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NEW AGENTS FOR THE EXTINGUISHMENT OF MAGNESIUM FIRES

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APRIL 1978

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CIVIL AND ENVIRONMENTAL
ENGINEERING DEVELOPMENT OFFICE
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Ground glass powders (frits) have been evaluated as possible suppressants for magnesium fires. Conceptually, these would melt and form a glass coating on the surface of the burning metal, isolating it from the oxygen supply. Some frits containing oxides of magnesium and lithium reacted violently with the burning magnesium. However, several low melting frits proved to be good suppressants and were better than commercial suppressants.

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PREFACE

This report was prepared by the Naval Research Laboratory, Chemistry Division, Combustion and Fuels Branch, under contract FY8952-76-65017 (MIPR) and AFCEC P.O. 77-10, Job Order Number 414N1005, for Detachment 1 (CEEDO) Armament Development Test Center, Tyndall AFB FL. Dr. Frederick W. Williams and Mr. Kenneth D. Lawrence were the principle investigators.

This report has been reviewed by the Information Office (IO) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

Magnesium and its alloys are frequently associated with aircraft fires. The occurrence of wheel-tire explosions began with the advent of high performance aircraft employing high landing speeds, high tire inflation pressures, and minimum weight magnesium wheel assemblies. When jet aircraft are subjected to high-speed landings or aborted take-offs, excessive braking actions can result in temperature rises up to 2000°F (1093°C) in components of the brake. Accidents have been reported involving overheated brakes and wheel-tire fires that resulted in failures of the wheel assembly with severe explosive force. In one incident, a part of the wheel rim which weighed 96 pounds (44 kg) was thrown approximately 600 feet (183 m).

The burning of magnesium metal in aircraft fire incidents creates specialized problems. In the first place, the combustion temperature of magnesium in air is extremely high (approximately 3600°C) and thus the metal becomes a dangerous ignition or pyrolysis source for other materials. Secondly, the routine fire suppression agents, such as water or foams, may actually enhance the burning or cause violent explosions from the secondary hydrogen formed. Other conventional agents such as CO_2, or dry chemical agent, also are restrictive or non-operative (reference 1). There are specialized, commercially available powders for magnesium fires. However, these are effective only where it is possible to completely cover the metal and thereby isolate it from the oxygen supply until it has cooled sufficiently to prevent reignition. Specialized liquid agents have been developed which are capable of being applied to vertical surfaces or fires above ground level (references 2-4). These agents, however, have undesirable storage, reactivity or toxicity characteristics (reference 3).

An extensive literature search was performed to determine what approaches have been tried in the past. Table 1 lists the liquids that have been suggested, while Table 2 lists the dry powders and solid agents. None of these agents are particularly effective on three-dimensional magnesium fires. Operating under the assumption that a new, previously untried approach to controlling magnesium fires was desired, the re-testing of these listed agents was limited to establishing the relative effectiveness of new agents.

SECTION II

EXPERIMENTAL

The lengthy literature search mentioned above was combined with discussions with experts on magnesium from Dow Chemical, National Bureau of Standards-Boulder, Battelle, Ansul Corporation, and the Ceramics Branch of the Naval Research Laboratory. This led to a proposal for testing ground glass powders (frits) as possible new suppressants for magnesium fires. Conceptually, these would melt and form a glass coating on the surface of the burning metal, isolating it from the oxygen supply. By selecting the proper flow properties, the glass layer should remain in place until the core metal had cooled below the ignition point. A wide variety of these frits is commercially available for use as ceramic glazes. A number of them were selected with widely varying chemical compositions and physical properties. These are listed in Table 3, and were obtained from Pemco Products Inc. of Baltimore, Maryland.

To determine the melting and suppressant characteristics of the glass frits, a series of magnesium fire tests was conducted. Considerable thermal energy is required to raise a mass of magnesium to its melting point of 1200°F (649°C). Once ignited, the metal is highly reactive and appears to burn with two types of flame. The first type appears as a dull red glow in or on the metal mass, and is relatively quiescent. The second is an intense, powerful actinic flame which burns with grape-like clusters over the molten metal surface and gives off wisps of burning vapor. An oxy-actylene torch was needed to melt the magnesium block and bring it to its ignition temperature.

First tests involved placing 100- to 150-gram blocks of magnesium in an open mesh metal tray 30 cm by 30 cm by 1 cm deep, placing this tray on a metal tripod 25 cm tall and 20 cm in diameter, and igniting the metal by a torch. This open configuration allowed maximum access of oxygen to the metal, but also allowed the molten magnesium to flow through the screen, as well as most of the suppressant powder. A new system was devised of placing the magnesium on a 30 cm by 30 cm sheet of Transite approximately 6 mm thick. After ignition, the fire was allowed to burn for 1 minute, after which the agent was applied manually with a spatula or scoop. Visual observation was sufficient to monitor the suppression, Table 4.

