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MASS DETONATION TESTS OF AGITATED HMX SLURRIES

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A test program has been performed to determine the mass detonability of agitated, HMX slurries in 1/1000 volumetric scale steel tanks (5 Gal) that were initiated on the bottom with a 100 gram Composition C-4 charge. No mass detonations were observed in each of the 20 replicate tests performed on both 8% crude HMX/92% spent acid and 20% recrystallized HMX/80% water slurries respectively. Results indicate that similar agitated,

20. Abstract (Continued)

in-process material of equal or lower HMX concentration should be assigned a non-mass-detonable designation. These slurries should not be included in determining the total Class 1.1 explosive load limit of explosives manufacturing buildings when they are in the agitated condition.

PREFACE

The experiments reported on in this program were performed to determine the mass detonability of agitated in-process HMX material in stirred tanks. These tanks were scaled down versions of those found in a typical HMX manufacturing process. The tanks and their slurry contents represent the process slurry conditions found in the nitrolysis, recrystallization and filtration buildings. Similar tests were conducted in the past on RDX slurries. These tests provided results which allowed the explosive classification of agitated RDX slurry materials to be lowered. Picatinny Arsenal Technical Report No. 4949, entitled, "Mass Detonation Testing of Agitated RDX slurries," dated June 1976 by Francis Strong contains details of this previous effort. Mr. Francis Strong was project Engineer on the previous program and was responsible for the initiation of the present effort.

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SUMMARY

A test program has been performed to determine the mass detonability of agitated, HMX slurries in 1/1000 volumetric scale steel tanks (5 gal) that were initiated on the bottom with a 100 gram Composition C-4 charge. No mass detonations were observed in each of the 20 replicate tests performed on both 8% crude HMX/92% spent acid and 20% recrystallized HMX/80% water slurries. Results indicate that similar agitated, in-process material of equal or lower HMX concentration should be assigned a non-mass-detonable designation. These slurries should not be included in determining the total Class 1.1 explosive load limit of explosives manufacturing buildings when they are in the agitated condition.

INTRODUCTION

This report summarizes the results of a series of experiments performed by Hazards Research Corporation, Denville, New Jersey under the technical direction of the Large Caliber Weapon Systems Laboratory, Energetic Systems Process Division, Mechanical Process & Plant Design Branch of ARRADCOM, Dover, New Jersey. The work was funded under Contract No. DAAK10-77-C-0189.

The objective of this program was to determine if 8% crude HMX/92% spent acid and 20% recrystallized HMX/80% water slurries are mass detonable under agitated conditions in 1/10th linear scale (approximately 1/1000th volumetric scale) tanks when initiated on the bottom center by a 100 gram Composition C-4 booster charge.

The in-process HMX material located in existing HMX manufacturing facilities as well as in the proposed RDX/HMX facility is presently considered to be Class 1.1 material (mass detonable). Results of this program are to be used to reclassify agitated material containing up to 8 weight percent crude HMX or up to 20 weight percent recrystallized HMX under the condition of assured constant agitation. This reclassification would result in substantial capital cost savings at both existing and planned HMX manufacturing facilities.

EXPERIMENTAL PROGRAM

Materials

The following materials were supplied by ARRADCOM for use in this test program:

(1) HMX, intermediate Class A, code 51004, batch #662 HW-282

(2) HMX, intermediate Crude, code 51000, batch #6 HBC-14

(3) Composition C-4

Hazards Research Corporation furnished the following materials:

(1) Cylindrical carbon steel and 304 stainless steel tanks, 30.5 cm (12 in) dia x 30.5 cm high x 0.095 cm (0.038 in) wall thickness with a dished radius of 30.5 cm

(2) E-83 blasting caps

(3) Wooden test stands

(4) Spent acid, 80% glacial acetic acid/20% water

(5) E-Cord by Ensign Bickford

(6) Lead witness plates, 10 cm (4 in) x 10 cm x 0.107 cm (0.042 in) thick

(7) Air-driven stirrer motors, 1/2 hp, M.F. Fawcett Co.

(8) Mixed flow impellers, high lift type, M.F. Fawcett Co.

