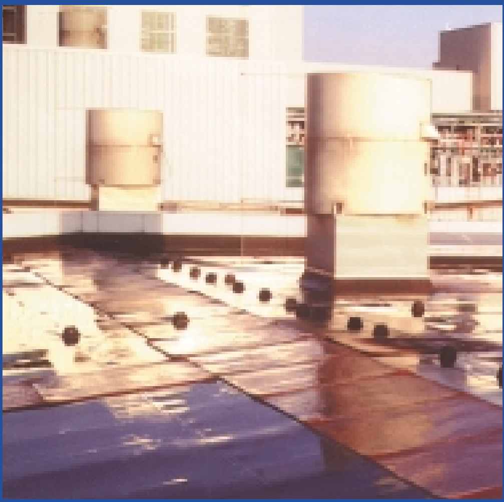

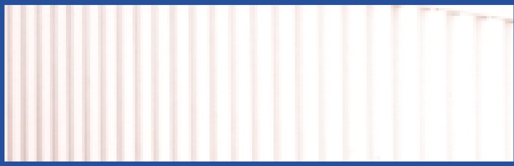

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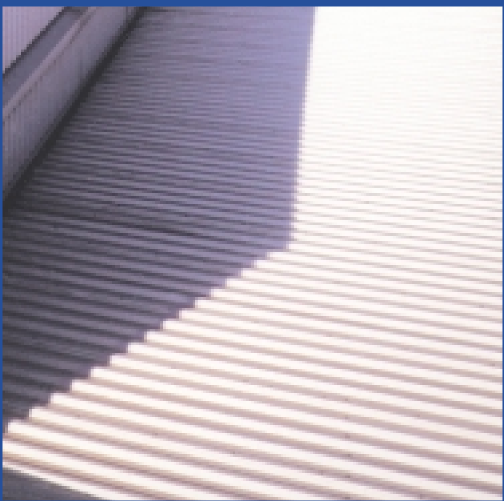
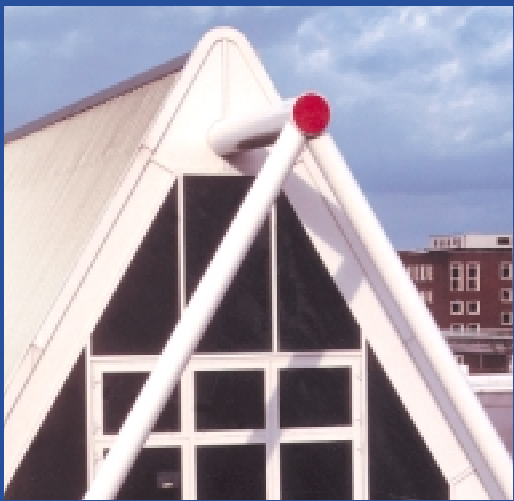
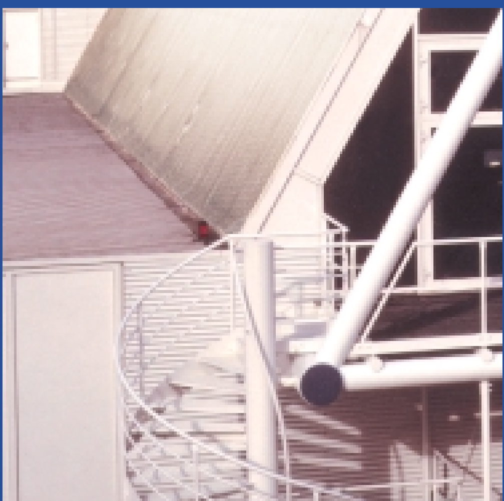
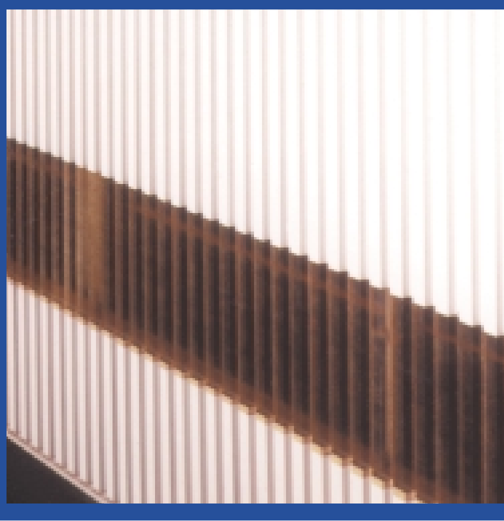