The higher melting range frits, such as 1 and 4 of Table 3, behaved much as the commercially available Metal-X and G-1 powders. Although they knocked the flames down and suppressed the fire, the glass frits remained separate from each other like a fine sand. This is shown in Figures 1 and 2. However, the lower melting range frits fused and formed a glass coating over the molten metal. Whenever the flames broke through, the glass self-sealed to suppress the flames. Application of about 400 g of powder was sufficient to quench totally flaming samples of magnesium of 100 to 150 g mass in less than 1 minute. This was less than the amount of sand or G-1 needed for comparable magnesium samples. The samples took from 15 to 30 minutes to cool. Although the glass contained the fire, examination of the remaining block showed that all of the magnesium under the glass crust was consumed. In the use of G-1 and Sand, 20 percent of the magnesium remained after the mass cooled. The stages of a typical fire are shown in Figures 3 through 8.

SECTION III

RESULTS AND DISCUSSION

In all, nine different powdered glasses were tested with varying degrees of success. The results of these tests are summarized in Table 4. All of the powders were much finer than commercial solid agents for the suppression of magnesium fires. Some of the powders (1 - 4, Table 3) proved to have too high a melting range to form a fused glass coating over the molten metal. Other powders (numbers 1,5,6, and 9) reacted quite violently with the molten magnesium, especially those containing the metallic oxides of magnesium and lithium. Lastly, the very fineness of the powders--90 percent of which was 325 mesh or finer--eliminated any possibility of using them in a conventional dry chemical extinguisher. The fine frits absorbed moisture and caked in the extinguishers. When they did leave the extinguisher, it was in the form of a fine smoke which could not be effectively applied to a fire.

A second series of experiments was performed using two new frits in the lower melting ranges (7 and 10, Table 3) and from formulations which excluded magnesium and lithium. To eliminate the moisture problem and to evaluate the delivery capabilities of these frits, a coarser granule glass was obtained. The glasses were ground by hand in a metal mortar and pestle and screened for use in a dry chemical extinguisher. It was decided that the required size should be be in the 100 mesh range or perhaps slightly larger, which is the granule size of the Metal-X suppressant.

Various sizes and shapes of orifices were tested in a 5-pound dry chemical extinguisher to determine flow characteristics and rates of delivery. A multiple orifice nozzle with four equally spaced side openings was selected for final testing and evaluation. Although this nozzle is available commercially on larger extinguishers holding 20 to 30 pounds of suppressant, one had to be fabricated to fit the 2-pound and 5-pound extinguishers used in the small scale fire tests. This nozzle is shown in Figure 9. The nozzle is 1.7 cm in diameter and 3.3 cm long. The end is tapered over 1.3 cm of length at an angle of 30 degrees. Four holes 0.95 cm in diameter are drilled perpendicular to the face, 0.64 cm from the end of the nozzle. The end is slotted for easy removal. Excellent flows and delivery rates were observed.

A general comparison between the currently utilized agents, Metal-X and G-1, with glass frits can be made based on these results. Metal-X does allow some recovery of magnesium (approximately 20 percent) and does provide some glazing over the molten mass of burning material. Very little control over the flowing magnesium is provided until the burning material is completely buried. G-1 allows about the same amount of metal recovery (approximately 20 percent) but does not form any glaze over the molten metal. It is too coarse for use in a gas propelled extinguisher and must be used at a distance for these extremely hot fires. The glass frits have good sticking ability on shallow fires and are excellent for controlling flows of molten magnesium. They self-seal and form an excellent glaze.

SECTION IV

CONCLUSIONS

Limited quantities of the most promising glass frits, 7, and 10, from Table 3, were ground and sized to specifications (100 mesh) by the Magic-Flow Vibrator Company of Carrolton, Ohio. The final selection of frits was tested in a 5-pound dry chemical extinguisher with the multiple orifice nozzle.

From these tests it was concluded that these glasses are excellent materials to contain the flow of molten magnesium. They do not react with the burning metal, they knock the flames down quickly, and they form a skin which prevents the molten magnesium from flowing. The white-hot stage of the fire is suppressed quickly, leaving only tiny flames which self-seal as the glass melts to form a crust over the molten metal.

These glasses appear to be noncorrosive to the extinguishers used in the tests, or to nearby equipment. They also seem to be nonhygroscopic and did not cake or cause nozzle plugging.

Due to the limited quantities of glass frits obtained, large scale tests were not possible. Typical cost of these frits (unground) range from about 87 cents a pound to 31 cents a pound in 1-ton and 10-ton quantities, depending upon formulation and amount purchased. This compares to about 97 cents per pound for the G-1 agent and 32 cents per pound for the Metal-X powder.

SECTION V

RECOMMENDATIONS

1. Materials available which are used as fluxes on molten steel and have a lower melting point than any of the glass frits tested should be investigated. These might have a better "sticking" ability on vertical magnesium fires.

