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AN INVESTIGATION OF DESENSITIZING AGENTS FOR PYROTECHNIC MIXTURES

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U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

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AN INVESTIGATION OF DESENSITIZING AGENTS FOR PYROTECHNIC MIXTURES

Prepared by

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ABSTRACT: Mixtures of 1:1 boron-sodium nitrate and 1:1 magnesium-sodium nitrate are more effective than black powder in igniting low flame temperature ("cool") propellants. They are also more impact sensitive. Several materials have been investigated as desensitizing agents for these mixtures. These included Armeen 16D, Aroclor 5460, camphor, D-2 Navy desensitizing wax, 1,3,dinitro, 2,2,dimethylpropane, paraffin, potassium dichromate, stearic acid, and talc. The experimental results show that these materials have relatively small effects on sensitivity unless the amount of desensitizing agent is fairly large. This greatly decreases the effectiveness of the mixture for igniting propellant grains. A more satisfactory method of desensitization will be sought.

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Studies carried out in the Naval Ordnance Laboratory in connection with an investigation of the mechanism of propellant ignition, indicated that hot solid bodies are very effective in igniting "cool" propellants. Of a number of pyrotechnic mixtures yielding high percentages of solids on ignition 1:1 boron-sodium nitrate and 1:1 atomized magnesium-sodium nitrate (reference a) proved to be the most effective in igniting "cool" propellants. However, their impact sensitivities are much higher than that of black powder which is now used in gun primers. Reference c, authorized the investigation of desensitizing agents for pyrotechnic mixtures which have been shown to be more effective than black powder in igniting "cool" propellants. The results of one phase of this investigation, carried out under task NOL-Re2a-184-1-52, are summarized in this report. The data presented are believed to be of interest to activities working in the fields of pyrotechnics and propellant ignition, even though the results are negative in nature.

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S. W. Booth
By direction

CONTENTS

REFERENCES

a. NAVORD Report 1578, Studies of Propellant Ignition by Pyrotechnic Mixtures, R. D. Cool, 18 Dec 1950.

b. NAVORD O.S. 5908 "Projectile Load Mark 9 Mod 0 (6"/47 Illuminating)", paragraph E8b Compounding of Relay Igniter.

c. BuOrd ltr Re2a-HWK NP51 Ser 23916 to NOL of 4 Aug 1951.

d. NAVORD Report 1589, "Impact Sensitivity Determinations of Explosive Compounds Tested During the Period from 1 Jan 1950 to 1 Nov 1950".

AN INVESTIGATION OF DESENSITIZING AGENTS FOR PYROTECHNIC MIXTURES

INTRODUCTION

1. Studies of propellant ignition by pyrotechnic mixtures (reference a) showed that 1:1 boron-sodium nitrate and 1:1 atomized magnesium-sodium nitrate mixtures were much more effective than black powder for igniting grains of pyro powder (IHCD-24), Cordite N powder (SPCG 9149), and experimental cool propellant having a flame temperature of 1900°K (EX-6627). Subsequent tests at the Naval Ordnance Laboratory showed similar results with grains of another experimental cool propellant having a flame temperature of 1700°K (EX-6465).

2. Impact sensitivity tests, using the apparatus described in reference d, showed drop heights of 202 cm and 153 cm for the magnesium and boron mixtures respectively. Black powder, which is widely used in primer tubes for propellant ignition, shows a value of 314 cm under the same conditions. Attempts were made to correct this undesirable property by coating constituents of the mixtures with the desensitizing agents listed in Table 1.

APPARATUS AND PROCEDURE

3. It was believed that the maximum desensitization with the minimum effect on ignition, might be achieved by a precipitation or an adsorption mechanism. Therefore, with the exception of a few attempts to coat boron with paraffin by melting, (reference b), and dry mixing with talc, the coating agents listed in Table 1 were dissolved in a suitable solvent. The material to be coated was then stirred mechanically for an hour in this solution. In most cases excess solution was then removed by filtration on a Buchner filter and the treated material was dried in air.

4. The D-2 wax dissolves completely in hot ethyl acetate but reprecipitates as the solution cools. This property was expected to be of advantage in giving uniform coatings. However, it was found that the amount of coating varied with the speed of filtration, resulting in varying amounts of solvent evaporation, but no simple satisfactory method was available for determining the amount of desensitizing agent present.