FIRE PERFORMANCE OF POLYURETHANE STEEL DECK ROOFING





FIRE PERFORMANCE OF POLYURETHANE STEEL DECK ROOFING

ISOPA

has funded a series of large-scale fire tests at the Materialforschungs- und Prüfungsanstalt (MFPA), Leipzig, on a polyurethane rigid foam insulated roof construction.

The tests showed that when the polyurethane expanding agent was changed from trichlorofluoro-methane (CFC 11) to n-pentane (ODP Zero), the fire performance of the roof was fully comparable.

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INTRODUCTION

Lightweight steel deck roofings insulated with polyurethane rigid foam provide highest insulation properties and are used predominantly in buildings intended for production and storage in industry and agriculture, as well as other spacious structures in which the typical characteristics of this roofing system give benefit because of wide spans, light weight and suitability for prefabricated construction (sandwich elements).

Lightweight steel deck roofings can be assembled from prefabricated elements or built up layer-by-layer on the construction site. The system generally consists of corrosion-protected steel (or less commonly aluminium) sheeting, which may be either flat, profiled or corrugated.

The roof may be sealed with a weather-resistant membrane or bitumen foils; for industrial prefabricated sandwich elements steel or aluminium sheet is also used for the upper facings.

FIRE SAFETY REQUIREMENTS

In terms of fire safety, it is typically assumed that any fire will start inside the building, and that the risk of a fire affecting the outside is comparatively low.

Fires on a roof are mostly initiated during construction works. There may also be an impact caused by radiant heat and flying brands from burning adjacent buildings. The latter scenario is simulated in intermediate scale test procedures determining the risk of spreading the fire outside and into the building. As ignition sources, wood wool baskets (1) are used, or in the case of a wind-aided scenario, the source is a locally applied radiant panel together with a wind machine (2).

A European standard to test the reaction of an interior to a roof-fire is not available; such a procedure, however, was developed in Germany (3). Work had also been carried out by III (International Isocyanate Institute) in 1976, using a protocol that demanded full scale tests; these tests became a benchmark for the industry (4).

FIRE PERFORMANCE OF LIGHTWEIGHT STEEL DECK ROOFINGS

Generally, in the case of roof composites, flame penetration is considerably slowed down by the presence of facings which act as an obstacle to the oxygen supply necessary for combustion. Protection of the insulant by structural modification, e.g. facings, can therefore be more effective than altering the insulant by incorporating additives, for example flame retardents.

In the case of steel deck roofings, the metal facings act as an effective barrier particularly in those parts of the room remote from the fire and in adjoining rooms. In the area directly affected by the fire, however, the foam undergoes pyrolysis caused by heat conduction through the metal facings. Weak points may occur where elements join and overlap. These should be tightly sealed when the roof is being installed. Gases emerging at butt and seam joints between panels can ignite and thus increase the heat load on the neighbouring surfaces. However, compared with the primary fire load within a building, this effect is still negligible.

The continuous voids found in profiled metal facings can encourage fire propagation, with the phenomenon being further exacerbated by the chimney effect. For all kinds of lightweight roofs - insulated with any material - the hollow channels formed by the steel sheet profiles of the roof deck should be suitably sealed at each end to a depth corresponding to the width of the supporting wall. The open cross-sections of the profiles at the edges of the roof should also be closed.

Regarding the outside surface of roofs, low-flammability roofing membranes or sanded bitumen sheetings have the advantage of limiting the spread of flame on top of the roof caused by wind and heat radiation. It can be assumed that bitumen-foil covered roofs, provided they are resistant to flying brands and radiant heat, make no contribution to the spread of fire beyond the area of the fire room. The presence of wind, however, can lead to local flame spread on the surface of the roof, but this will not necessarily set fire to the insulation below the roof membrane.

