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A FIRE TEST ON A STEEL SOLVENTS CUPBOARD

by

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SUMMARY

A steel cupboard of a design proposed for the storage of flammable liquids has been subjected to an all-enveloping kerosine fire. The interior and contents of the cupboard rapidly reached high temperatures leading to the collapse of one of the shelves, destruction of gauze vents, fracture of glass bottles and the ignition of their contents, and general distortion of the cupboard.

Comparison with the results of earlier tests on wooden cupboards for solvents indicates that the steel cupboard tested afforded much less protection from fire to its contents.

It must be expected that any simple steel cupboard even if it were of acceptable integrity would, when exposed to a similar fire, permit its contents to be heated sufficiently for flammable liquids in bottles to escape and ignite.

The cupboard was designed before the issue of the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations, 1972, under the Factories Act, 1961 and does not satisfy the requirements for Certificate of Approval No.1 Schedule Part 4 under those Regulations.

Department of the Environment and Fire Offices' Committee
Joint Fire Research Organization

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1. INTRODUCTION

The Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972[1] were made under the Factories Act 1961 and apply only to premises covered by that Act.

Regulation 5(1)d permits the storage in a workroom of up to 50 litres of highly flammable liquid in suitable closed vessels kept in a suitable closed cupboard which is a 'fire resisting structure' as defined. Certificate of Approval No.1 specifies the requirements for a fire resisting structure[2]. Cupboards are, inter alia, required to satisfy the requirements of BS 476 : Part 8[3] test as to freedom from collapse and resistance to the passage of flame for not less than half an hour but the insulation criterion is waived. Sheet steel is an acceptable material for the cladding of such cupboards.

The management of other premises not covered by the Factories Act has been concerned that storage cupboards in their premises should possess resistance to the effects of fire on their contents[4]. For example, a wooden cupboard has been developed, and tested at the Fire Research Station, that will provide protection from a surrounding spillage fire for a period in excess of 5 minutes, a period during which first aid fire fighting could be expected to extinguish the surrounding fire, should this be possible[5].

This note describes a test on the resistance to a surrounding fire of a steel cupboard, as used in offices, modified for the storage of flammable liquids, and on the protection afforded to its contents of flammable liquids in bottles. We are indebted to the Department of Pure and Applied Chemistry, University of Strathclyde for the supply of the modified cupboard for test.

2. EXPERIMENTAL

(i) Details of the cupboard

The cupboard, shown in Plates 1 and 2, was constructed from panels of 18 SWG mild steel sheet. The full width double doors were each fitted with upper and lower hinges and closed by a ganged catch and lock on one door, bolting the doors at top, middle and base. A plastic foam sealing strip had been fitted to the closing edges of the doors. Two gauze vents were fitted, one at the top of one side panel of the cupboard and one at the bottom of the other. These consisted of 0.12 m diameter discs of about 1 mm mesh gauze secured against a hole in the panel by a steel ring with light alloy rivets, on the inside of the cupboard. There were gaps between the back and side panels, which in some places exceeded 2 mm width. Two shelves, fabricated from 25 mm wide 3 mm thick galvanised steel strip and welded to form an open structured decking, were fitted, one just above a liquid-tight base and one just below the centre-line. Each shelf rested on "L" shaped brackets of similar gauge to the panelling, secured by light alloy rivets. The unpainted liquid-tight base was about 200 mm high and of sufficient capacity to contain liquid from the entire contents in the event of spillage.

(ii) Cupboard contents and instrumentation

The cupboard was loaded with a Winchester bottle and a 250 ml bottle on each shelf (Plate 2). These contained either a mineral hydraulic oil or dibutyl phthalate to half their capacity. Fluids of high boiling point were chosen to lessen the risk of explosion of released vapours, but to have a similar specific heat to more volatile flammable liquids. Thermocouples were positioned in the liquid in three of the bottles and a further three thermocouples were brazed to the top shelf and the inside and outside of the back panel. The thermocouple outputs were measured on a multi channel potentiometric millivolt chart recorder. A continuous 16 mm movie record of the test was made and colour and black and white still photographs were taken before, during and after the test.