2. Larger scale fires should be extinguished to further evaluate effectiveness and delivery techniques.

3. It seems apparent that all of the magnesium is totally consumed if the molten cake is allowed to cool without further action. The suggestion is made that glass frits could be used to contain a magnesium fire, at which time conventional means would be used to actually extinguish the fire.

4. Conventional fire fighting techniques used in conjunction with the glass frits should be investigated to prevent total consumption of the magnesium.

Table 1. LIQUID AGENTS FOR THE SUPPRESSION OF MAGNESIUM FIRES

Agent	Date	Ref
Pitch	1943	5
CCl_4 (carbon tetrachloride)	1943	6
Paraffin-CO_2 foam	1943	7
Inorganic esters of H_3PO_4, SiO_2, H_3BO_3	1944	8
Casein, talc, and $MgCO_3$	1946	9
Trimethoxyboroxine	1956	10
Liquid halocarbons	1958	11
H_3BO_3-glycol mixture	1959	12
NaCl, $MgCO_3$, etc. mixture	1959	13
Halophosphates	1966	14
Tricresylphosphates	1970	15

Table 2. SOME SOLID AGENTS FOR THE SUPPRESSSION OF MAGNESIUM FIRES

Agent	Date	Ref
Asbestos	1943	16
Rock Dust	1943	16
Graphite	1943	16
Talc	1943	16
Feldspar	1943	17
G-1	1945	18
Metal-X	1960	19
Carbon Microspheres	1973	20

Table 3. PROPERTIES OF GLASS FRITS

Glass No	Chemical Composition - percent									Melting Range (°C)	Incipient Flow (°C)
	ZnO	SiO_2	Al_2O_3	MgO	CaO	BaO	K_2O	Na_2O	B_2O_3		
1		61	20	16	3					1250-1300	>700
2		43	11		12	18	12	4		800-1100	>700
3		27			45				28	950-1000	>700
4	65	16							19	1100-1150	660
5		44	14	10	2				30	950-1050	694
6		76	6	1	1			16		800-950	565
7		41	17				3	7	32	800-850	535
8		50	10		9		7	8	16	750-800	558
9	1	70	1				2		26	800-950	562
10	16	41			4			9	30	750-800	570
11	60	8							32	750-800	595

Table 4. MAGNESIUM FIRE SUPPRESSION PROPERTIES OF GLASS FRITS

Glass No.	Amount Needed to Extinguish*		Seconds Until Flame "Knockdown"	Self-Sealing Qualities	Quality of Glaze	Magnesium Recovered	Reaction
1	14 oz	400 g	120	Poor	Poor	None	Some flare-ups
2	(This powder was not tested)						
3	2 lb 8 oz	1150 g	30	Good	Good	None	None
4	2 lb 6 oz	1100 g	45	Good	Good	None	None
5	1 lb	450 g	No knockdown	Minimal	Poor	None	Violent
6	1 lb	450 g	120	Minimal	Good	None	Violent
7	12 oz	350 g	60	Excellent	Excellent	None	Minimal
8	2 lb 2 oz	950 g	120	Minimal	Poor	None	Flare-ups
9	14 oz	400 g	45 to 60	Good	Good	None	Violent
10	1 lb 12 oz	800 g	45 to 60	Excellent	Excellent	None	None
11	(This glass arrived too late to test completely)						
Metal-X	1 lb 8 oz	675 g	45	None	Good	Minimal	None
G-1	1 lb 3 oz	550 g	30 to 45	None	None	20 %	None
Sand	1 lb 6 oz	624 g	60	None	None	20%	None

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* This amount needed to extinguish completely burning 5 oz blocks (150 g) of magnesium.