Description of Experiments

The 42 tests performed during this program were conducted using the test container shown in Figure 1. It was suspended 15.2 cm (6 in) above the ground by a plywood support stand. Figure 2 presents the internal details of the container and the location of the impeller. Figure 3 is a photograph which shows the location of the 100 gram, Composition C-4 booster on the test container. The one-half horsepower air motor, and 10.2 cm (4 in) diameter high lift impeller are presented in Figure 4. A photograph of a typical test set-up is presented in Figure 5.

A typical test sequence started with the taping of a 100 gram, Composition C-4, conical booster onto the bottom center of the test container. The container was then positioned in its plywood support stand. A length of E-cord was taped to the side of the container and strung out a distance of 5 meters (16.4 ft). A lead witness plate was folded around the E-cord and placed under a barricade. Pre-weighed portions of wet HMX and the test liquid were then poured into the test container. The air motor was positioned in the center of the tank and the air was turned on. After approximately five minutes of mixing time, a portable, photoelectric tachometer was used to set the agitator speed at 1,000 rpm. Two 40 ml samples were then extracted from the slurry. One sample was taken from the bottom of the tank and the second sample from the top. These samples were taken to the laboratory where they were later analyzed for percentage HMX concentration.

The final step involved the arming of the C-4 booster with an E-83 blasting cap and the remote detonation of the cap. Before-and-after still photographs documented each test. Because of the go, no-go nature of the tests, no instrumentation was required.

Description of Experimental Methods

Preparation of Slurries

All HMX used on this program was received packaged in duck cloth storage bags which were encased in plastic bags. Intermediate Class A HMX contained an average of 6.4% volatiles while the intermediate Crude HMX averaged 54% volatiles. The volatiles content was taken into account in all calculations of explosive weight concentration. Volatiles content was determined by taking four samples of wet HMX from four different locations within each duck cloth bag. These samples were weighed and placed in an oven and dried to determine volatiles content. The average value of these four readings was then used to calculate the volatiles content of the HMX. This value was then used to determine the amount of wet HMX required to give the equivalent dry weight of HMX called for in the experiment. The volatiles in the HMX were then subtracted from the total liquid requirement to yield the desired solids concentration of the slurry.

Preparation of Spent Acid

Spent acid was made by mixing 80% glacial acetic acid with 20% water.

Booster Configuration

The boosters were made by hand tamping C-4 into the shape of a frustum of a right circular cone using a plastic mold. The two diameters were 3.3 cm (1.3 in) and 6.1 cm (2.4 in) with a height of 4 cm (1.6 in). Each booster weighed 100 grams.

Agitator Speed

Proper agitation speed was determined experimentally using sand and water. A 20% sand and 80% water slurry was placed into a 19 liter (5 Gal) glass container of the same physical dimensions as the steel test container. Impeller speed was increased until the speed was attained at which no sand remained on the bottom of the tank. This was approximately 800 rpm. A value of 1,000 rpm was then selected to provide an adequate safety margin.

Characterization of Detonation Propagation Phenomena

The determination of whether or not the booster-initiated detonation propagated through the slurries was made by physical inspection and a lead witness plate. Prior to testing explosive slurries, a water blank test and an acetic acid blank test were performed. These were reference tests which were used to determine the effect of the booster on the test container. Figure 7 shows the water blank test set-up while Figure 8 reveals the damage that resulted from detonation of the booster. It is seen that the tank ruptured at the bottom and up the length of the side wall. It banana peeled back from the center of the tank. This result is typical for a non-propagating reaction.

Mass detonation of the contents of a tank would result in complete fragmentation of the tank wall. Very few pieces of the tank would be recovered after the test. In addition, the E-cord would be initiated by the shock wave and it would split the lead witness plate in half. Finally, the air motor and impeller would be fragmented.

One unagitated, 8% HMX/92% spent acid test was performed to serve as the basis for comparison to a mass detonation. As anticipated, the lead witness plate was split in half and the tank was completely fragmented.

Experimental Results

A total of 40 experiments were performed on this program to determine the detonability of agitated HMX slurries in scaled down process tankage. The results of the sample analysis performed on 40 ml samples taken prior to each test are presented in Table 1. Table 2 contains the results of the 20 replicate tests performed on agitated, crude HMX slurries at 8% HMX/92% spent acid concentrations. Table 3 presents the results of 20 replicate tests performed on agitated, Class A HMX slurries at 20% HMX/80% water weight concentrations.

