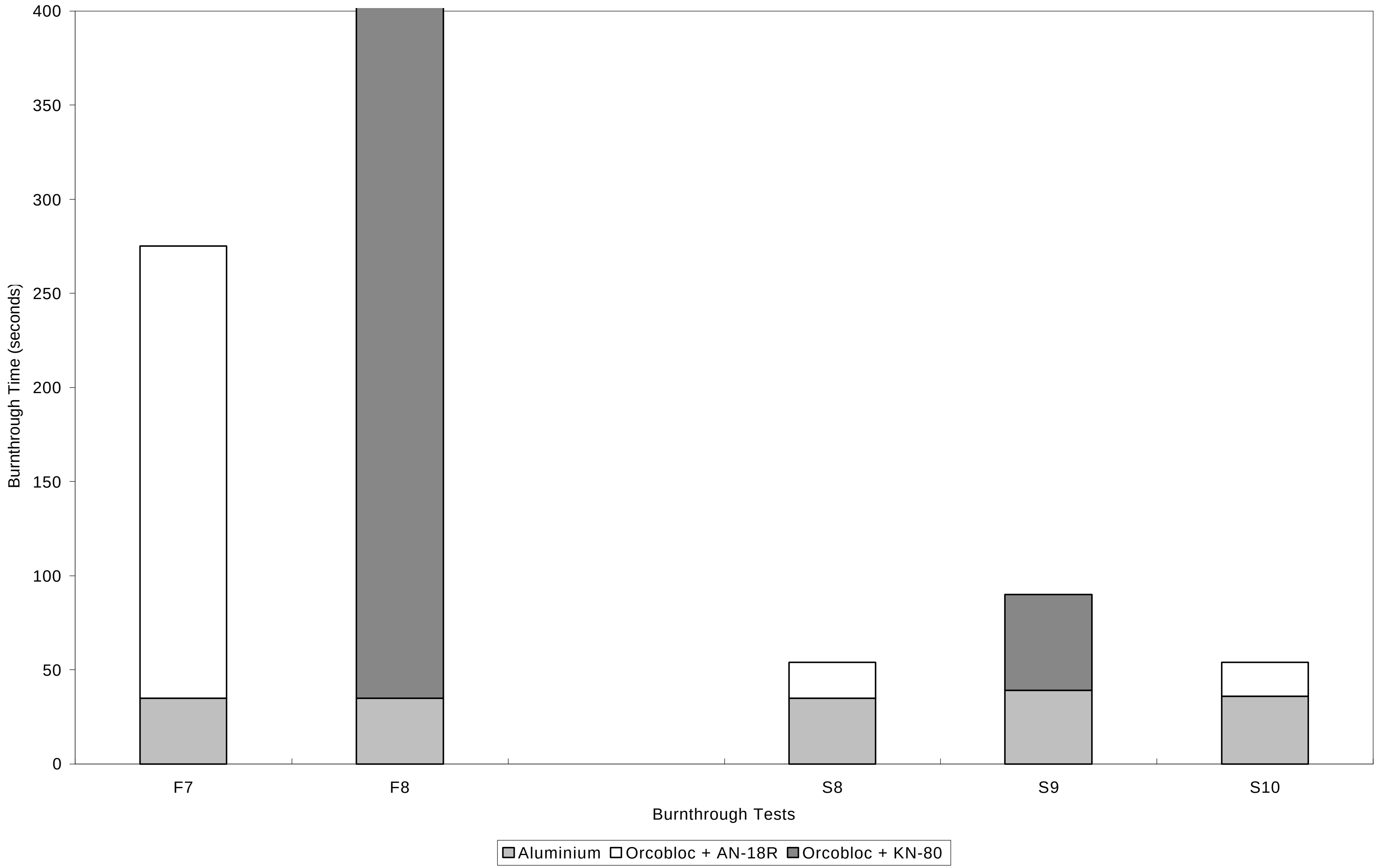


Figure 2 Medium Scale Burnthrough Test Results for Aluminium Panels and Orcobloc Insulation