(iii) Test arrangements

The cupboard was positioned centrally in a steel tray 2 m x 1 m x 0.15 m containing 12.5 gallons of kerosine floating on water. The kerosine was ignited by quickly pouring 50 ml of petrol gently onto its surface and applying a lighted match. A 2-gallon fluorinated chamical foam extinguisher was used at the end of the test to extinguish the fire in order to examine the value of such an extinguisher in this type of fire situation. A one inch hosereel was also made ready for action, should it have been needed.

3. RESULTS

Figures 1 and 2 give the time-temperature curves of the thermocouples in the cupboard and bottles respectively. The fire developed rapidly and after one minute the cupboard was enveloped in flames. The sound of breaking glass at two and a half minutes was followed by flaming from the top of the doors. Plate 3 shows the situation at four minutes. After four and a half minutes two dull explosions were heard followed by falling glass, and at five minutes by a crash, assumed to be the collapse of the top shelf. This resulted in more vigorous flaming from the top of the doors as shown in Plate 4 at five and a half minutes of test.

The fluorinated chemical foam was applied at eight minutes, the complete extinction process taking about forty seconds although, as Plates 5 and 6 show, the fire was well controlled after ten seconds. The surface of the cupboard was cooled with a fine, gentle spray of water before investigation for damage.

The doors, the locking handle of which had melted, leaving a hole, fell out on attempting to open them, the hinges also having become detached from the cupboard. (Plate 7). The plastic foam sealing strip was totally consumed. The securing ring and gauze of the upper vent had fallen into the base of the cupboard, the alloy rivets having failed. The lower gauze had buckled and would no longer have been able to function as a flame trap. Alloy rivets had also been used to secure the top shelf brackets and probably led to their collapse. The Winchester bottle on the bottom shelf was still standing but was badly cracked and shattered when touched. The back panel had become detached from the side member near the base, resulting in a tapering gap 10 mm wide at its widest point. Plate 8 shows the gap and the buckled lower vent gauze.

4. DISCUSSION

The time-temperature curves, Fig. 1, show the rapid rate of rise of temperatures of the cupboard surfaces and the shelf. The higher temperatures registered inside the cupboard over that of the outer surface after 2 mine 20 s were probably due to the burning of the stored liquids. The temperatures reached the Curie point of steel, about 550°C, in 2 min 50 s, at which distortion of the folded steel panels of the cupboard would be expected.

The almost equally rapid rises in temperature recorded by the thermocouples in the bottles of liquids, Fig. 2, were probably due to the thermocouples being exposed to air on the breaking of the bottles, except for the Winchester on the lower shelf, for which the reason would appear to be disturbance of the thermocouple, possibly by the falling shelf. As the boiling points of the oil and dibutyl phthalate were both about 360°C, temperatures registered by the thermocouple in the lower Winchester bottle after 6 min were probably due to the liquid or its vapour at boiling point. If it is assumed that the temperature of the liquids rose gradually between 2 and 6 min to that indicated for the lower Winchester, then diethyl ether, b.pt 35°C, would have boiled less than 2 min after ignition of the kerosine fire, and hexane, b. pt 68°C, in less than 5 min. Thus there could have been an explosive atmosphere within cupboard containing low boiling solvents under the conditions of test, and as the surfaces of the cupboard reached temperatures exceeding the self-ignition temperatures of such liquids (for example, diethyl ether, 180°C) in less than 3 min, an explosion could well have occurred in this time. The gaps existing before test between the back and side panels, the destruction of the plastic foam strip around the doors during test and the distortion of the steel sheet panels by heat would each have presented gaps through which flames could have passed. The loss of the light alloy handle by melting, and the failure of the alloy rivets securing the hinges also produced holes or gaps through which vapours could escape or flames could enter the cupboard. Each of these conditions would have added to the risk of ignition or explosion of solvents vapours within the cupboard.