It is seen that no mass detonation occurred in any of the 40 tests performed on this program. Each tank was ruptured by the detonation of the booster. Unreacted HMX was distributed over the surface of the test site. All tanks were recovered and all witness plates were intact. Figures 5 and 6 are before and after photographs of experiment number 33. Figures 9, 10, and 11 show the before and after photographs of experiment number 2. It is seen that there is very little difference in physical damage to the tanks.

CONCLUSIONS

Results of 40 mass detonation tests on agitated HMX slurries in scaled down steel process tanks, indicate that neither 8% crude HMX/92% spent acid slurries nor 20% recrystallized HMX/80% water slurries mass detonated. These test results provide a logical basis for assigning a non-mass-detonable classification to similar in-process slurried HMX where the HMX is of equal or lower concentration as long as agitation is assured.

RECOMMENDATIONS

It is recommended that a non-mass-detonable designation be assigned to in-process agitated slurry material containing:

(1) Up to 8% crude HMX

(2) Up to 20% recrystallized HMX

These HMX slurries should not be included in determining the total Class 1.1 explosive load limit of the explosive manufacturing buildings as long as agitation is assured.

Table 1

Sample analysis

Test No.	Series using 8% HMX/92% spent acid — HMX wt percent		Test No.	Series using 20% HMX/80% water — HMX wt percent	
	Top	Bottom		Top	Bottom
1	7.0	8.8	21	18.7	16.9
2	7.9	7.0	22	17.0	19.8
3	7.4	8.1	23	18.9	20.1
4	7.9	8.6	24	16.5	19.9
5	8.4	7.9	25	17.6	20.4
6	8.2	7.9	26	18.4	19.5
7	9.3	9.0	27	17.0	18.9
8	8.8	7.2	28	22.0	19.0
9	7.3	8.2	29	20.0	20.5
10	8.3	6.9	30	19.0	18.5
11	8.4	7.7	31	20.0	19.0
12	8.5	6.9	32	18.0	20.0
13	8.1	6.9	33	18.0	19.0
14	8.8	6.2	34	18.0	19.8
15	7.8	6.9	35	19.0	19.0
16	8.9	8.0	36	18.0	19.5
17	9.7	6.2	37	22.0	19.0
18	7.1	8.1	38	18.0	20.1
19	6.0	7.8	38	18.0	19.3
20	9.0	6.9	40	17.0	19.6

Table 2

Results of mass detonation tests on agitated, crude HMX slurries

Liquid	Test No.	Slurry composition wt% HMX	Slurry composition wt (kg) acid	Slurry composition wt (kg) HMX	Slurry temp. (°C)	Agitator Speed (rpm)	Physical evidence[b]	Result[a]
80% acetic acid (aqueous)	A	0	15.14	0	14	0	Tank ruptured	(-)
	1	8	15.14	1.32	14	1025	Tank ruptured	(-)
	2	8	15.14	1.32	14	1055	Tank ruptured	(-)
	3	8	15.14	1.32	14	1000	Tank ruptured	(-)
	4	8	15.14	1.32	14	1000	Tank ruptured	(-)
	5	8	15.14	1.32	14	1020	Tank ruptured	(-)
	6	8	15.14	1.32	14	1000	Tank ruptured	(-)
	7	8	15.14	1.32	15	1000	Tank ruptured	(-)
	8	8	15.14	1.32	15	1050	Tank ruptured	(-)
	9	8	15.14	1.32	15	1000	Tank ruptured	(-)
	10	8	15.14	1.32	15	1050	Tank ruptured	(-)

[a](+) indicates booster initiated detonation propagated.
(-) indicates no propagation.

[b]All tests were conducted in cylindrical steel tanks, 30.5 cm (12 in) dia x 30.5 cm high x 0.095 cm (0.038 in) wall thickness with 30.5 cm dished radius.

Table 2

Results of mass detonation tests of agitated, crude HMX slurries (cont.)