Fire walls must generally extend through the roofing, at least to a height of 0.3m.

AIM OF THE INVESTIGATIONS

Following the ecological demand by changing the blowing agent of the polyurethane rigid foam from CFC 11 to other blowing agents, e.g. pentane, was seen as a major change to the product concerning fire. To ensure security in the application, ISOPA (European Isocyanate Producers Association) decided to fund full scale fire tests using the III protocol. The full scale tests use material composites which realistically simulate the sequence and thickness of the layers, the position of each component when installed in the building and the type of fire load.

The objective of the investigations was a comparison of the fire performance of a built-up steel roof construction, containing polyurethane rigid foam insulation which had been produced using candidates from two different families of blowing agents: pentane (flammable) and CFC 11 (non-flammable). The previous large-scale tests with enduse conditions carried out at Technical Centre for Fire Prevention (TNO) in Delft (5), were aimed at determining the basic principle of flame spread in a realistic fire, and how fire can travel across partition walls. Within the framework of these tests, the risk of fire spreading from a fire compartment to adjacent rooms through the insulating layer should be assessed.

TEST PROCEDURE

In 1976 full scale tests with lightweight roofs were made at TNO. The same test configuration (fig.1 and 2) was chosen for the tests at the Materials Research and Testing Institute (MFPA) in Leipzig (6).