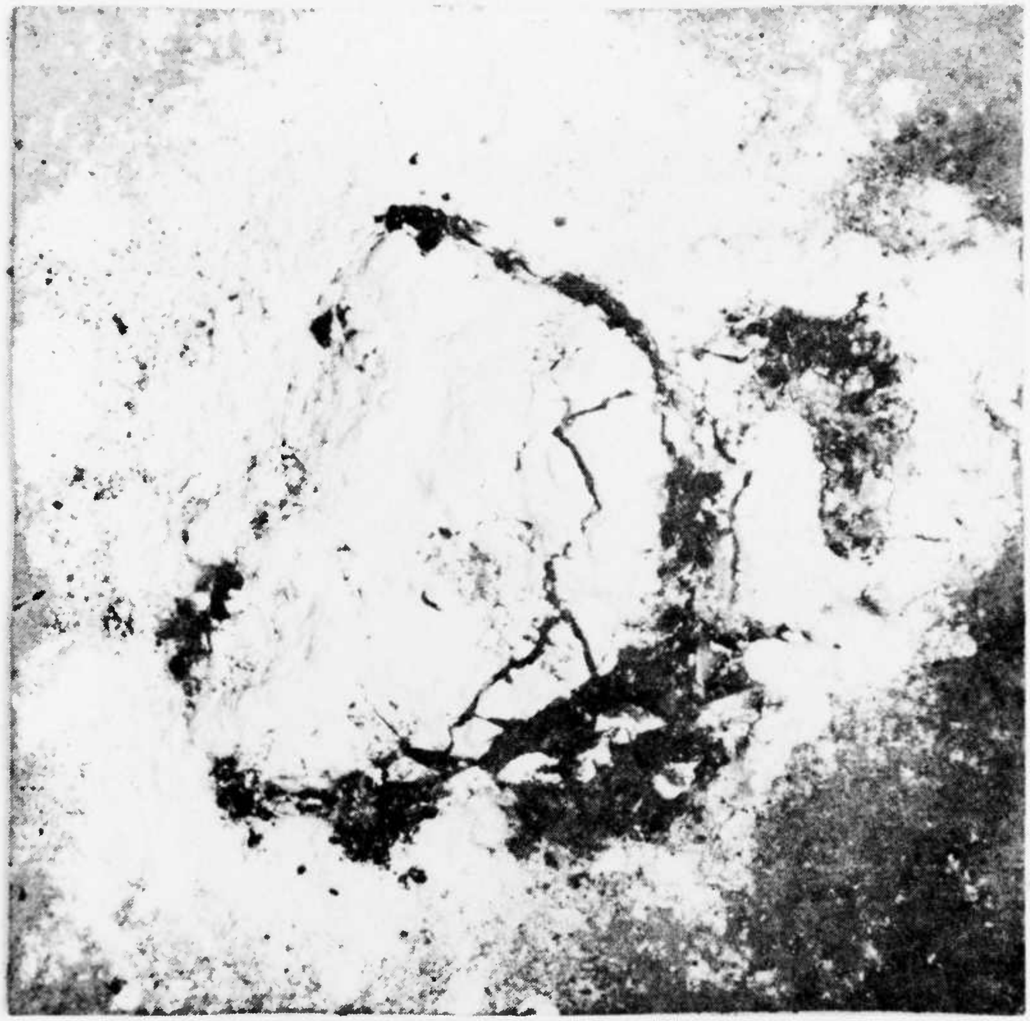

Figure 1. Magnesium Block Intact (Small Amount of Glass Flow Can Be Observed)