Liquid	Test No.	Slurry composition wt% HMX	Slurry composition wt (kg) acid	Slurry composition wt (kg) HMX	Slurry temp (°C)	Agitation Speed (rpm)	Physical evidence[b]	Result[a]
80% acetic acid (aqueous)	11	8	15.14	1.32	13	1055	Tank ruptured	(-)
	12	8	15.14	1.32	10	1000	Tank ruptured	(-)
	13	8	15.14	1.32	10	1050	Tank ruptured	(-)
	14	8	15.14	1.32	11	1000	Tank ruptured	(-)
	15	8	15.14	1.32	11	1000	Tank ruptured	(-)
	16	8	15.14	1.32	8	1020	Tank ruptured	(-)
	17	8	15.14	1.32	8	1000	Tank ruptured	(-)
	18	8	15.14	1.32	9	1000	Tank ruptured	(-)
	19	8	15.14	1.32	8	1000	Tank ruptured	(-)
	20	8	15.14	1.32	8	1000	Tank ruptured	(-)

[a] (+) indicates booster initiated detonation propagated.
(-) indicates no propagation.

[b] All tests were conducted in cylindrical steel tanks, 30.5 cm (12 in) dia x 30.5 cm high x 0.095 cm (0.038 in) wall thickness with 30.5 cm dished radius.

Table 3

Results of mass detonation tests on agitated, Class A HMX slurries

Liquid	Test No.	Slurry composition wt% HMX	Slurry composition wt (kg) water	Slurry composition wt (kg) HMX	Slurry temp (°C)	Agitator Speed (rpm)	Physical Evidence[b]	Result[a]
water	B	0	15.14	0	14	0	Tank ruptured	(-)
	21	20	15.14	3.79	14	1025	Tank ruptured	(-)
	22	20	15.14	3.79	14	1050	Tank ruptured	(-)
	23	20	15.14	3.79	14	1020	Tank ruptured	(-)
	24	20	15.14	3.79	11	1050	Tank ruptured	(-)
	25	20	15.14	3.79	11	1070	Tank ruptured	(-)
	26	20	15.14	3.79	11	1020	Tank ruptured	(-)
	27	20	15.14	3.79	12	1025	Tank ruptured	(-)
	28	20	15.14	3.79	12	1025	Tank ruptured	(-)
	29	20	15.14	3.79	12	1025	Tank ruptured	(-)
	30	20	15.14	3.79	12	1100	Tank ruptured	(-)

[a] (+) indicates booster initiated detonation propagated.
(-) indicates no propagation.

[b] All tests were conducted in cylindrical steel tanks, 30.5 cm (12 in) dia x 30.5 cm high x 0.095 cm (0.038 in) wall thickness with 30.5 cm dished radius.

Table 3

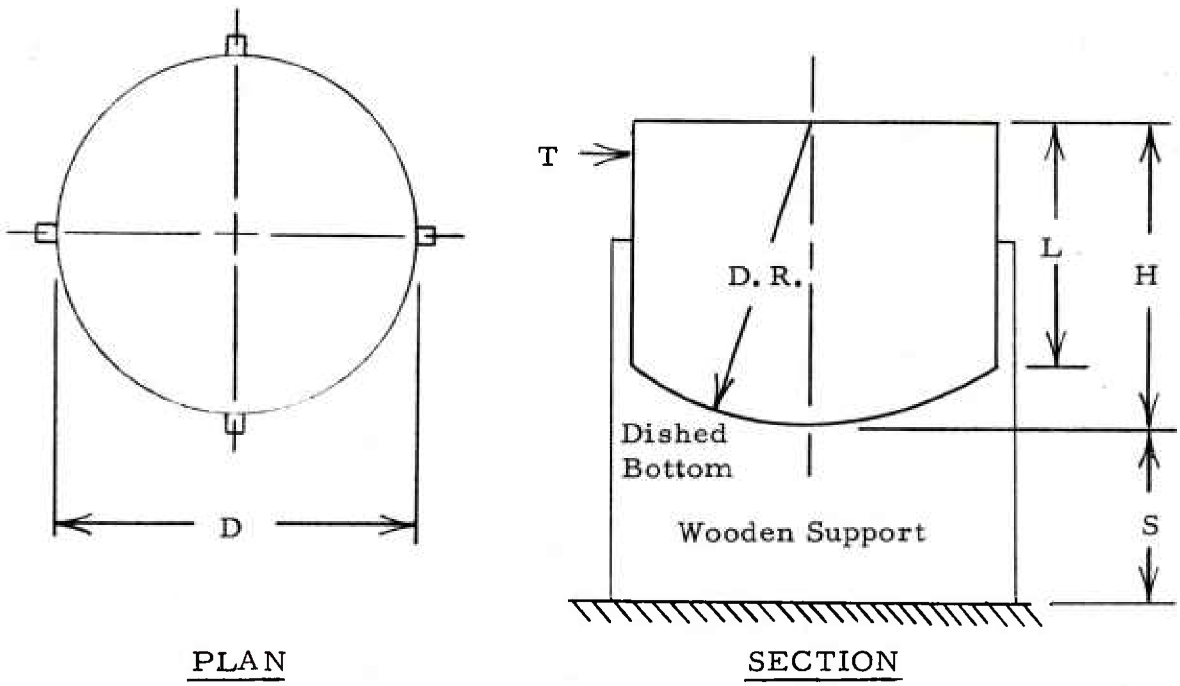
Results of mass detonation tests on agitated, Class A HMX slurries (cont.)