5. When preliminary tests indicated that appreciable desensitization required much more desensitizing agent than had been expected, preparations were made by spreading out the stirred mixtures, suspended in the minimum amount of solvent required (50 ml. to 75 ml. for the amounts of material used here), in a thin layer and letting the solvent evaporate spontaneously. This insured the presence of all the desensitizing agent added but did not guarantee uniformity in coating.

6. With the exception of several check samples mixed mechanically all boron-sodium nitrate and magnesium-sodium nitrate mixtures were carefully made on glazed paper with a spatula.

7. Impact tests were made by the Bruceton procedure using about 25 samples per determination. The apparatus described in reference (d) was not readily available so the drop tester shown in NOL Ammunition Division Sketch 1914 was used. This apparatus was modified by omitting the parts represented by A.D. Sketches 1917 and 1930. The tools shown in NOL Sketch 549483 were substituted for those shown in AD 1914 (AD Sketches 1931 and 1932). A 10 mg sample was pressed at 87 lb. dead load into the cup shown in Figure 1. The firing pin shown in NOL Sketch 549483 rests on top of the pressed powder and a 2 kilogram weight is dropped directly on the firing pin. With this apparatus, black powder could not be initiated with a drop height of 25 inches, which is about the limit for the tools being used.

8. Ignition tests were made in the steel bomb described in reference (a). The propellant used was EX-6465 having a flame temperature of 1700°K. Small samples of the stock mixtures were weighed on a magnetically damped chainomatic analytical balance. The ignition element was fired by 110 volt A.C. from the wall circuit.

RESULTS

9. Results of impact tests are listed in order of decreasing sensitivity for boron-sodium nitrate mixtures in Table 2 and for magnesium-sodium nitrate mixtures in Table 3. These tables also show the identity and quantity of the material treated and the desensitizing medium used.

10. Results with different mixtures of the same composition (Table 6) show that the uniformity of the mixtures is highly important and considerable care is required to obtain thorough and uniform mixing. Hand mixing gave more uniform samples than the mechanical method employed here (tumbling air-dried constituents, without pebbles).

11. Preparations 43, 44 and 45 (Table 7) show no significant change in sensitivity with decrease in particle size of sodium nitrate when mixed with untreated boron.

12. Preparations 5, 36 and 37 (Table 8) show that 2%, 5% and 10% additions of paraffin to boron do not significantly affect the sensitivity of the mixtures. Similarly, preparations 193, 194 and 195 (Table 9) show that the addition of 1%, 2% and 10% of camphor to boron does not significantly affect the sensitivity of the mixtures. The low sensitivities obtained in mixtures of sodium nitrate with boron and magnesium when treated with solutions of high concentrations of D-2 wax in ethyl acetate (Table 11) are doubtless due to a dilution effect. A rough check indicated a weight of D-2 wax approximately equal to the weight of boron present in preparation 119. The sensitivity obtained with a known addition of D-2 wax equal to 10% of the boron treated is close to that obtained when boron was treated with a solution of 1 g. D-2 wax in 100 ml ethyl acetate.

13. On the other hand, preparations 116, 117 and 118 (Table 12) show a difference of only 0.15 in. between additions of 1% and 2% Armeen 16D to boron and a difference of 1.0 in. between 2% and 10% additions. Rough measurements on the amount of Armeen 16D added to the boron used for preparation 115 indicated that it equaled, or slightly exceeded, the weight of the boron. Preparations 123 and 124 also show a definite lowering of sensitivity, 5.88 in. to 8.20 in., when the percentage stearic acid added to the boron is increased from 2% to 10%.

14. Table 13 shows that treating the fuel is much more effective than treating the oxidant with Navy Desensitizing Wax D-2 or Aroclor 5460. The magnesium-sodium nitrate mixtures show this to a smaller extent than the boron-sodium nitrate mixtures. The desensitizing effect on treating the sodium nitrate increases with the screen size of the oxidant from <325 to 100-200 mesh.

15. Results in Table 4 show that the efficiency of igniting the propellant by coated mixtures of boron and sodium nitrate is decreased as the sensitivity is decreased.

16. Magnesium mixtures (Table 5) gave irregular results. A number of mixtures fired with a hot-wire initiator but would not fire with XC-9 charged units. It is thought this may be due to the magnesium mixtures having a conductance with high resistance which would heat up the mixture sufficiently to ignite it.

