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THE EXTINCTION OF MAGNESIUM FIRES

by

I. C. Emson

Summary

A study has been made of the extinction of magnesium fires using trimethoxyboroxine and a mixture of chlorobromomethane and mineral oil.

It has been shown that both agents are capable of reducing the white fire of burning magnesium vapour to a glowing red, after which it is possible to apply water to complete the extinction.

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Introduction

The increasing use of magnesium alloys in modern aircraft for wheel casting, heavy structural members, etc. presents a special fire hazard in the event of a crash since water, foam and carbon dioxide all react with burning magnesium to intensify and scatter the fire.

A new material known as trimethoxyboroxine (T.M.B.) has been developed which, after a programme of tests by the Naval Research Laboratory, Washington, D.C. was reported (1) to be effective in extinguishing magnesium fires.

T.M.B., which is a colourless liquid, is an anhydrous compound of boron having a specific gravity of 1.2. It decomposes readily with water and water vapour to form methanol and orthoboric acid.

A preliminary study of the use of T.M.B. on a magnesium fire has been made in order to examine the method of extinction and gain experience in the use of this material.

Investigations have also been made using a mixture of mineral oil and chlorobromomethane (C.B.) as an extinguishing agent (2).

Small scale tests

To investigate the effect of various agents on a magnesium fire small scale tests similar to those reported (1) were made in a 6 in. square x ¾ in. deep steel tray (Plate 1), dished to reduce buckling. The average temperature over the bottom of the tray was measured by an 18 s.w.g. chromel-alumel thermocouple, the wires being peened into the bottom of the tray, 3 in. apart.

A quantity of magnesium alloy in the form of a slab cut from an aircraft wheel casting and weighing about 200 g. was placed in the tray and heated with a blowlamp until the metal melted and ignition occurred. It was found that the characteristic 'white fire' of burning magnesium vapour occurred from a mixture of oxide and metal, and covered the surface of the tray after all the molten metal had been mixed with oxide to form a paste.

Application of an extinguishing agent was made at this stage and its effect on the fire and on the temperature at the bottom of the tray was recorded.

The various extinguishing agents used were applied in the form of a jet at a rate of 100 gm. per min. from a polythene wash bottle through a glass tube, one end of which was drawn out to form a nozzle. The size of the nozzle was adjusted to allow for the differing viscosities of the agents.

Results of small scale tests

A number of tests were carried out which confirmed previous findings (1) that two kinds of combustion occurred, both of which would eventually convert the magnesium to the oxide.

The first was the brilliant white fire typical of burning magnesium vapour which took place from the surface of the material. This was followed by a type of combustion characterized by a dull red glow, and occurred throughout the mass.

At this point the mass was quite hard, and if it was broken a white fire burned for a short time from the newly-exposed surface.

1. Oil - C.B.

A mixture of 40 per cent mineral oil and 60 per cent C.B. by weight was applied. On striking the burning magnesium the white fire was rapidly extinguished and a relatively large secondary oil fire occurred. When this had died away the surface of the magnesium was found to be coated with a thin black deposit. The temperature at the bottom of the tray slowly decreased to below the melting point of the alloy, about 650°C.

The test was repeated using an oil - C.B. mixture followed by a jet of water as soon as the white fire was extinguished. There was no reaction between the water and the magnesium provided the force of the jet did not expose a fresh surface of burning alloy. If a fresh surface was exposed there was a local increase in the intensity of the fire which, however, was soon extinguished due to conduction of heat to the adjacent parts which had been cooled by the water. The temperature at the bottom of the tray fell more rapidly than before due to the cooling effect of the water.

2. T. M. B.

When T.M.B. was applied to burning magnesium the white fire was again rapidly extinguished. The resulting secondary fire, which was green in colour, was considerably less intense than that caused by the oil - C.B. mixture of the previous test. After the secondary fire had died down the surface of the metal was covered with a frothy mass which, as it cooled, formed a foamed coating with a hard glassy skin. The temperature at the bottom of the tray again fell slowly below the melting point of the alloy.

In further tests T.M.B. was applied to extinguish the white fire, followed by the application of a jet of water. There was no visible or apparent reaction between the water and the magnesium, and the temperature at the bottom of the tray fell to below 650°.

3. $C.O_2$

To examine the effect of carbon dioxide gas on burning magnesium a stream of gas from a $C.O_2$ cylinder was directed onto the fire through a $\frac{1}{4}$ in. diameter tube, the flow being controlled by a valve. A high velocity stream had the effect of intensifying the fire, probably due to reaction with the magnesium combined with an increased rate of burning caused by the additional oxygen supplied by entrained air. A low velocity stream produced a slight local diminution of the fire which, however, returned to its original state as soon as the stream was removed.