A comparison of the temperature curves for the steel cupboard, Figs 1 and 2, with those for the wooden cupboard[4] tested previously, Fig. 3, indicates that although the wooden cupboard was subjected to fire conditions raising the outer surface to similar high temperatures, but for a longer time, neither the internal surfaces nor the contents of a Winchester bottle reached as high temperatures as in the steel cupboard. Indeed the temperature of the liquids in the wooden cupboard did not reach the boiling point of ether for 7 min, or hexane during the effective period of test, 10 min. Also, none of the four bottles, similar to those in the steel cupboard, failed in any way, although some of the low boiling solvents contained in the smaller bottles were lost by evaporation.

It seems reasonable to suggest that the protection required by solvents cupboards within a laboratory or store containing other combustibles need extend only for the time during which first aid fire fighting could be attempted. If there were a spillage or general fire which continued to burn for a longer period of time, there would be the likelihood that the room and its contents would be destroyed. In respect of resistance to fire for the short period for first aid fighting, estimated at about 5 min, the wooden cupboard is clearly superior to the steel one.

It would also be reasonable to expect that after the first 5 min or so of a fire, at the discovery of which a fire brigade should have been called, the industrial or local authority brigade would be in operation, with appropriate equipment to deal with fully developed room fires, when the involvement of the contents of a solvents cupboard in addition to the remaining room contents would not impose a severe burden on fire fighting facilities.

The effective extinction of the fire involving the steel cupboard with a 2 gallon fluorinated chemical foam extinguisher in a very short period of time indicates the value of this agent, often referred to as AFFF, (aqueous film forming foams), for fires of this kind. The extinguisher was used by an officer who had not previously used such an extinguisher, and who was given short verbal instruction on its use before the test. Extinction with water spray, after the test on the wooden cupboard, took about 5 min, as compared with the 40 s for extinction after the test on the steel cupboard.

5. CONCLUSIONS

1. The tests conducted by the Fire Research Station on a wooden and a steel solvents cupboard indicate that a well designed wooden cupboard provides greater protection from a surrounding spillage fire than a steel office type cupboard to store flammable liquids during the early stages of a fire. Although the wood of the cupboard contributed some fuel to the fire, and accordingly departed from the requirements for issue of a Certificate of Approval, the insulation it provided protected the contents from a rapid rise in temperature.

2. The steel cupboard tested allowed rapid heat transfer from the surrounding flames and hot gases to the contents, resulting in rapid heating and cracking of glass bottles, and, because of the construction with light alloy rivets and handles, rapid failure of such items. Heat distortion was also greater with the steel cupboard than with the wooden cupboard.

3. The form of construction of the steel cupboard tested does not conform to the requirements for the issue of a Certificate of Approval No.1 under the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations, 1972 which calls for integrity unaffected by exposure to fire or accidental impacts, both for the main structure of the cupboard and for any fastenings. There is also a requirement for the supports and fastenings to be non-combustible when tested in accordance with British Standard 476 : Part 4[6]. Thus, although the handle and rivets used in the construction of the tested cupboard might satisfy the latter requirement, they would fail on the requirement for integrity.

4. There are a number of establishments using flammable solvents to which the Factories Act does not apply, but where it would be advisable for appropriate precautions to be taken to minimise the risk of serious fires in order to protect both lives and property. The tests reported on here should enable decisions to be taken as to the type of solvents cupboard suitable for installation in laboratories and stores in such establishments.

5. A 2-gallon fluorinated chemical foam extinguisher is likely to be effective for the first aid extinction of solvent spillage fires.

6. ACKNOWLEDGMENTS

Thanks are due to Messrs J G Corrie and A G Griffiths, who provided equipment and advice on first aid fighting, and to Mr R Moss who assisted in the tests.

7. REFERENCES

1. Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972. Guide to the Regulations. HMSO 1973.

2. Factories Act 1961. The Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972. Certificate of Approval No.1, 1973. Leaflet F2434, HMSO 1973.

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5. STARK, G W V, WHITE, R W and MOSELEY, G E. Wooden laboratory cupboards for the fire protection of solvents. Chem. and Ind. 1971 (42) 1193-5.