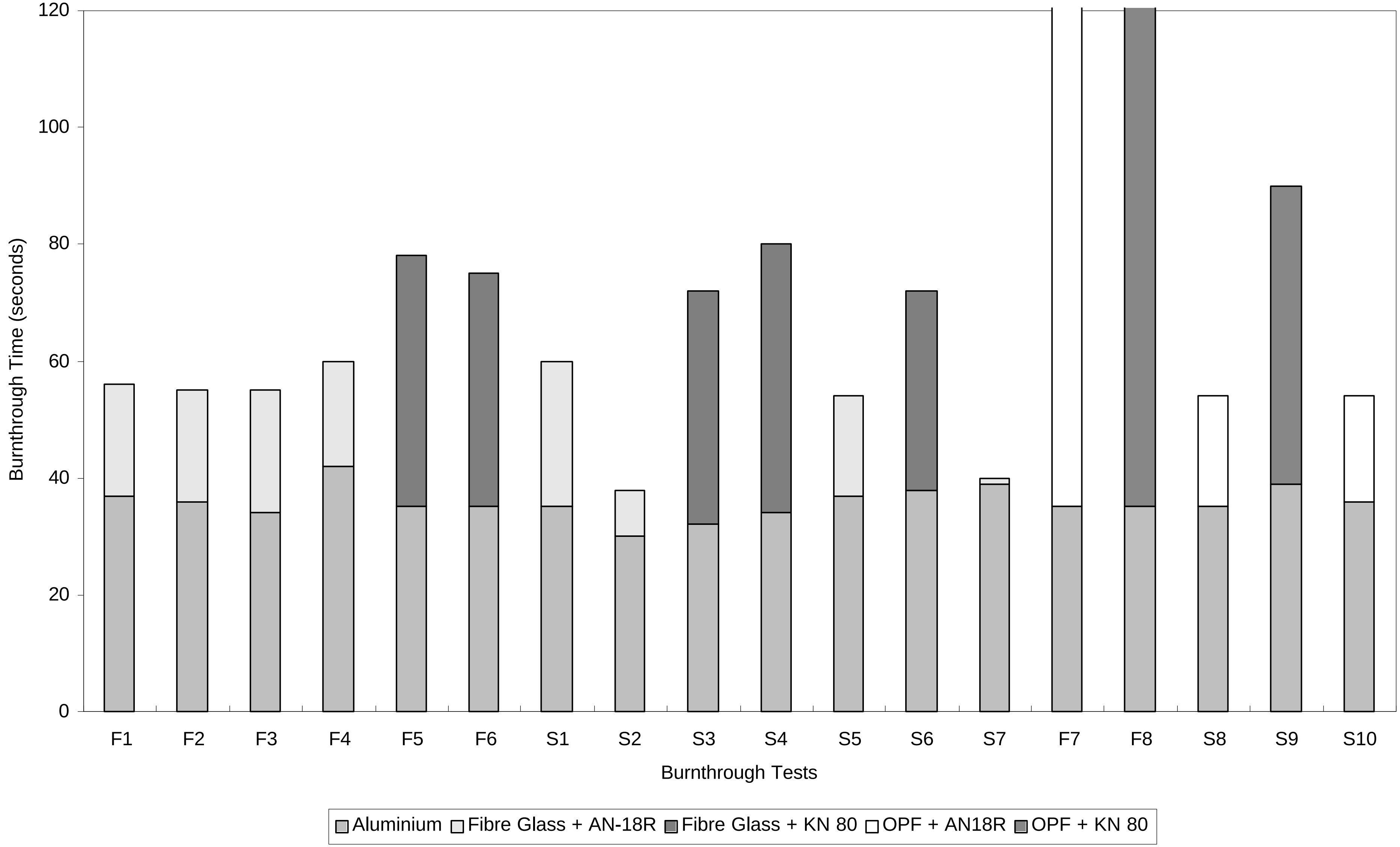


Figure 3 Summary Graph of Medium Scale Insulation