The small scale tests indicated that both T.M.B. and a mineral oil - C.B. mixture were capable of 'knocking out' the white fire of burning magnesium vapour, after which it was possible to apply water to cool the mass without any violent reaction between the water and the magnesium.

It was realized, however, that the tray fires represented a particular case unlikely to be found in practice due to the evenness and accessibility of the burning surface and also to the fact that with the small amount of material used there was a large surface area : volume ratio allowing rapid cooling. Further tests were therefore made using T.M.B. and a mineral oil - C.B. mixture, on fires involving larger quantities of material.

Large scale tests

Four tests were made each involving an aircraft wheel casting weighing 15 lb., which was ignited by means of an oxy-acetylene torch (Plate 2). The extinguishing agent was applied through an 0.140 in. diameter nozzle connected to a 2-gallon fire extinguisher by a 12 in. length of flexible hose. The extinguisher was maintained at a pressure of 100 lb/sq. in. The flow of liquid was controlled by means of a valve on the extinguisher.

Results of large scale tests

Test 1

A mixture of 60% mineral oil and 40% C.B. by weight was applied in the form of a jet to the burning casting at a rate of about 30 lb/min. Copious volumes of black smoke were produced from the secondary fire, together with choking fumes resulting from the decomposition of C.B. Application was stopped when it was thought that the white fire had been extinguished and a coarse spray of water from a 1 in. hose reel was directed onto the fire, which soon increased in intensity, however, due to the reaction of the water with unextinguished pockets of white fire. A further application of oil - C.B. was made followed by a jet of water. Local flare-ups occurred but the quantity of water applied was sufficient to cool the mass generally to below its melting point. A total of 9 lb. of oil - C.B. mixture was used.

Test 2

T.M.B. was applied to the second casting in the form of a jet which, on hitting the burning magnesium, resulted in a secondary fire, characterised by a green flame and a quantity of white smoke (Plate 3). The mass was cooled by a spray of water without any violent reaction, but when the spray was changed to a jet, the mass was moved by the force of the jet exposing fresh surfaces of white fire which immediately increased in intensity. The fire was extinguished by a further application of T.M.B. followed by a spray of water, a total of 10 lb. of T.M.B. being used.

Test 3

This test was made with a cast iron brake drum bolted into the wheel casting. After ignition a spray of T.M.B. was directed onto the casting and it was noted that secondary fire was greater and the radiation from it more intense when the agent was put on in the form of a spray than when the jet was used in the previous test. Reduction of the white fire by T.M.B. was followed by the application of mechanical foam to blanket the whole mass. There was no tendency for the foam to react violently with the magnesium, which continued to burn beneath the blanket, however, and eventually destroyed much of the covering foam. The remaining fire was put out with T.M.B., of which 11 lb. was used during the test.

Test 4

After ignition of the casting the white fire was reduced using 3 lb. of a mixture of 40% mineral oil and 60% C.B. by weight applied as a jet (Plate 4). This was followed by a water spray which rapidly cooled the alloy without any violent reaction with the water. The casting was reignited and a spray of mineral oil alone was applied, followed by a spray of water. Although 10 lb. of oil was used on the reduced amount of burning alloy, reaction between the water and magnesium resulted in flare up from several places in the mass, which was eventually extinguished by using a jet of water to break it into small parts which were cooled separately.

Conclusions

Although it was not possible to carry out any quantitative tests with the limited amount of materials available, it was found that both T.M.B. and a mineral oil - C.B. mixture were effective in reducing the white fire of burning magnesium vapour, after which it was possible to apply water to cool the mass without any violent reaction between the water and the magnesium.

Results of the tests suggest that it is preferable to apply water in the form of a spray in order that there should be a minimum of physical disturbance to the mass of magnesium.

T.M.B. has the effect of forming a skin of boric oxide when it comes into contact with a fire. This skin prevents contact between burning magnesium and water and also prevents rekindling of hot spots. The small secondary fire which occurs when T.M.B. strikes a hot surface and which is caused by the combustion of methanol and methyl borate, is considered to be of minor importance compared with the effectiveness of the liquid in extinguishing magnesium fires. Further work is needed to decide upon the best way of supplying T.M.B., but it was noted that there was a larger secondary fire and more radiation when it was applied in the form of a spray.

A mixture of mineral oil and C.B. was also capable of reducing the white fire of burning magnesium vapour allowing the safe application of water, but it suffered from the disadvantage of producing a relatively large secondary fire together with quantities of toxic vapours due to the decomposition of C.B.

The present series of tests have indicated the effectiveness of both T.M.B. and a mineral oil - C.B. mixture in dealing with fires of up to 15 lb. of magnesium alloy, but it is considered that further work is required to assess their value against fires involving much larger quantities of metal.