Liquid	Test No.	Slurry composition wt% HMX	Slurry composition wt (kg) water	Slurry composition wt (kg) HMX	Slurry temp (°C)	Agitator Speed (rpm)	Physical evidence[b]	Result[a]
water	31	20	15.14	3.79	12	1025	Tank ruptured	(-)
	32	20	15.14	3.79	12	1100	Tank ruptured	(-)
	33	20	15.14	3.79	8	1100	Tank ruptured	(-)
	34	20	15.14	3.79	8	1050	Tank ruptured	(-)
	35	20	15.14	3.79	8	950	Tank ruptured	(-)
	36	20	15.14	3.79	8	1050	Tank ruptured	(-)
	37	20	15.14	3.79	8	1075	Tank ruptured	(-)
	38	20	15.14	3.79	8	1125	Tank ruptured	(-)
	39	20	15.14	3.79	8	1025	Tank ruptured	(-)
	40	20	15.14	3.79	8	1100	Tank ruptured	(-)

[a] (+) indicates booster initiated detonation propagated.
(-) indicates no propagation.

[b] All tests were conducted in cylindrical steel tanks, 30.5 cm (12 in) dia. x 30.5 cm high x 0.095 cm (0.038 in) wall thickness with 30.5 cm dished radius.

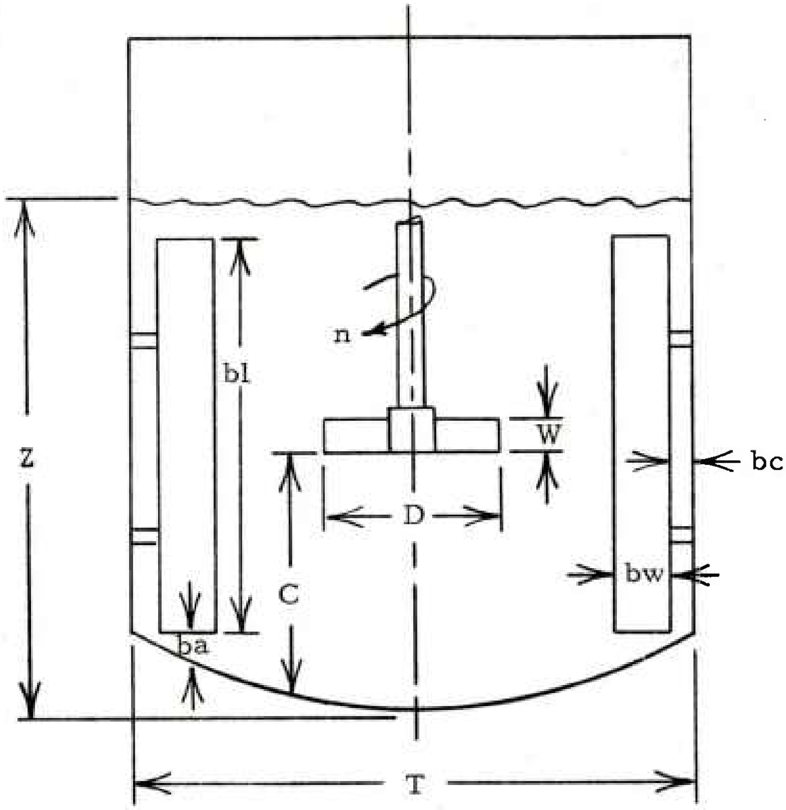
Material of Construction: Carbon or Stainless Steel