6. British Standard 476 : Part 4 : 1970. Non-combustibility test for materials.

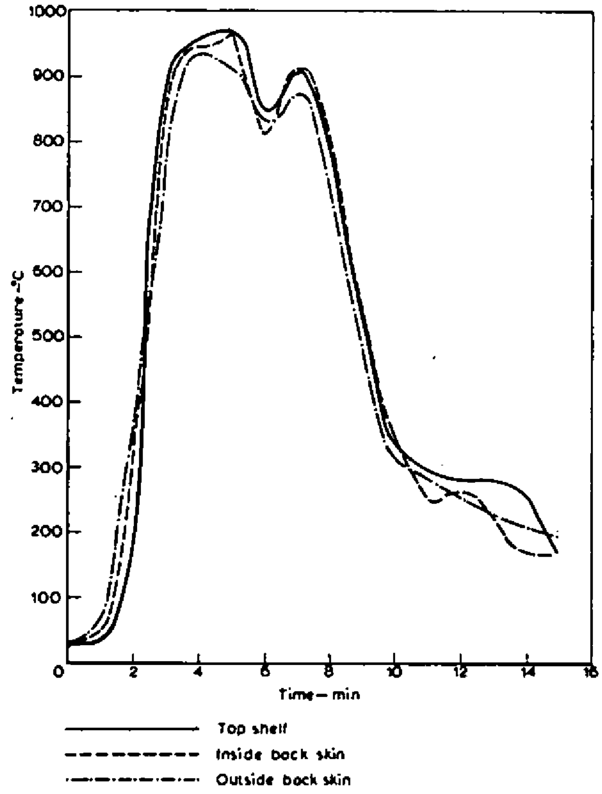

Figure 1 Fire test of steel solvents cupboard — temperatures measured on the steelwork

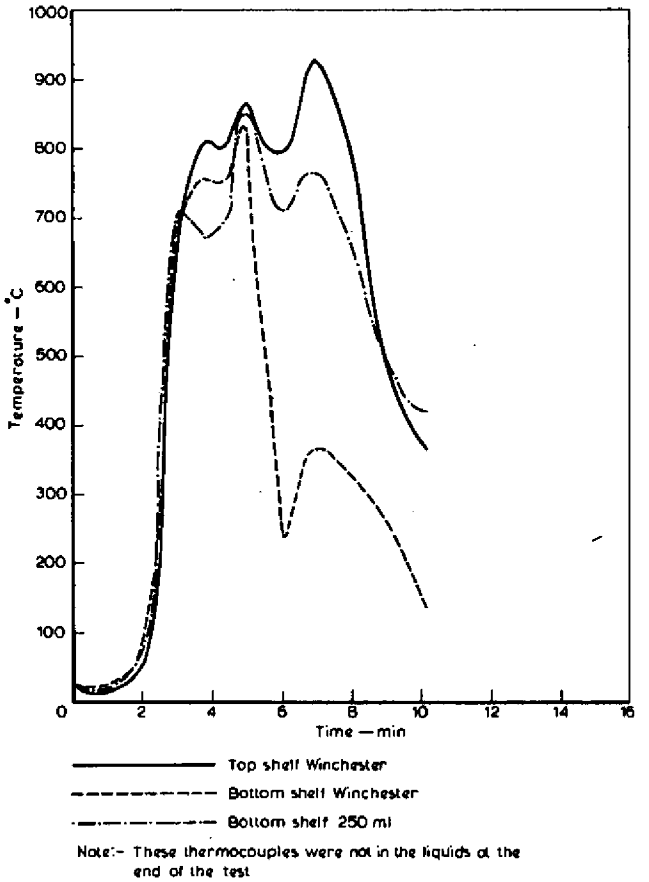

Figure 2 Fire test of steel solvent cupboard — temperatures measured in liquids in bottles on the shelves