Figure 1: Test building at Leipzig

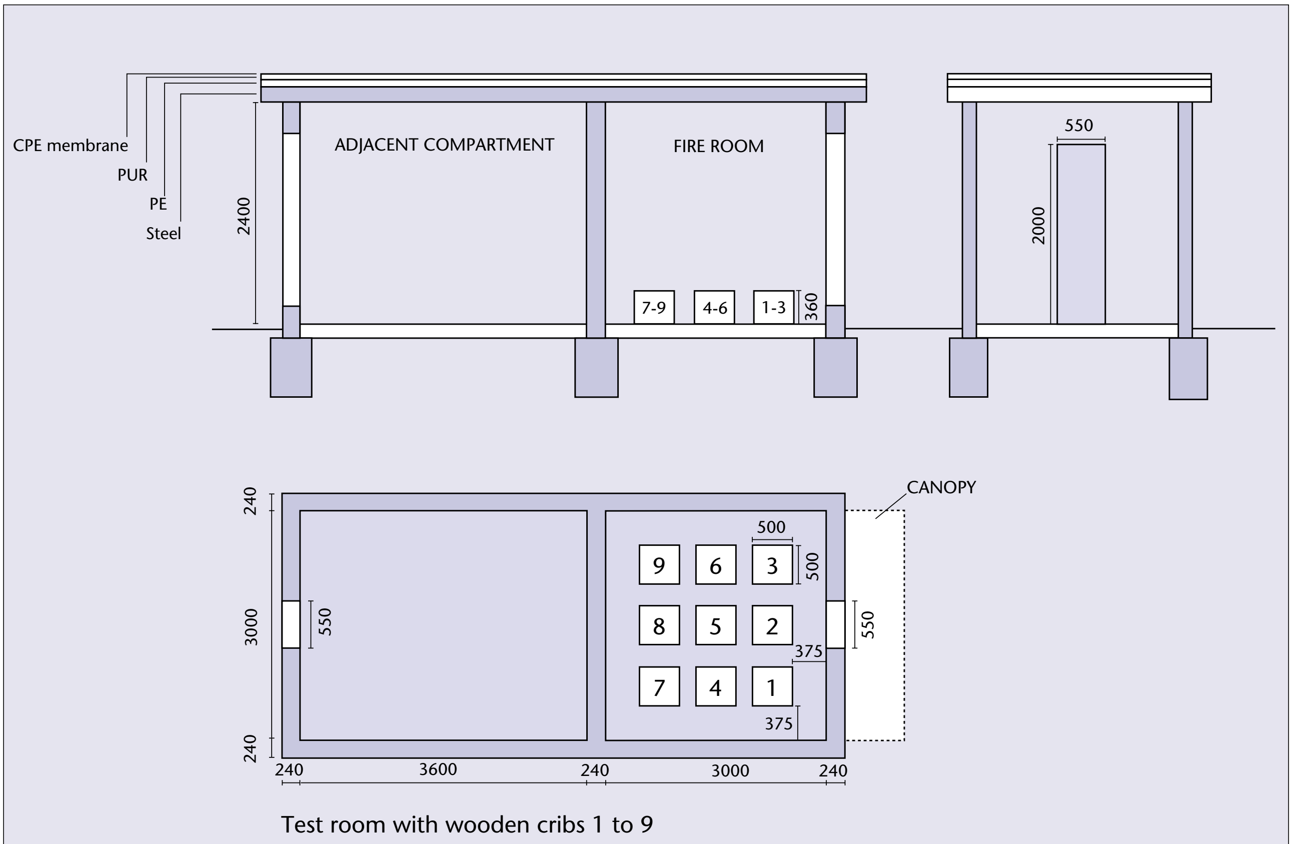

Figure 2: Dimensions of the test building and arrangement of the fire load

The test building consisted of two rooms, the fire floor area was 3.0m x 3.0m and 3.6m x 3.0m for the observation room, its internal height was 2.4m.

The roof construction consisted of four layers as shown in figure 2. It was built up from trapezoidal profiled steel sheets (0.75mm thick), laid with the channels parallel to the partition wall of the building, the air space of the channel over the separating wall was filled with mineral wool. A low density polyethylene sheet (0.2mm thick) provided a vapour barrier and was laid on the steel sheets. The polyurethane insulation boards had paper facings and fulfilled B2 quality according to DIN 4102. The boards had dimensions 1200 x 600 x 40mm and sufficient boards were mechanically fastend to the steel sheets covering the roof. The roof was finished by a roofing membrane of CPE foil (1.2mm thick "Alkorflex").

The ignition source was chosen to generate flashover fire conditions. Nine wooden cribs, each weighing 30kg, were placed in a symmetrical pattern. Alcohol impregnated mineral fibre torches were used to ignite the cribs. The result of such a fire in a realistic compartment is the complete destruction of the lower surface of the roof - at least in the area with direct flame impingement.

TEST RESULTS

Visual observations, still photography and video recordings were made. Time-temperature profiles were recorded using thermocouples located at different positions.

Figure 3: Roof during fire test - CFC blown foam

Figure 4: Roof during fire test - Pentane blown foam

Visual Observations	Time (Min)	
	CFC	PENTANE
Flames reach interior of roof	*4*	*5.5*
Smoke emission from fire room cornice	*7.5*	*4*
Cracking of CPE foil, smoke emission	*32-36*	*29-34*
Flames on top of the roof above fire room	*37.5*	*39*
Flame spread over whole part of the roof above fire room	*38-45*	*39-45*
Flames extinguish	*56*	*56*

In figure 5 and 6 temperatures at the partition wall in the fire room area are plotted:

———	100mm below ceiling
- - - - -	between polyurethane and sealing membrane (CPE)
....	on top of roof