D = 30.5 cm (12 in)
H = 30.5 cm (12 in)
L = 26.2 cm (10.3 in)
S = 15.2 cm (6 in)
D.R. = 30.5 cm (12 in)
T = 0.095 cm (0.038 in)

Fig 1 Test container details

4 Baffles @ 90°



C	=	7.6 cm (3 in), Turbine clearance
D	=	10.2 cm (4 in), Turbine diameter
T	=	30.5 cm (12 in), Tank diameter
W	=	1.3 cm (0.5 in), Blade width
n	=	1000 rpm, Shaft speed
Z	=	22.9 cm (9 in), Liquid depth
Z-C	=	15.2 cm (6 in), Height of liquid above impeller
ba	=	Distance to bottom of side wall
bc	=	1.3 cm (0.5 in), Clearance between tank wall and baffle
bw	=	2.5 cm (1.0 in), Baffle width
bl	=	24.1 cm (9.5 in), Baffle length

Fig 2 Internal details of container and impeller

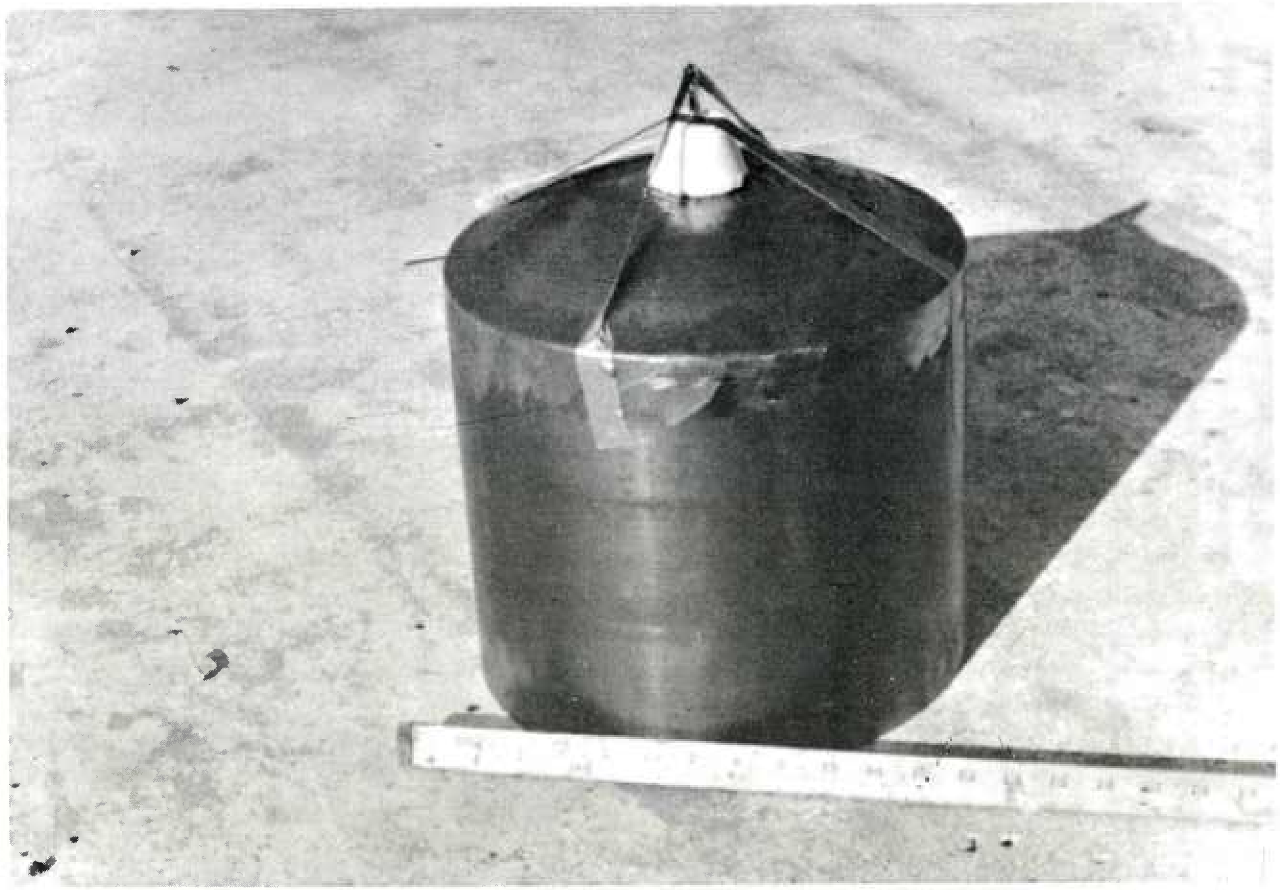


Fig 3 Test container with booster in position

Fig 4 Air operated stirrer, impeller, and tank lid

Fig 5 HMX water slurry test set-up