References

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2. RICHMAN, S. I. and GREENSTEIN, L. M. Extinguishing agents for magnesium fires. U. S. Patent No. 2,827,431. March 1958.

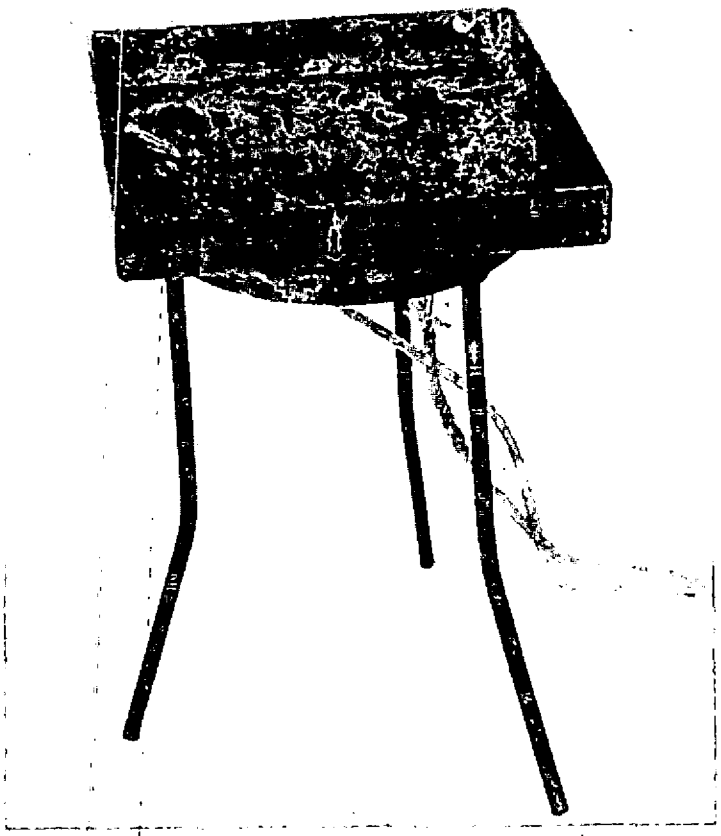

PLATE 1. TRAY USED FOR SMALL SCALE TESTS