17. Boron and magnesium were treated with solutions of varying concentrations of paraffin in benzene. The results of the impact tests shown in Table 10 indicate that this treatment did not appreciably affect the sensitivity of the boron-nitrate or the magnesium-nitrate mixtures.

CONCLUSION

18. It is possible to reduce the impact sensitivity of boron-sodium nitrate and magnesium-sodium nitrate mixtures by adding desensitizing agents. However, in order to get sensitivities which compare favorably with that of black powder, the methods described in this report require such a large amount of added agent that the effectiveness in igniting propellant grains is reduced too much.

STATUS

19. Other methods of desensitizing boron-sodium nitrate and magnesium-sodium nitrate mixtures will be sought.

20. Pelleting these mixtures under pressure and the resulting change in sensitivity should be investigated.

TABLE 1

MATERIALS USED

Fuels

Boron (82% + purity, F. W. Berk & Co., Wood Ridge, N.J.) < 325 mesh
Magnesium, atomized < 325 mesh.

Oxidant

Sodium nitrate (Reagent) < 325, 200-325, 100-200 mesh

Coatings

Armeen 16D (hexadecylamine) Lot 5795, Armour, Chicago.
Aroclor 5460 (Chlorinated diphenyl, m.p. 100-105°C., density 1.74 Lot No. 568. Monsanto, St. Louis).
Camphor (U.S.P. Dupont)
D-2 Navy Desensitizing Wax (Paraffin, lecithin, nitrocellulose, m.p. 170-175°C.)
1,3,Dinitro, 2,2, dimethyl propane (m.p. 90°C.)
Paraffin wax
Potassium dichromate (Reagent)
Stearic acid (Reagent)
Talc (Technical grade, Universal Asbestos Corp., Richmond Hill, N.Y.).

Solvents

Benzene (Reagent)
Chloroform (U.S.P.)
Ethyl acetate (Reagent)

Propellant

EX 6465

TABLE 2

IMPACT TESTS ON 1:1 BORON-SODIUM NITRATE MIXTURES

(Sodium nitrate is 200-325 mesh unless shown otherwise. Boron powder all passed through a 325 mesh screen).

Prepn. No.	50% Ht. in ins.	Std. Dev.	Const. Treated	Wt. in gm.	Treatment
16	4.75	0.76	B	3	1g. D-2 wax/100 ml. chloroform
8	5.40	0.43	B	5	5g. Paraffin/100 ml. benzene
90	5.40	0.52	B	3	6g. $K_2Cr_2O_7$/100 ml. water $NaNO_3$ ($<$325)
13	5.41	0.44	B	3	1g. D-2 wax/100 ml. benzene
4/5/51[b]	5.50	0.32	None		Untreated
39	5.87	1.00	B	3	1g. D-2 wax/100 ml. hot water
123	5.88	0.18	B		Added 2%(a) stearic acid from benzene soln.
121	5.89	0.33	B		Added 1%(a) D-2 wax from ethyl acetate soln.
5	5.91	0.21	B		Added 2%(a) paraffin by melting & stirring
45	5.98	1.24	None		Untreated $NaNO_3$ (100-200)
44	6.13	0.44	None		Untreated $NaNO_3$ (200-325)
193	6.16	0.44	B		Added 1%(a) camphor from benzene soln.
10	6.25	0.36	B	5	10g. paraffin/100 ml. benzene
80	6.25	0.32	$NaNO_3$	5	0.1g. D-2 wax/75 ml. ethyl acetate
7	6.29	0.52	B	5	5g. paraffin/100 ml. benzene
116	6.35	0.48	B		Added 1%(a) Armeen 16D
104	6.42	0.74	B		Added approx. 30% 1,3, dinitro, 2,2, dimethyl propane from benzene solution.
70	6.48	0.66	$NaNO_3$	5	5g. D-2 wax/75 ml. ethyl acetate
117	6.50	0.87	B		Added 2%(a) Armeen 16D
194	6.50	0.37	B		Added 2%(a) Camphor
81	6.52	0.23	$NaNO_3$	5	0.1g. D-2 wax/75 ml. ethyl acetate
75	6.57	0.80	$NaNO_3$ (100-200)	5	1g. D-2 wax/75 ml. ethyl acetate
29	6.57	0.19	B	3	2g. paraffin/100 ml. benzene
50	6.59	1.09	$NaNO_3$	10	25g. Aroclor 5460/50 ml. chloroform
			B	3	1g. D-2 wax/100 ml boiling water
71	6.59	1.80	$NaNO_3$	5	1g. D-2 wax/75 ml ethyl acetate
83	6.59	1.46	B		10%(a) talc added
25	6.61	0.81	B	3	1g. paraffin/100 ml benzene
43	6.63	0.57	None		Untreated $NaNO_3$ ($<$325)
195	6.67	0.28	B		Added 10%(a) camphor from benzene soln.
65	6.70	1.55	$NaNO_3$ ($<$325)	10	25g. Aroclor 5460/50 ml chloroform
103	6.71	0.09	B	3	1g. 1,3 dinitro, 2,2, dimethylpropane/ 50 ml benzene
120	6.80	0.68	B		Added 2%(a) D-2 wax from ethyl acetate soln.
37	6.86	0.85	B		Added 10%(a) paraffin by melting & stirring.
36	6.90	0.51	B		Added 5%(a) paraffin by melting & stirring.
79	7.00	0.55	B	5	0.1g. D-2 wax/75 ml ethyl acetate