Burnthrough Testwork

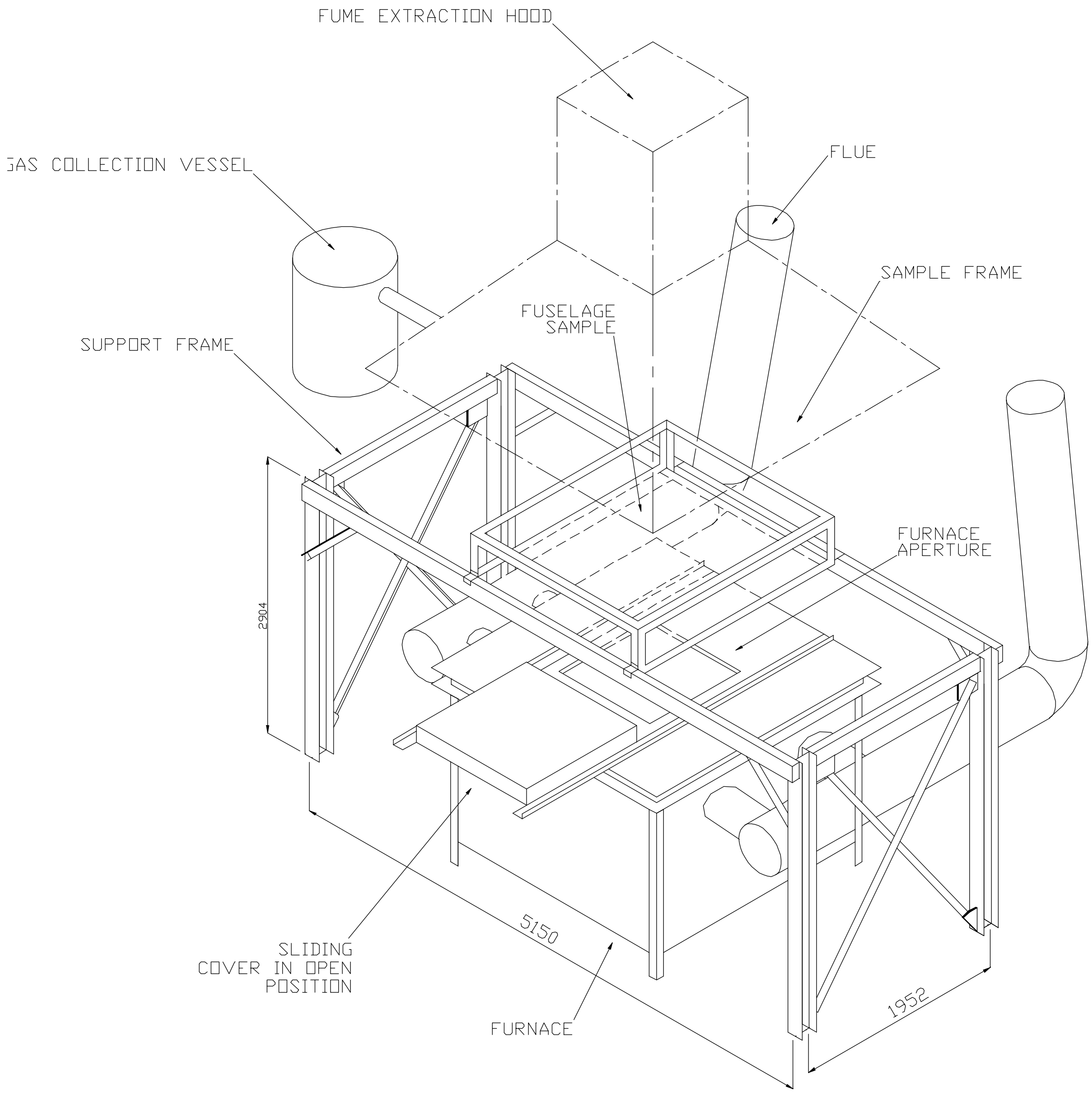


Figure 4 Medium Scale Fuselage Burnthrough Facility