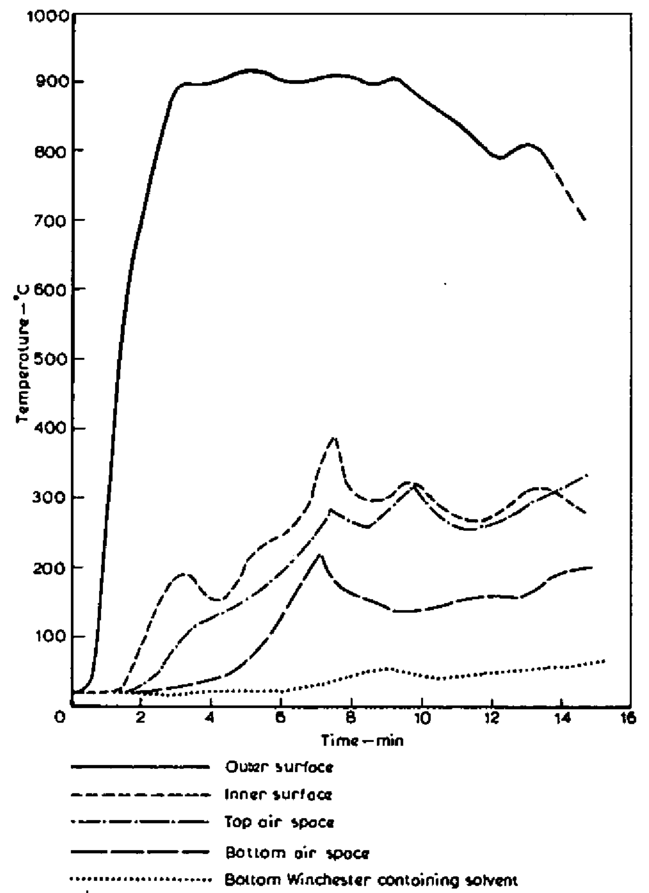

Figure 3 Temperatures measured during a test on a wooden cupboard

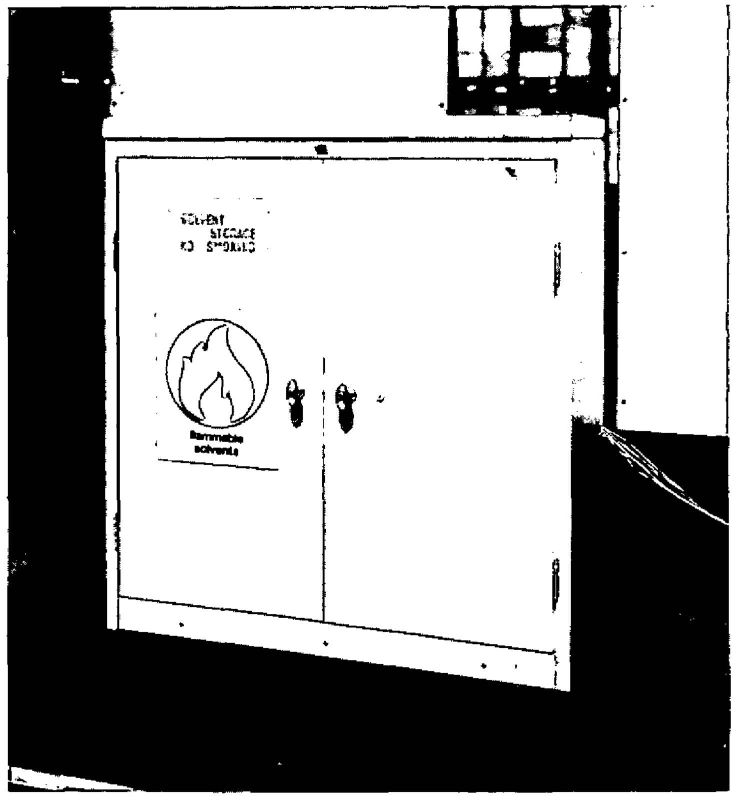

PLATE 1. OUTSIDE VIEW OF CUPBOARD