TABLE 2 (continued)

Prepn. No.	50% Ht. in ins.	Std. Dev.	Const. Treated	Wt. in gm.	Treatment
57	7.09	0.34	$NaNO_3$ (100-200)	10	25g. Aroclor 5460/50 ml chloroform
118	7.50	0.36	B		10%(a) Armeen 16D added.
22-b	7.61	1.90	None		Mixed mechanically
4	7.87	8.55	B	3	6g. stearic acid/100 ml. benzene
92	7.97	3.60	B	3	10g. stearic acid/75 ml benzene
124	8.20	0.97	B		Added 10%(a) stearic acid
51-b	8.39	7.22	None		Mixed mechanically
			B	3	25g. Aroclor 5460/50 ml chloroform
66	9.30	1.71	$NaNO_3$ (<325)	10	25g. Aroclor 5460/50 ml chloroform
58	10.36	1.23	B	3	25g. Aroclor/60 ml chloroform
			$NaNO_3$ (100-200)	10	25g. Aroclor/50 ml chloroform
122	10.90	1.96	B		Added 10%(a) D-2 wax
40	11.29	1.02	B	3	1g. D-2 wax/100 ml ethyl acetate
			B	3	25g. Aroclor/60 ml chloroform
52	11.69	1.32	$NaNO_3$	10	25g. Aroclor 5460/50 ml chloroform
46	11.70	2.13	B	3	25g. Aroclor/60 ml chloroform
87	12.86	2.30	$NaNO_3$	5	5g. D-2 wax/75 ml ethyl acetate
			B	3	1g. D-2 wax/100 ml ethyl acetate
76	13.00	21.87	$NaNO_3$ (100-200)	5	1g. D-2 wax/75 ml ethyl acetate
19	14.75	0.90	B	3	1g. D-2 wax/100 ml ethyl acetate
115	17.94	1.62	B	4	10g. Armeen 16D/100 ml benzene
85	>25		B	5	5g. D-2 wax/75 ml ethyl acetate
			B	5	5g. D-2 wax/75 ml ethyl acetate
89	>25		$NaNO_3$	5	5g. D-2 wax/75 ml ethyl acetate
93	>25		B	3	10g. stearic acid/75 ml benzene
119	>25		B	5	5g. D-2 wax/75 ml ethyl acetate

(a) "Added x%" means a weight of desensitizing agent equal to that (x) percent of the substance treated. It does not indicate percent of agent in terms of total weight of the mixture.
(b) Data taken from earlier work.

TABLE 3

IMPACT TESTS ON 1:1 MAGNESIUM-SODIUM NITRATE MIXTURES

(Sodium nitrate is 200-325 mesh unless shown otherwise. Magnesium powder all passed through a 325 mesh screen).