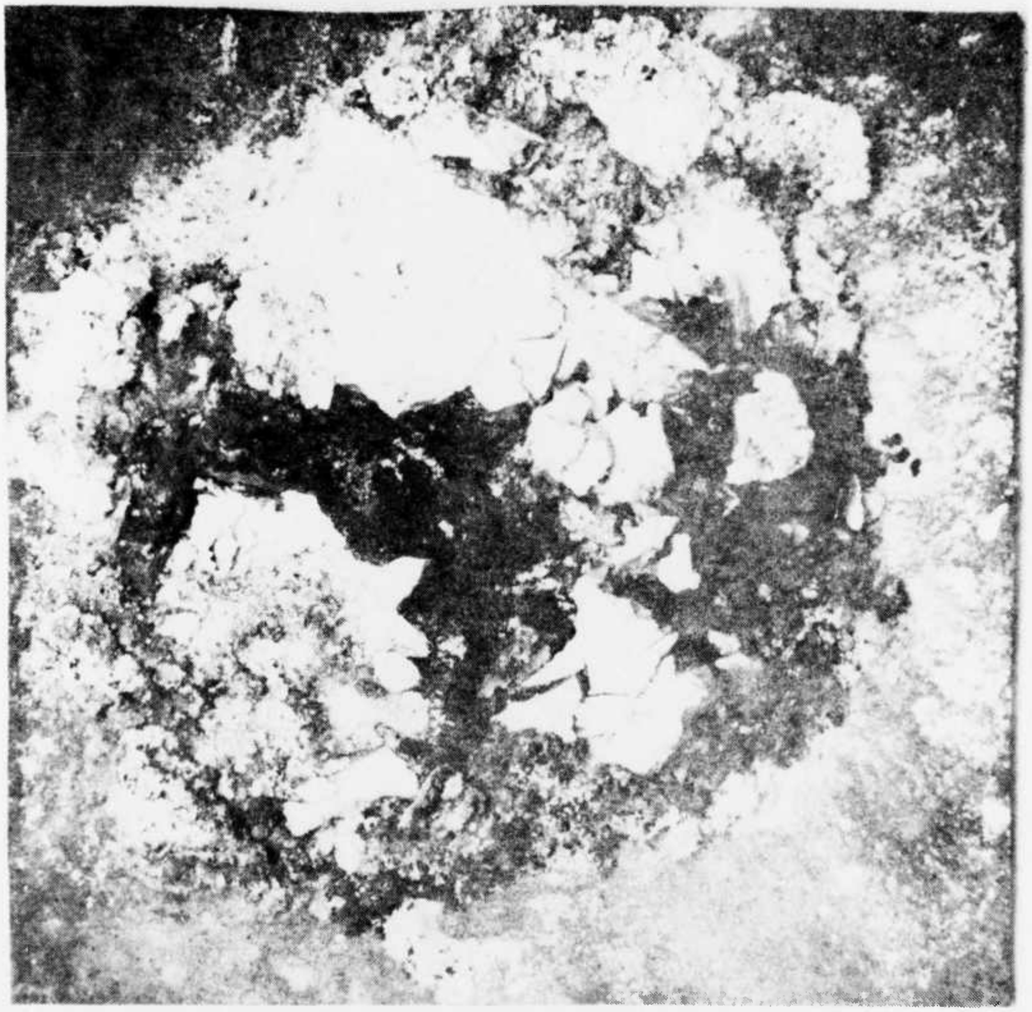

Figure 2. Magnesium Block Broken

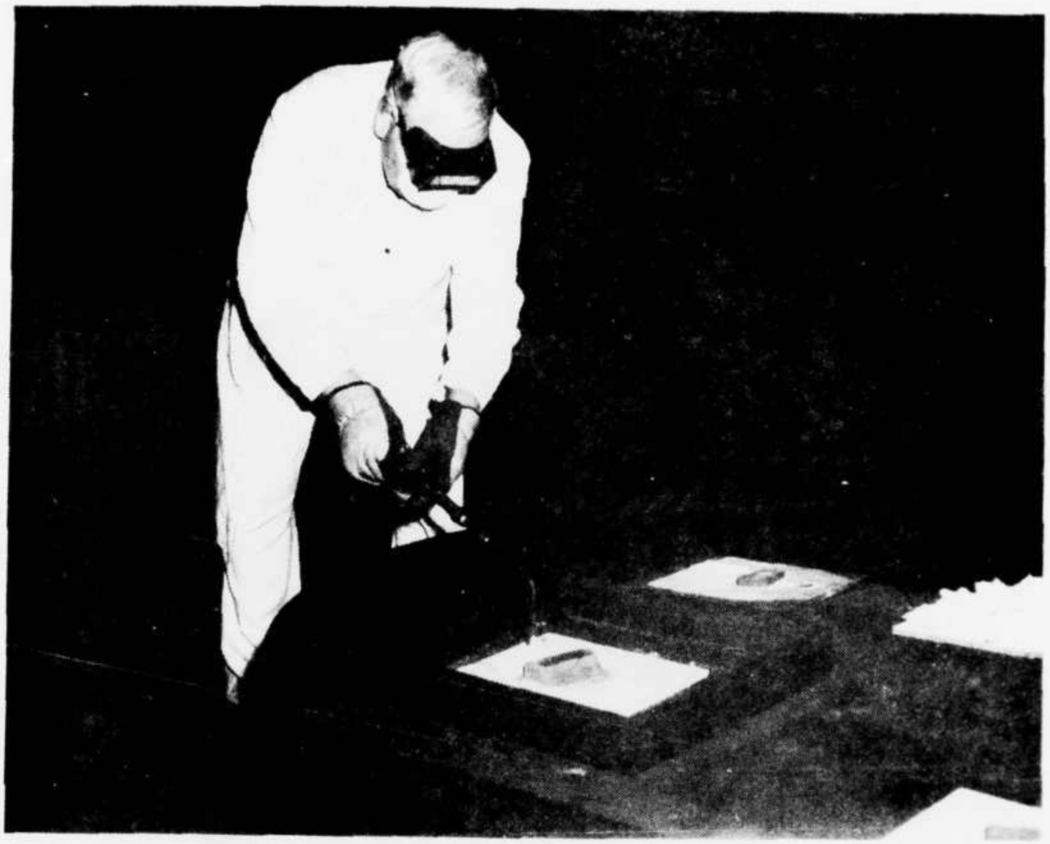

Figure 3. Magnesium Block Melted with Oxy-acetylene Torch Before Ignition

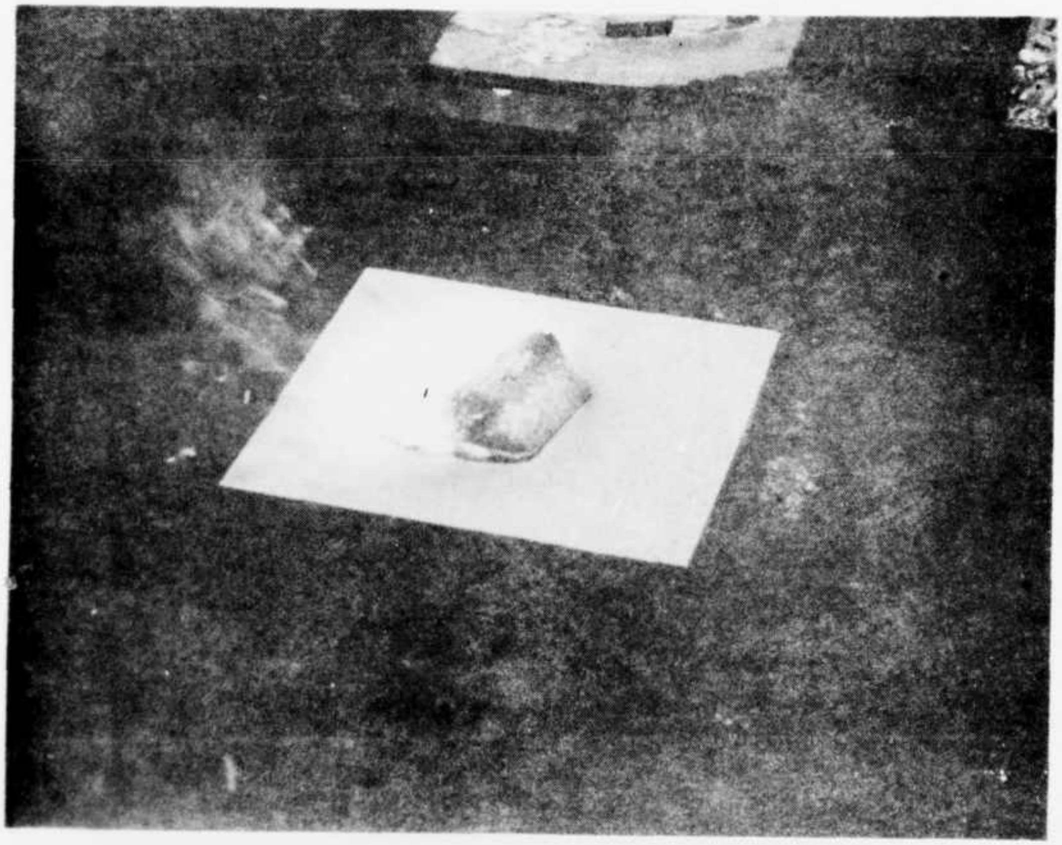