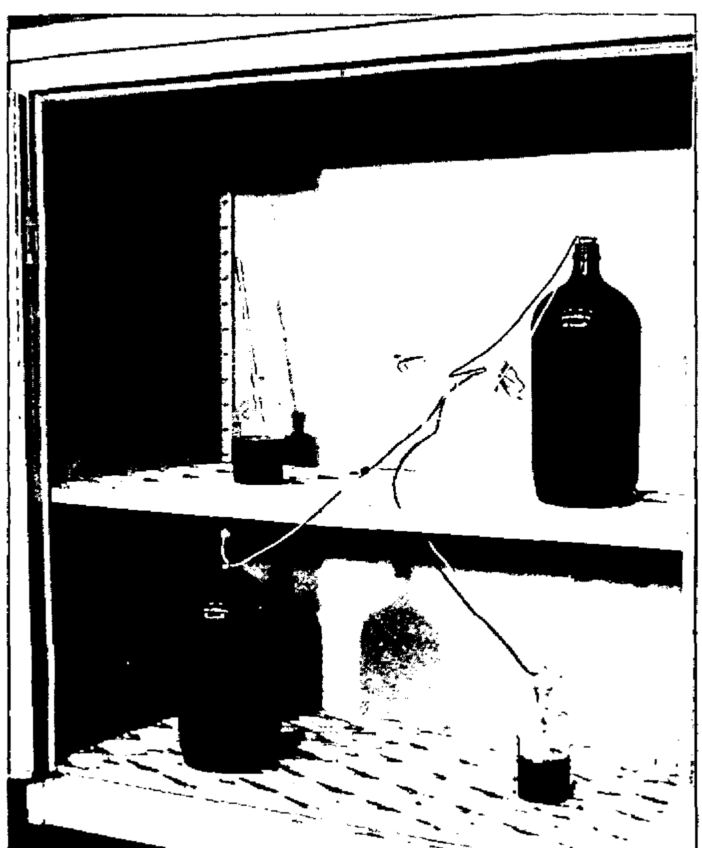

PLATE 2. INTERIOR OF THE CUPBOARD

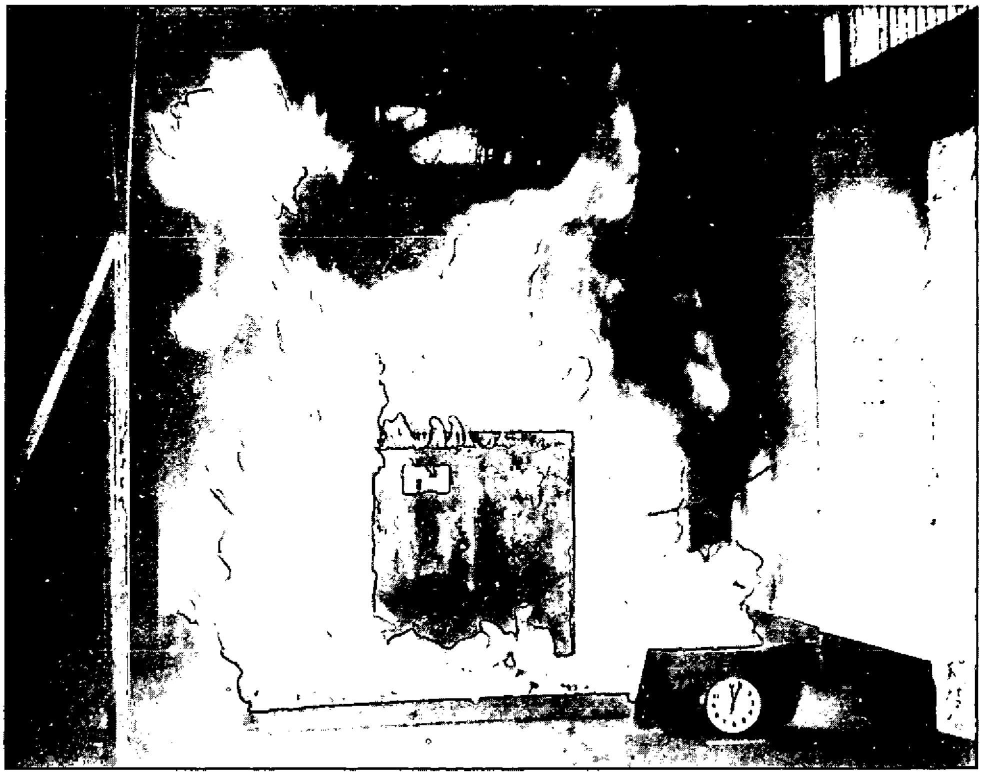

PLATE 3. SHOWING FLAMING FROM TOP OF DOORS AT 4 MINUTES

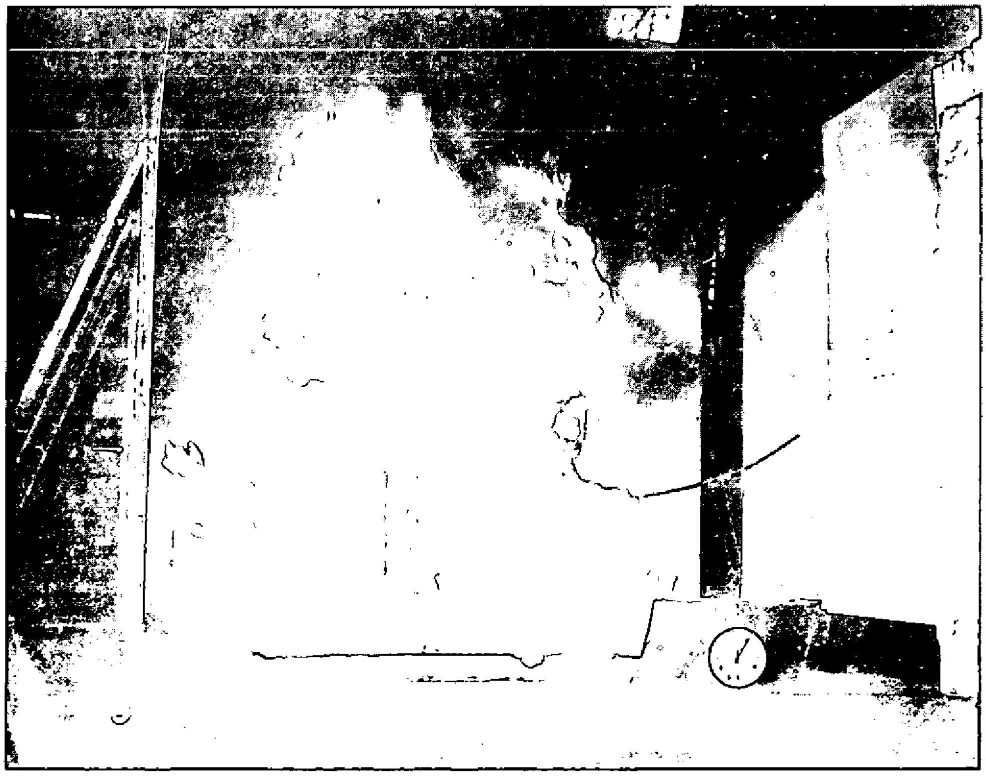