Prepn. No.	50% Ht. in ins.	Std. Dev.	Const. Treated	Wt. in gm.	Treatment
14	12.57	0.21	Mg	5	10g. paraffin/100 ml benzene
4/27/51(a)	12.81	1.14	None		Untreated mixture
68	12.90	1.34	$NaNO_3$	5	1g.D-2 wax/75 ml ethyl acetate
73	13.25	2.79	$NaNO_3$ 100-200	5	1g.D-2 wax/75 ml ethyl acetate
96	13.52	0.81	Mg	5	6g. potassium dichromate/100 ml water
21	13.68	0.87	Mg	5	1g. paraffin/100 ml benzene
62	14.25	0.49	$NaNO_3$ <325	10	25g. Aroclor 5460/50 ml chloroform
30	14.45	2.67	Mg	5	5g. paraffin/100 ml benzene
41	14.50	4.28	Mg	5	1g.D-2 wax/100 ml ethyl acetate
63	14.57	1.23	Mg & $NaNO_3$ <325	5 10	25g. Aroclor 5460/50 ml chloroform
61	14.92	4.12	Mg & $NaNO_3$ 100-200	5 10	25g. Aroclor 5460/50 ml chloroform
55	14.98	1.39	$NaNO_3$ 200-325	10	25g. Aroclor 5460/50 ml chloroform
60	15.13	1.25	$NaNO_3$ 100-200	10	25g. Aroclor 5460/50 ml chloroform
22(a)	15.15	1.77	None		Untreated mixture, mixed mechanically
26	15.64	0.91	Mg	5	2g. paraffin/100 ml benzene
48	15.85	12.91	Mg	5	25g. Aroclor 5460/50 ml chloroform
54	16.25	1.09	Mg & $NaNO_3$ 200-325	5	25g. Aroclor 5460/50 ml chloroform
51(a)	16.53	4.42	None		Untreated mixture, mixed mechanically
31	16.54	0.63	Mg	5	6g. stearic acid/100 ml benzene
69	16.55	9.82	Mg & $NaNO_3$ 200-325	5	1g.D-2 wax/75 ml ethyl acetate
98	17.92	3.40	$NaNO_3$	5	5g.D-2 wax/75 ml ethyl acetate
74	>25		Mg & $NaNO_3$ 100-200	5 5	1g.D-2 wax/75 ml ethyl acetate
97	>25		Mg	5	5g.D-2 wax/75 ml ethyl acetate
99	>25		Mg & $NaNO_3$ 200-325	5	5g.D-2 wax/75 ml ethyl acetate

(a) Data taken from earlier work

TABLE 4

IGNITION TESTS ON 1:1 BORON-SODIUM NITRATE MIXTURES

Prepn. No.	0.50g	0.40g	0.30g	0.10g	0.050g.	0.035g.	0.030g.	0.025g.	0.020g.	0.010g.	Desensitizing Agent	Impact Sensitivity (inches)
	Weight of Mixture Taken for Test											
-	+	+	+	+							None	5.5
51-b				+	+		x+	+	-+	x	Aroclor	8.39
85	(x)		(x)		(x)		x				D-2	>25
89	(x)		(-)								D-2	>25
93	(x)		(-)								Stearic acid	>25
119	(x)		(x)								D-2	>25
115	(+)	(+)	(-)	(-)	(-)	x					Armeen	17.9
19	(-)	(-)	(-)	(x)			x				D-2	14.7
76	(x)		(-)								D-2	13
87	(x)		(x)				x				D-2	12.9
46	(+)	(+)	(-)				x				Aroclor	11.7
52	(+)	(-)	(-)								Aroclor	11.7
40	(+/5)	(-)	(-)		x				x		D-2	11.3
122	(+)	(+)(+)	(-)								D-2	10.9
58	(+)	(+)	-								Aroclor	10.4
103							2/3+				1,3 dinitro-2,2-dimethyl propane	6.7

Symbols:
- \+ The grain ignited and burned completely.
- +/5 The grain ignited, but only the lower 1/5 burned.
- \- The grain did not ignite.
- x The experimental mixture did not ignite.
- () This indicates XC-9 was used to ignite the mixture. Omission of parentheses indicates ignition by the bridge wire of a Mk 39 element.

Each symbol in a space represents a separate test

TABLE 5

IGNITION TESTS ON 1:1 MAGNESIUM-SODIUM NITRATE MIXTURES

Prepn. No.	Desensitizing Agent	Impact Sensitivity (inches)	Weight of Mixture Taken for Test 0.30g.	0.10g.	0.050g.	0.030g.
	None	12.8	+	+		
74	D-2	>25	+(-)(-)(x)	+(+)	+(+/5)	(+/3)(x)
97	D-2	>25	+(-)	(+)	(x)	
99	D-2	>25	x(-)(+/2)	(x)		
69	D-2	16.6	x(-)	(-)(-)		
31	Stearic acid	16.5	+(-)	(-)		
54	Aroclor	16.3	(-)+	(-)		
41	D-2	14.5	+(-)	(-)	x	