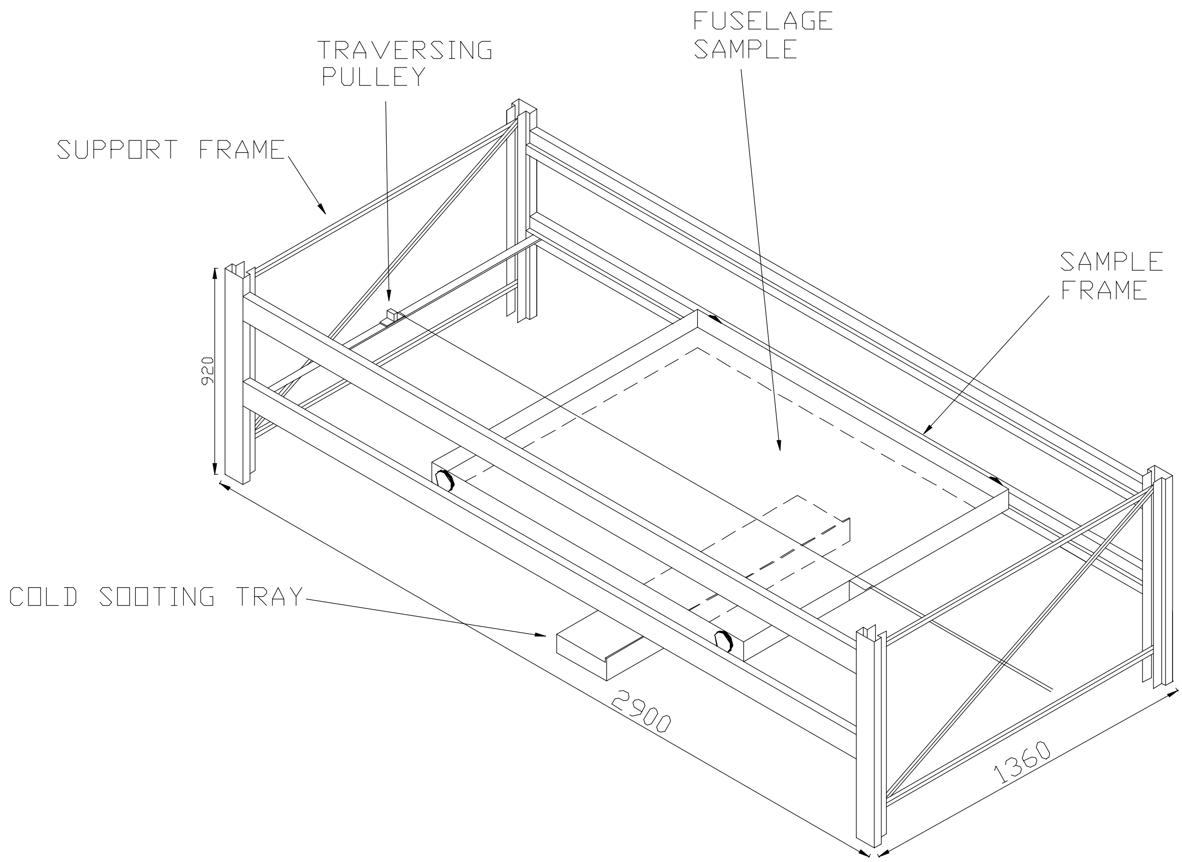
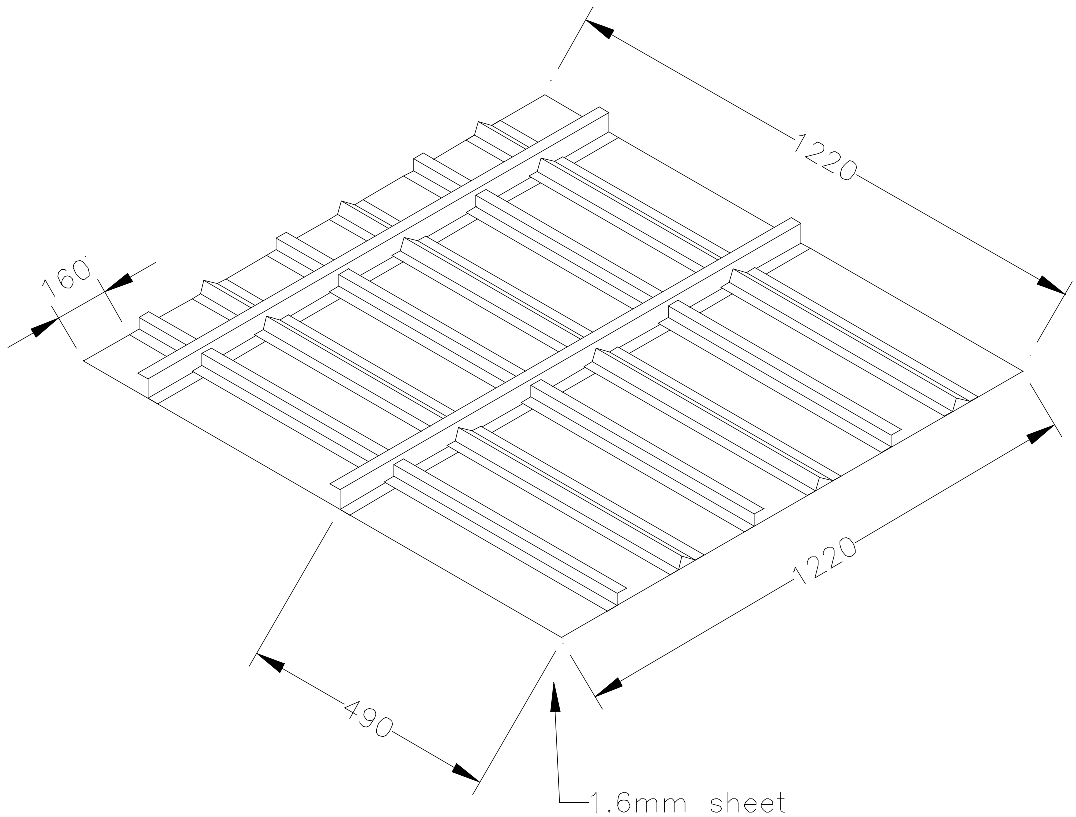