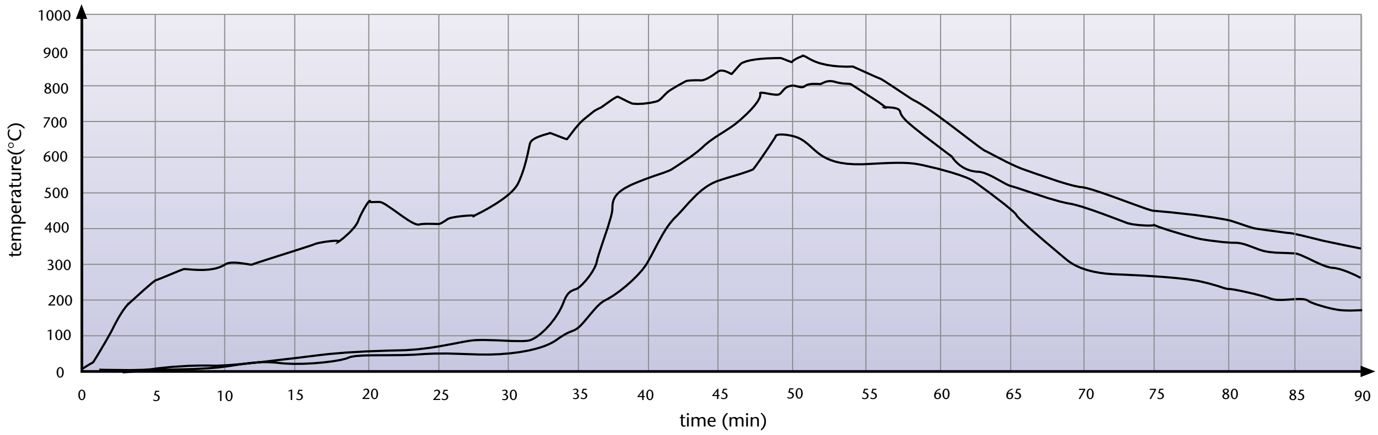

Figure 5: Temperatures in the fire room at the partition wall - CFC blown foam

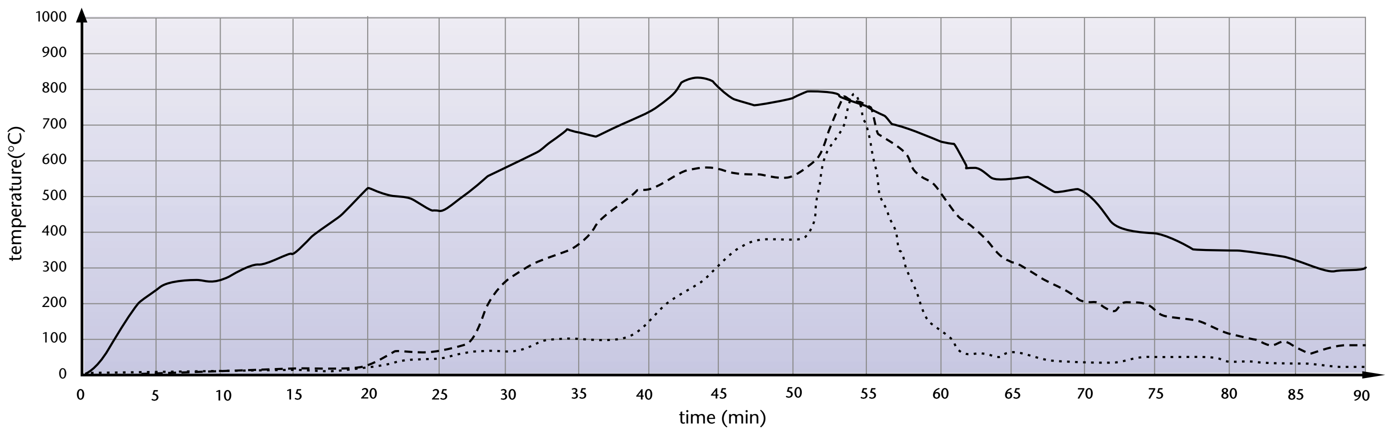

Figure 6: Temperatures in the fire room at the partition wall - Pentane blown foam

Figure 7: Roof after test - CFC blown foam

Figure 8: Roof after test - Pentane blown foam

The results - visual observations and temperature measurements - showed that changing the foam blowing agent from non-flammable CFC 11 to flammable n-pentane did not have any appreciable effect on the fire performance of the roof construction. The roof construction retained its integrity. Fire damage could be confined to the part of the roof over the fire source, there was no spread of fire across the roof to the area over the observation room. The temperature increase in the neighbouring room was negligible.