See Table 4 for significance of symbols

TABLE 6

IMPACT TEST RESULTS ON 1:1 MIXTURES OF UNTREATED BORON (< 325) (a), AND SODIUM NITRATE (200-325) (b)

Preparation	50% Height in inches	Standard Deviation
4/5/51 hand mixed (c)	5.50	0.32
44	6.13	0.44
22-b mechanically mixed	7.61	1.90
51-b mechanically mixed	8.39	7.22

(a) (< 325) All material passed through a sieve with 325 meshes to the inch.
(b) (200-325) The material passed through a 200 mesh sieve but was retained on a 325 mesh sieve.
(c) Data taken from earlier work.

TABLE 7

EFFECT OF PARTICLE SIZE OF SODIUM NITRATE ON SENSITIVITY OF 1:1 MIXTURES OF BORON (< 325) AND SODIUM NITRATE

Preparation	Screen Size of Sodium Nitrate	50% Height in inches	Standard Deviation
43	< 325	6.63	0.57
44	200-325	6.13	0.44
45	100-200	5.98	1.24

TABLE 8

EFFECT OF ADDING MELTED PARAFFIN TO BORON, WHEN USED IN 1:1 MIXTURES OF < 325 MESH BORON + 200-325 MESH SODIUM NITRATE

Preparation	Amount of Paraffin added to Boron	50% Height in inches	Standard Deviation
44	0	6.13	0.44
5	2%	5.91	0.21
36	5%	6.90	0.51
37	10%	6.86	0.85

TABLE 9

EFFECT OF ADDING CAMPHOR, FROM BENZENE SOLUTIONS, TO BORON
<325 MESH BORON MIXED WITH AN EQUAL WEIGHT OF 200-325
SODIUM NITRATE

Preparation	Amount of Camphor added to Boron	50% Height in inches	Standard Deviation
44	0	6.13	0.44
193	1%	6.16	0.44
194	2%	6.50	0.37
195	10%	6.67	0.28

TABLE 10

EFFECT OF TREATING BORON AND MAGNESIUM WITH BENZENE SOLUTIONS OF PARAFFIN. EXCESS SOLUTION WAS REMOVED ON BUCHNER FILTER. 200-325 MESH SODIUM NITRATE USED IN ALL MIXTURES 1:1.

Preparation	Substance Treated	Solution Used	50% Height in inches	Standard Deviation
44	Boron	0	6.13	0.44
25	Boron	1g. Paraffin/100 ml benzene	6.61	0.81
29	Boron	2g. Paraffin/100 ml benzene	6.57	0.19
7	Boron	5g. Paraffin/100 ml benzene	6.29	0.52
10	Boron	10g. Paraffin/100 ml benzene	6.25	0.36
21	Magnesium	1g. Paraffin/100 ml benzene	13.68	0.87
26	Magnesium	2g. Paraffin/100 ml benzene	15.64	0.91
30	Magnesium	.5g. Paraffin/100 ml benzene	14.45	2.67
14	Magnesium	10g. Paraffin/100 ml benzene	12.57	0.21

TABLE 11

EFFECT OF ADDING D-2 WAX FROM SOLUTIONS IN ETHYL ACETATE. HOT AT START, COLD AT END OF MIXING. 200-325 MESH SODIUM NITRATE USED IN ALL MIXTURES 1:1

Preparation	Substance Treated	Solution	50% Height in inches	Standard Deviation
44	Boron	None	6.13	0.44
79	Boron	0.1g.D-2 wax/75 ml ethyl acetate	7.00	0.55
40	Boron	1g.D-2 wax/100 ml ethyl acetate	11.29	1.02
85	Boron	5g.D-2 wax/75 ml ethyl acetate	>25	
119	Boron	5g.D-2 wax/75 ml ethyl acetate	>25	
121	Boron	1% D-2 added to boron from ethyl acetate soln.	5.89	0.33
120	Boron	1% D-2 added to boron from ethyl acetate soln.	6.80	0.68
122	Boron	10% D-2 added to boron from ethyl acetate soln.	10.90	1.96
41	Magnesium	1g.D-2 wax/100 ml ethyl acetate	14.50	4.28
97	Magnesium	5g.D-2 wax/75 ml ethyl acetate	>25	

TABLE 12

EFFECT OF TREATINB BORON WITH ARMEEN 16D. 200-325 MESH SODIUM NITRATE USED IN ALL MIXTURES 1:1.