PLATE 4. INCREASED FLAMING AFTER COLLAPSE OF SHELF AT 5½ MINUTES

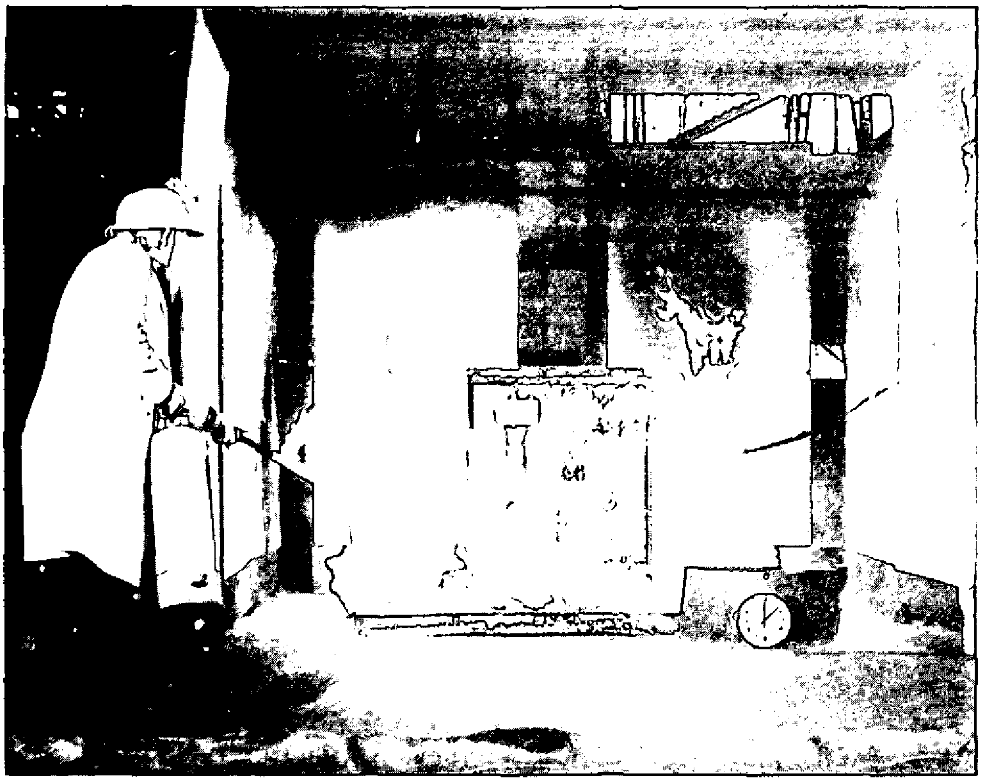

PLATE 5. START OF EXTINCTION

PLATE 6. 10 SECONDS AFTER START OF EXTINCTION