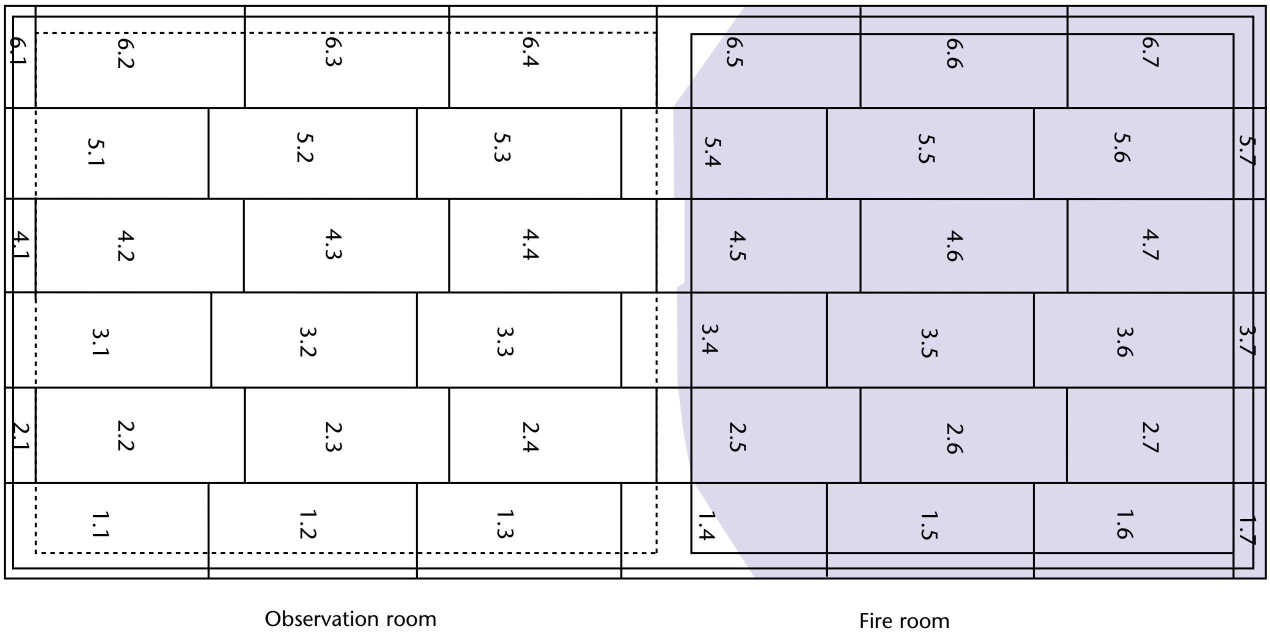

Figure 9: Area of roof damage, pattern, and numbers of boards, observation room left, fire room right - CFC blown foam