Preparation	Treatment	50% Height in inches	Standard Deviation
44	0	6.13	0.44
116	1% Armeen 16D added from benzene soln.	6.35	0.48
117	2% " " " " " "	6.50	0.87
118	10% " " " " " "	7.50	0.36
115	Soln. 10g. Armeen 16D/100 ml benzene	17.94	1.62

TABLE 13

EFFECTS OF COATING FUELS AND OXIDANT

Prepn.	Fuel	Oxidant	50% Height inches	Standard Deviation
43	B	$NaNO_3$ (< 325)	6.63	0.57
65	B	(A) "	6.70	1.55
66	(A)"	(A) "	9.30	1.71
44	"	$NaNO_3$ (200-325)	6.13	0.44
46	(A)"	"	11.70	2.13
50	"	(A) "	6.59	1.09
52	(A)"	(A) "	11.69	1.32
45	"	$NaNO_3$ (100-200)	5.98	1.24
57	"	(A) "	7.09	0.34
58	(A)"	(A) "	10.36	1.23
62	Mg	(A) $NaNO_3$ (<325)	14.25	0.49
63	(A)"	(A) "	14.57	1.23
4/5/51	"	$NaNO_3$ (200-325)	12.81	1.14
48	(A)"	"	15.85	12.91
55	"	(A) "	14.98	1.39
54	(A)"	(A) "	16.25	1.09
60	"	(A) $NaNO_3$ (100-200)	15.13	1.25
61	(A)"	(A) "	14.92	4.12
70	B	(D-2) $NaNO_3$ (200-325)	6.48	0.66
71	(D-2)B	(D-2) "	6.59	1.80
75	"	(D-2) $NaNO_3$ (100-200)	6.57	0.80
76	(D-2)"	(D-2) "	13.00	21.87
68	Mg	(D-2) $NaNO_3$ (200-325)	12.90	1.34
69	(D-2)Mg	(D-2) "	16.55	9.82
73	Mg	(D-2) $NaNO_3$ (100-200)	13.25	2.79
74	(D-2)Mg	(D-2) "	>25	

(A) indicates coating with Aroclor 5460. See Tables 2 and 3 for details of treatment.
(D-2) indicates coating with D-2 desensitizing wax. See Tables 2 and 3 for details of treatment.

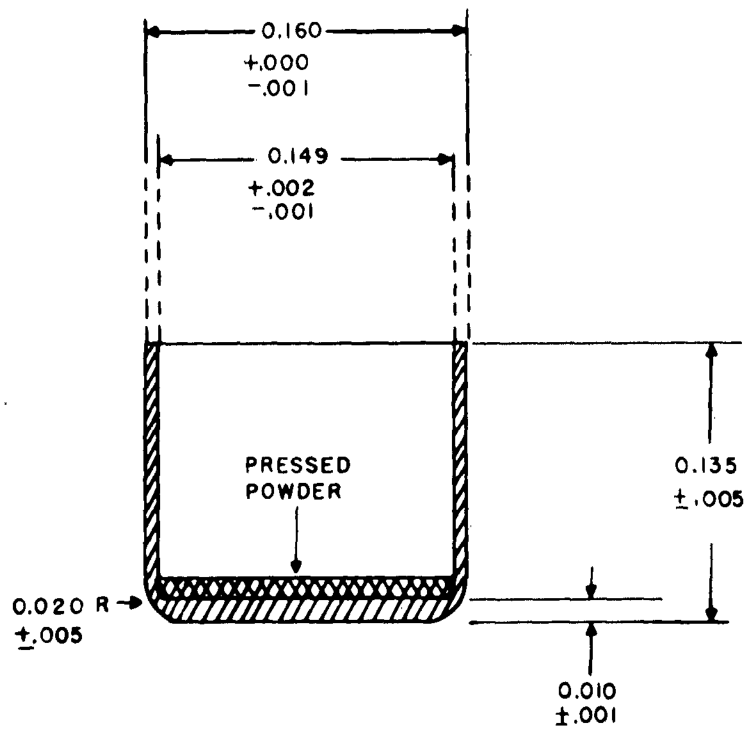

FIG. I COPPER CUP USED IN IMPACT SENSITIVITY TESTS