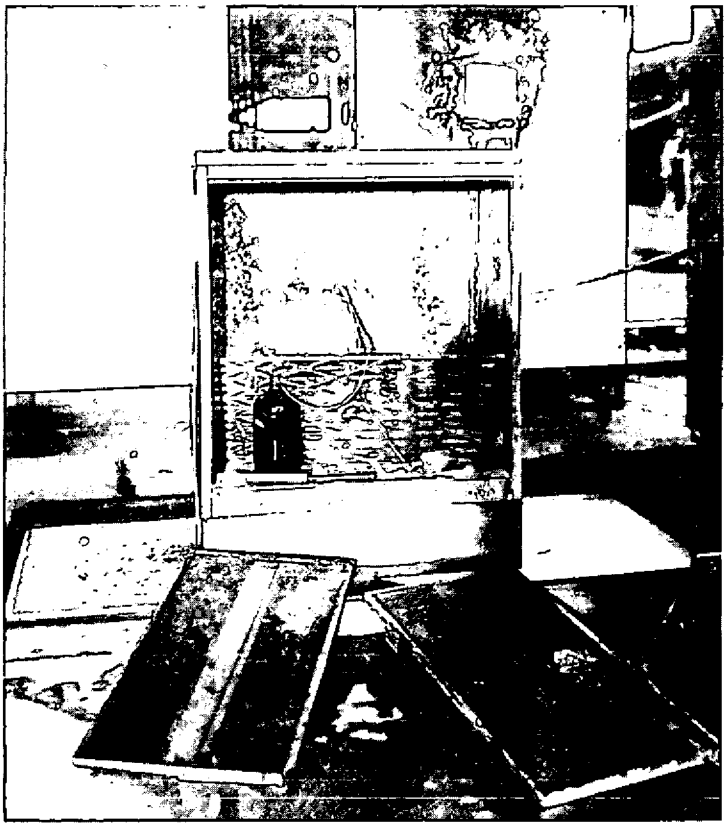

PLATE 7. GENERAL VIEW AT END OF TEST AFTER DOORS HAD FALLEN AWAY

PLATE 8. SHOWING WARPING OF BACK PANEL AND DISLODGED FLAME TRAP/ EXPLOSION RELIEF GAUZE