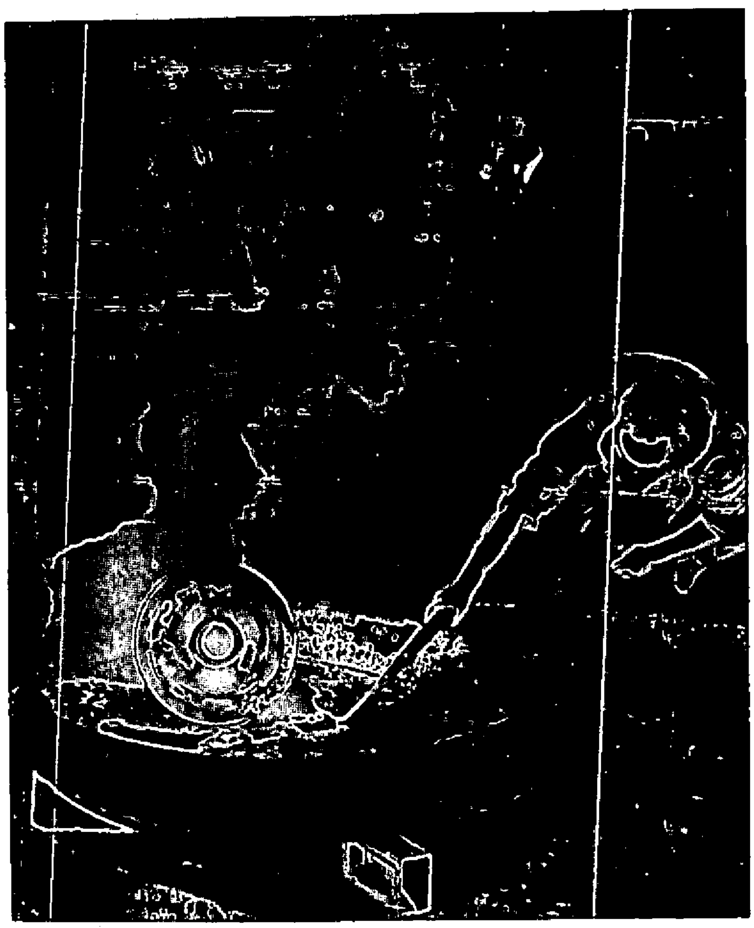

PLATE 2. IGNITION OF WHEEL CASTING BY OXY-ACETYLENE TORCH

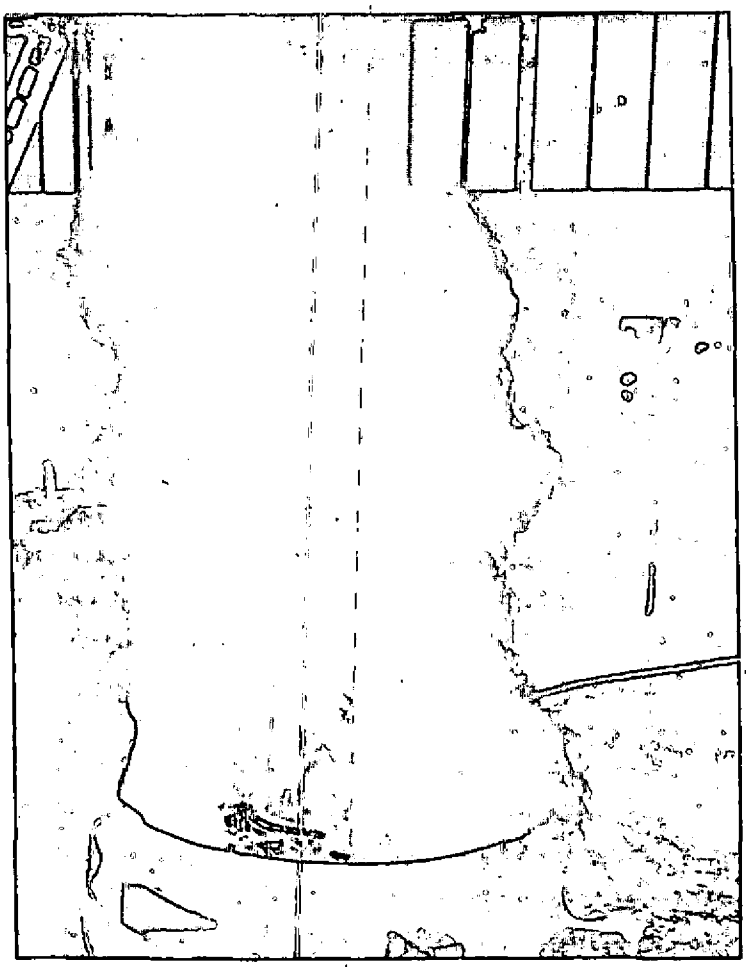

PLATE 3. TMB APPLIED TO A MAGNESIUM FIRE

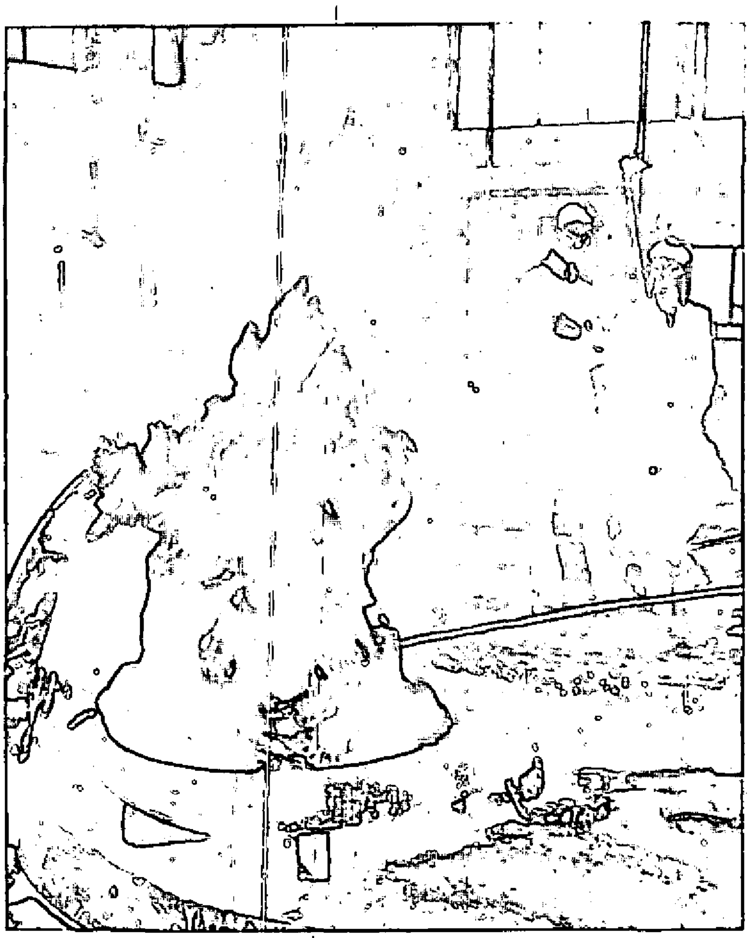

PLATE 4. OIL-CB MIXTURE APPLIED TO A MAGNESIUM FIRE