Figure 5 Cold Sooting Rig



FRAMES MADE OUT OF
2024–T3 ALUMINIUM
1.6mm THICK. STRINGERS
MADE OF A COMMERCIAL GRADE
ALUMINIUM 0.8mm.

0.8mm sheet of width 80mm which is divided equally into three parts with two right angles at 25mm 'fold' being introduced to gain the required shape.

0.8mm sheet of width 100mm which is divided equally into four parts with two 45 and one right angle at 25mm 'fold being introduced to gain the required shape.

1.6mm sheet of width 100mm folded with two right angles of 25mm 'fold' at 25mm from each edge.

Figure 6 Stylised Fuselage Panel

REFERENCES

Dodd, D.C., Hall, C.T.M. , Pollard, J., and Snell, M.A., 1994, 'Burnthrough Resistance of Fuselages : Initial Findings' CAA Paper 94002, Civil Aviation Authority, London.

Dodd, D.C., Jenkins, C.R., and Snell, M.A., 1995, 'Burnthrough Resistance of Fuselages: Further Investigation' CAA Paper 95003, Civil Aviation Authority, London.

Dodd, D.C., Jenkins, C.R., and Snell, M.A., 1996, 'Burnthrough Assessment Study' CAA Paper 96002, Civil Aviation Authority, London.

Hill, R (FAA), and Povey, N.J (CAA), 1993, 'The Future of Aircraft Cabin Fire Safety', *Proceedings International Conference for the Promotion of Advanced Fire Resistant Aircraft Interior Materials*, Atlantic City, New Jersey, USA, February 9-11 1993.

'Report on the Accident to Boeing 737-236 Series 1 G-BGJL at Manchester International Airport on 22 August 1985'**.** Air Accidents Investigation Branch (1988). Aircraft Accident Report 8/88, London: Her Majesty's Stationary Office.