Fig 6 Test container after HMX water slurry test

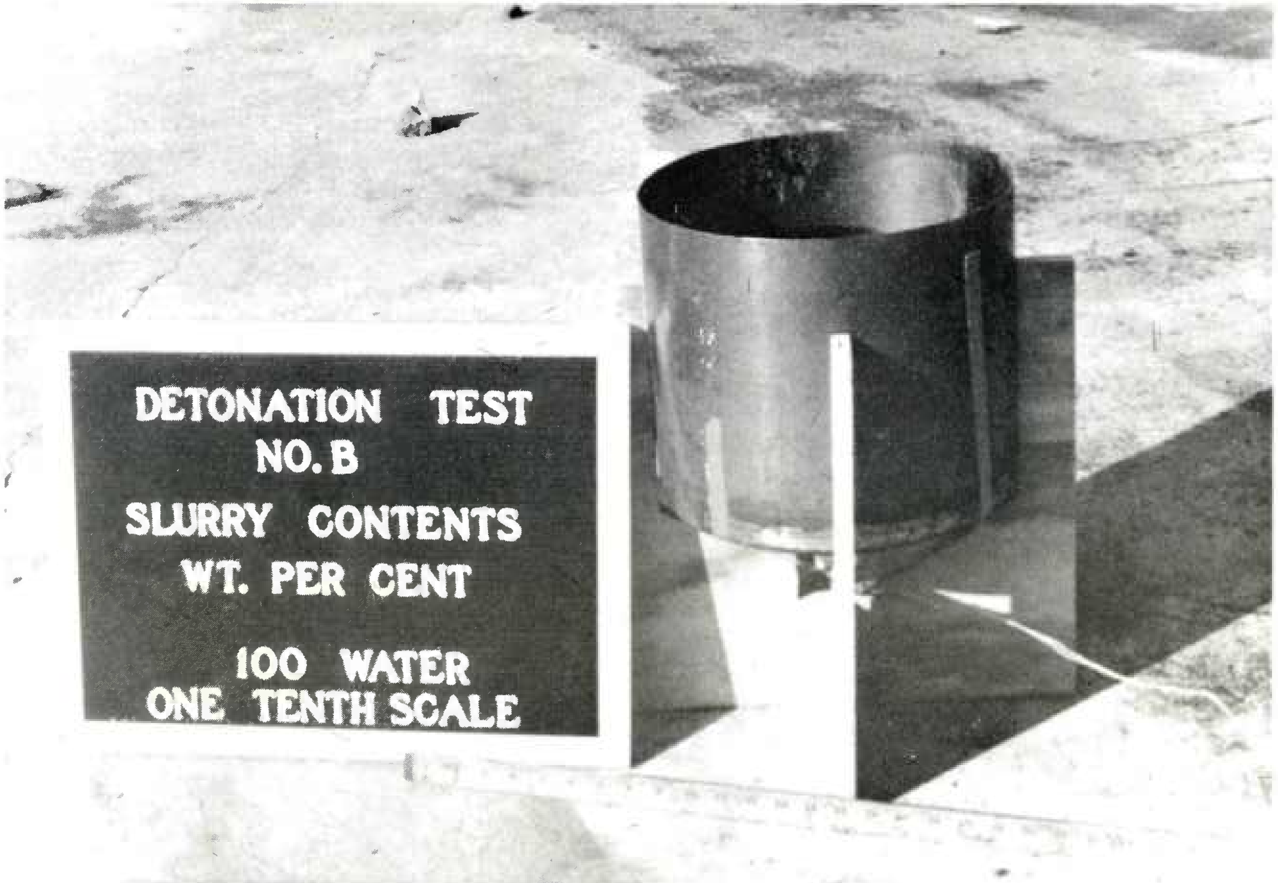


Fig 7 Water blank test set-up

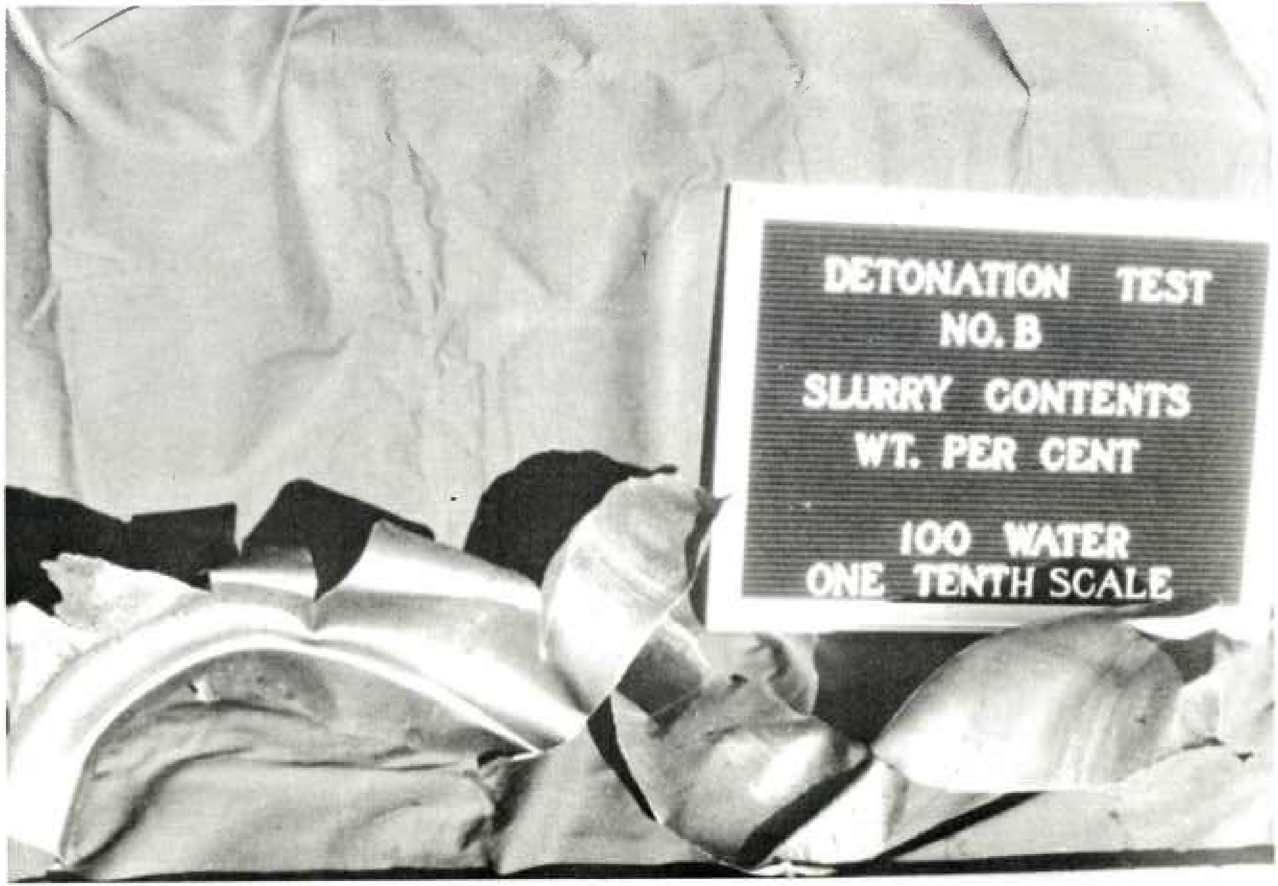


Fig 8 Test container after water blank test

Fig 9 HMX spent acid slurry test set-up

Fig 10 Test site after HMX spent acid slurry test

Fig 11 Test container after HMX spent acid slurry test

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