Figure 4. Magnesium Block with Partial Fire Involvement

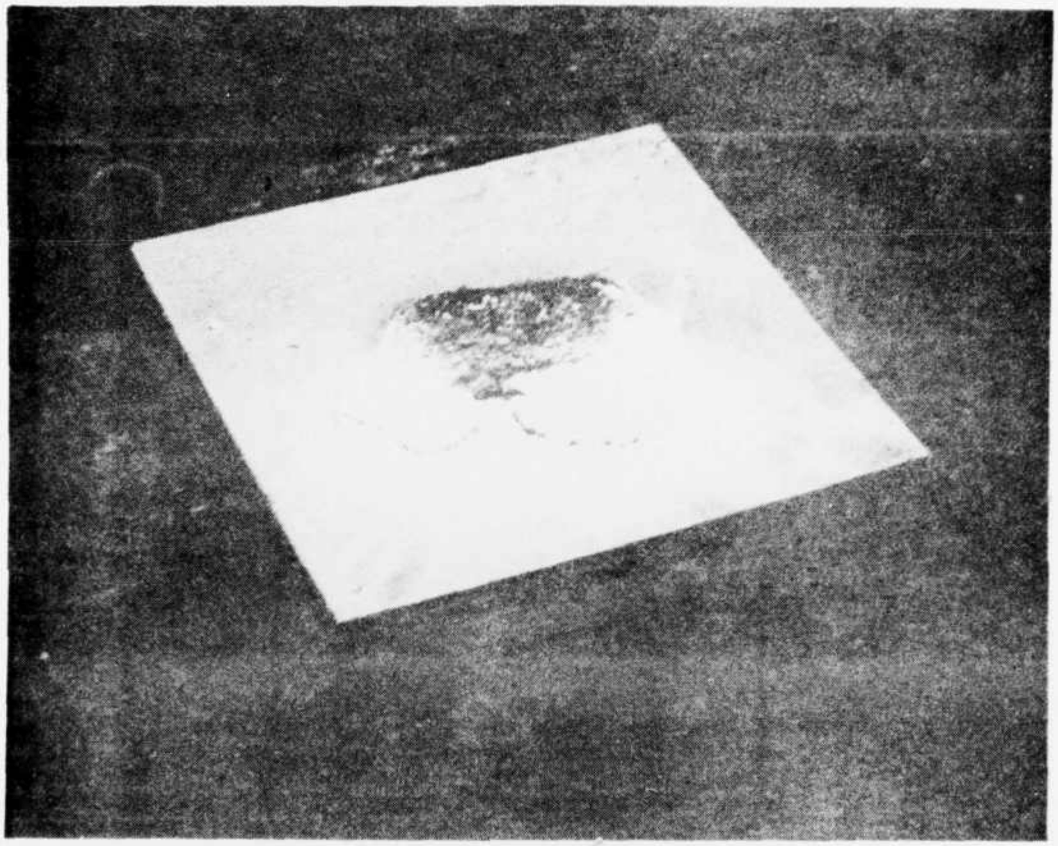

Figure 5. Magnesium Block Flowing with Partial Fire Involvement

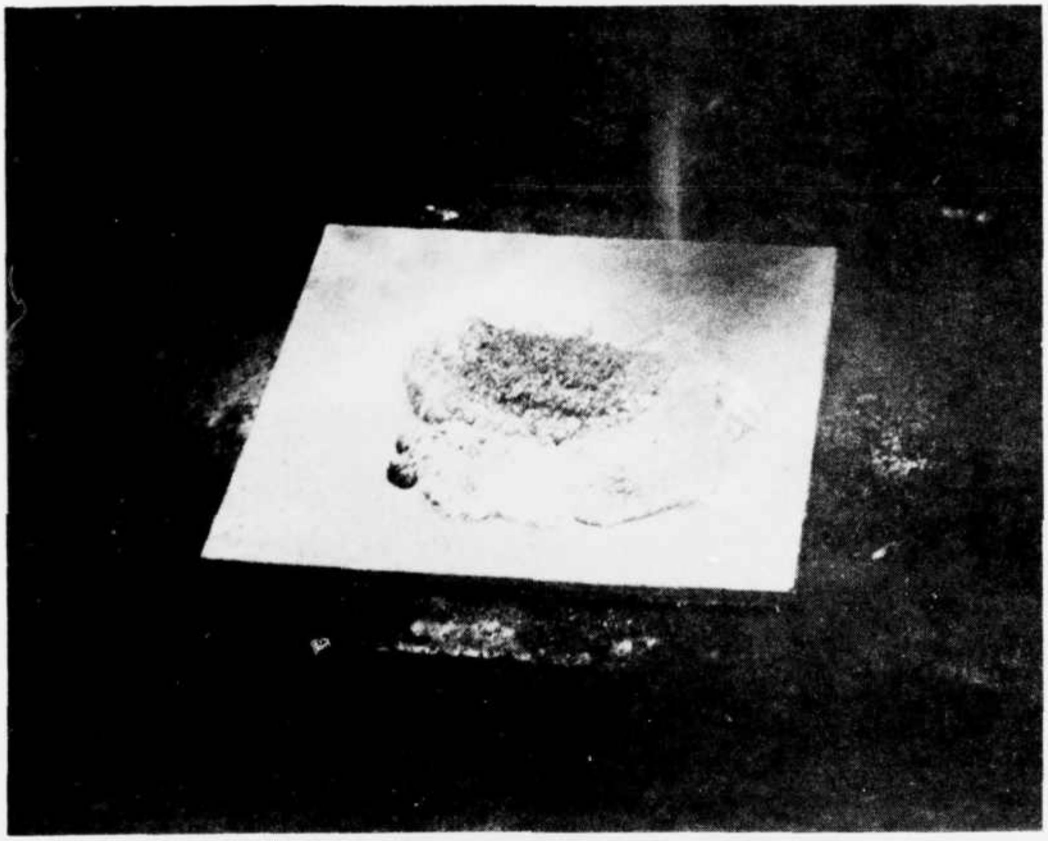