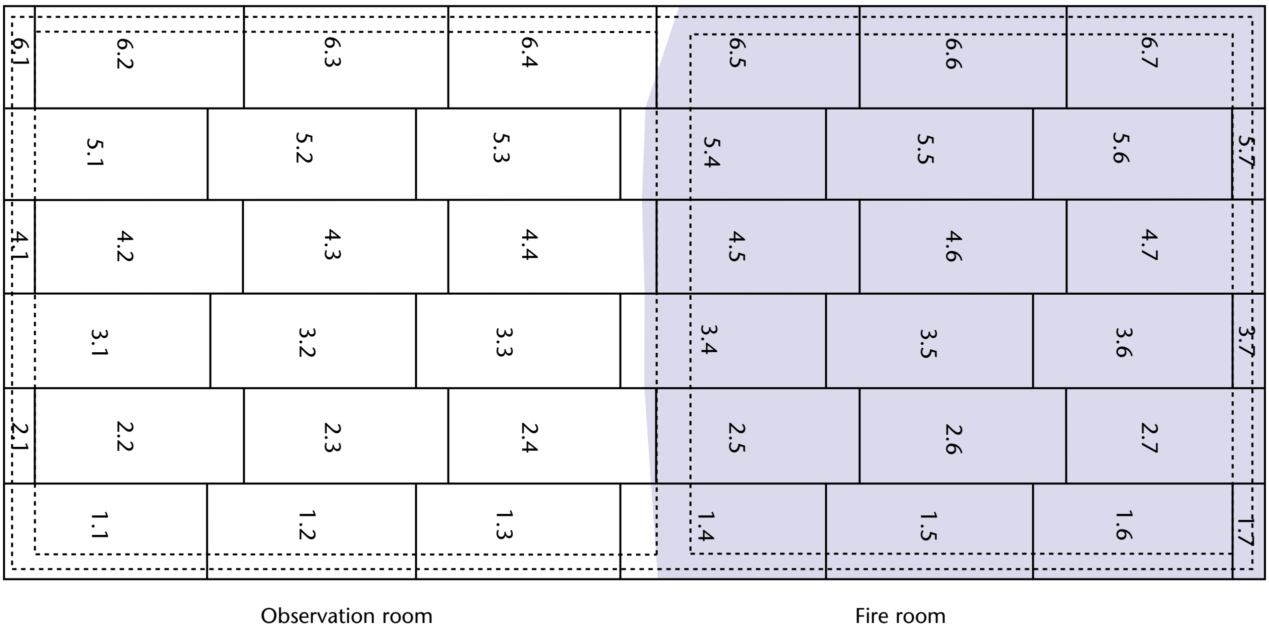

Figure 10: Area of roof damage, pattern, and numbers of boards, observation room left, fire room right - Pentane blown foam

CONCLUSION

The results at Leipzig confirmed the TNO findings that the contribution of the insulating material to the total heat release was found not to be a predominant factor. The flammability ratings of the individual insulating materials such as polyurethane, polyisocyanurate, expanded polystyrene, phenolic and mineral wool did not appear to have a significant impact on the spread of fire across the roof. In the early stages, the fire spreads due to the fire load long before ignition or penetration of the roofing partition occurs. The fire behaviour of roofs is predominantly affected by the sealing layer and its quality.

The comparative tests carried out at the MFPA in Leipzig have shown that, as far as the fire behaviour is concerned, there is no difference between roofs insulated with CFC-blown and pentane-blown polyurethane rigid foams. The fire penetration time, maximum temperatures and size of area destroyed on both types of roof are virtually the same. The polyurethane insulation in the lightweight steel deck roofings does not contribute to any additional spread of flame: there was no spread of flame to the adjacent compartment.

In addition to these full-scale tests, extensive bench scale investigations of the burning behaviour of CFC and pentane blown foams have shown that the same standard classifications are achieved in both cases (7).

Summarizing all existing data, it can be concluded that conventional types of lightweight steel deck roofing insulated with polyurethane rigid foam do not constitute a special fire risk provided installation work is properly carried out. The insulation and the roofing membrane will only be destroyed in the area immediately above the fire room and the stability of the whole steel deck depends mainly on the quality of the supporting structure and the fire resistance of the neighbouring building components.

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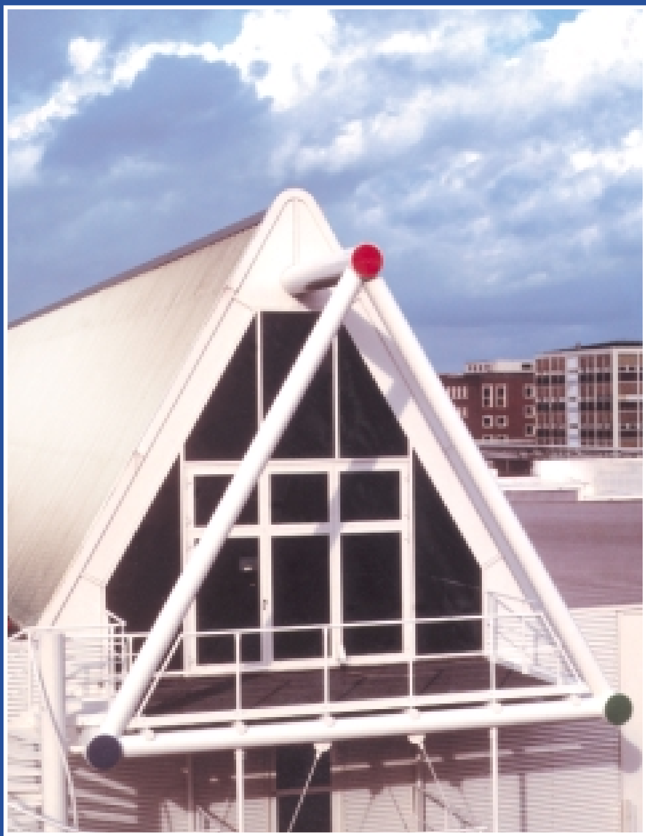

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