Figure 6. Low Melting Frit Being Applied Manually to Magnesium Fire

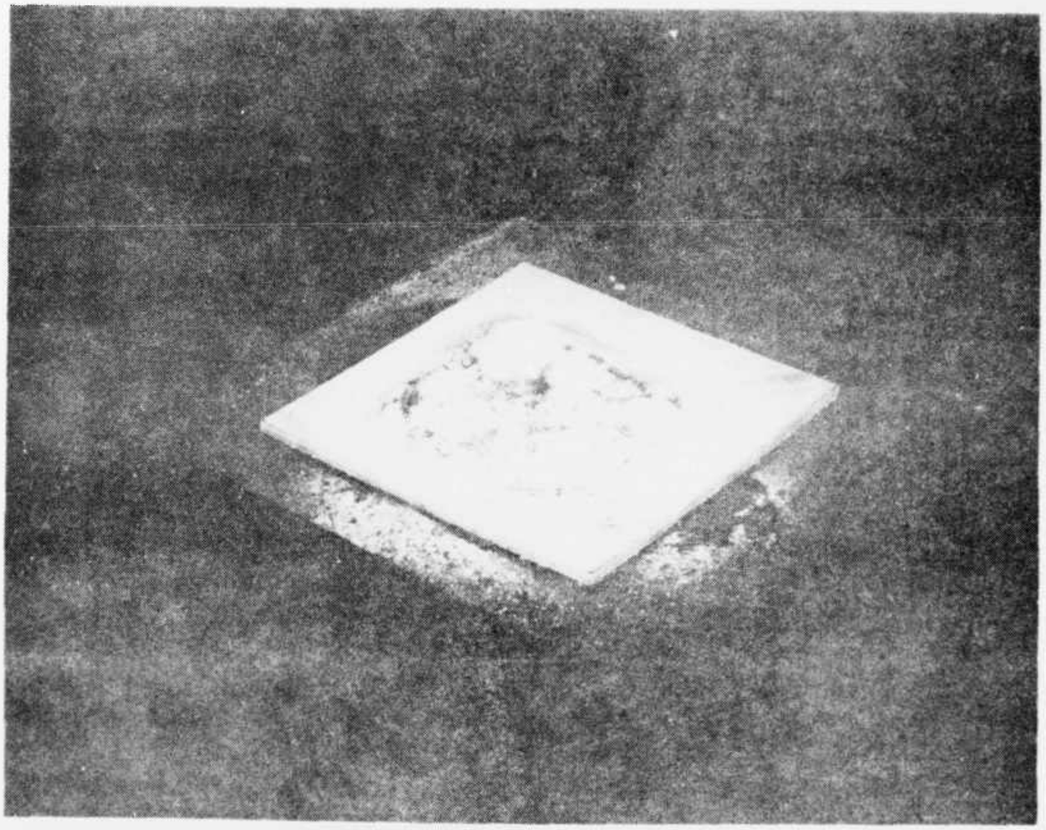

Figure 7. Self-Sealing Action of the Low Melting Frit Beginning to Work

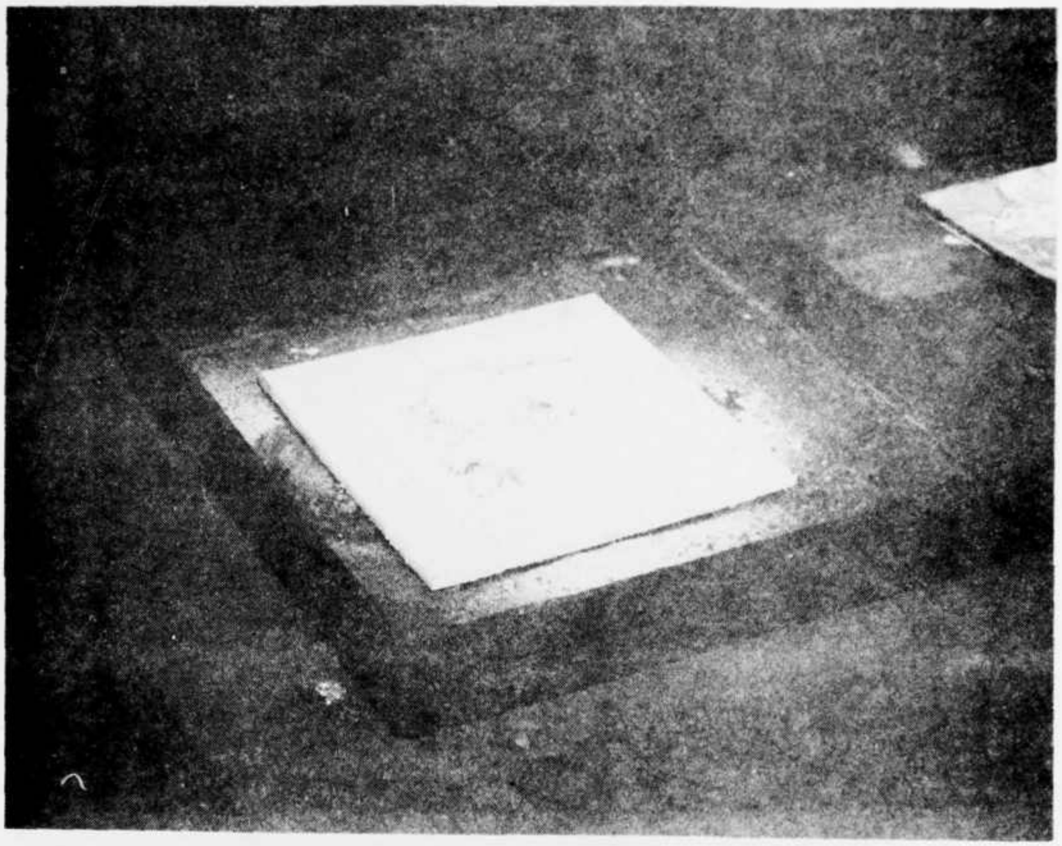

Figure 8. Flaming Combustion Completely Contained Without Further Application of Agent

Figure 9. Nozzle Designed to Deliver Frits from 2- and 5-Pound Extinguishers

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