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IMPACT SENSITIVITY OF PRIMER EXPLOSIVES

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ABSTRACT

A new apparatus for the use in testing the sensitivity of primer explosives to impact was designed and built.

Several explosives were tested. The results and procedure are reported in the thesis.

The writer wishes to thank Professors James W. Wilson and James E. Sinclair of the United States Naval Postgraduate School for the assistance and encouragement given him during this investigation.

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1. INTRODUCTION.

In determining the uses of explosive materials and the necessary safe handling practices, many tests have been devised. One of the most widely used tests for the determining the sensitivity of explosives is the impact test. A great deal of research has been done on this type of testing with a major part of the investigations being carried out on high explosives of the TNT, RDX, tetryl range and with an apparatus that dropped a weight of two kilograms or greater on a given mass of explosive. This has led to some application of impact sensitivity testing for more sensitive explosive materials, in particular primer explosives.

One of the shortcomings of impact sensitivity testing is that reports of sensitivity vary with procedure and type of apparatus used. While the report of sensitivity is relative to some standard explosive, much information can be gained from knowing comparative sensitivities when the potential uses and precautions for safe handling are desired.

During this investigation no correlation was attempted between the mechanical energy imparted to the explosive material by the drop weight and the internal energy change of the explosive. An attempt has been made to present an apparatus and a procedure for testing the more sensitive solid primer explosives.

The impact machine presently in use in the explosive laboratory of the United States Naval Postgraduate School is of the "standard" type machine using a two kilogram drop weight. After studying this machine, it was decided that for testing of more sensitive explosive for more reliable and reproducible results, a new apparatus should be devised which would employ a lighter drop weight.

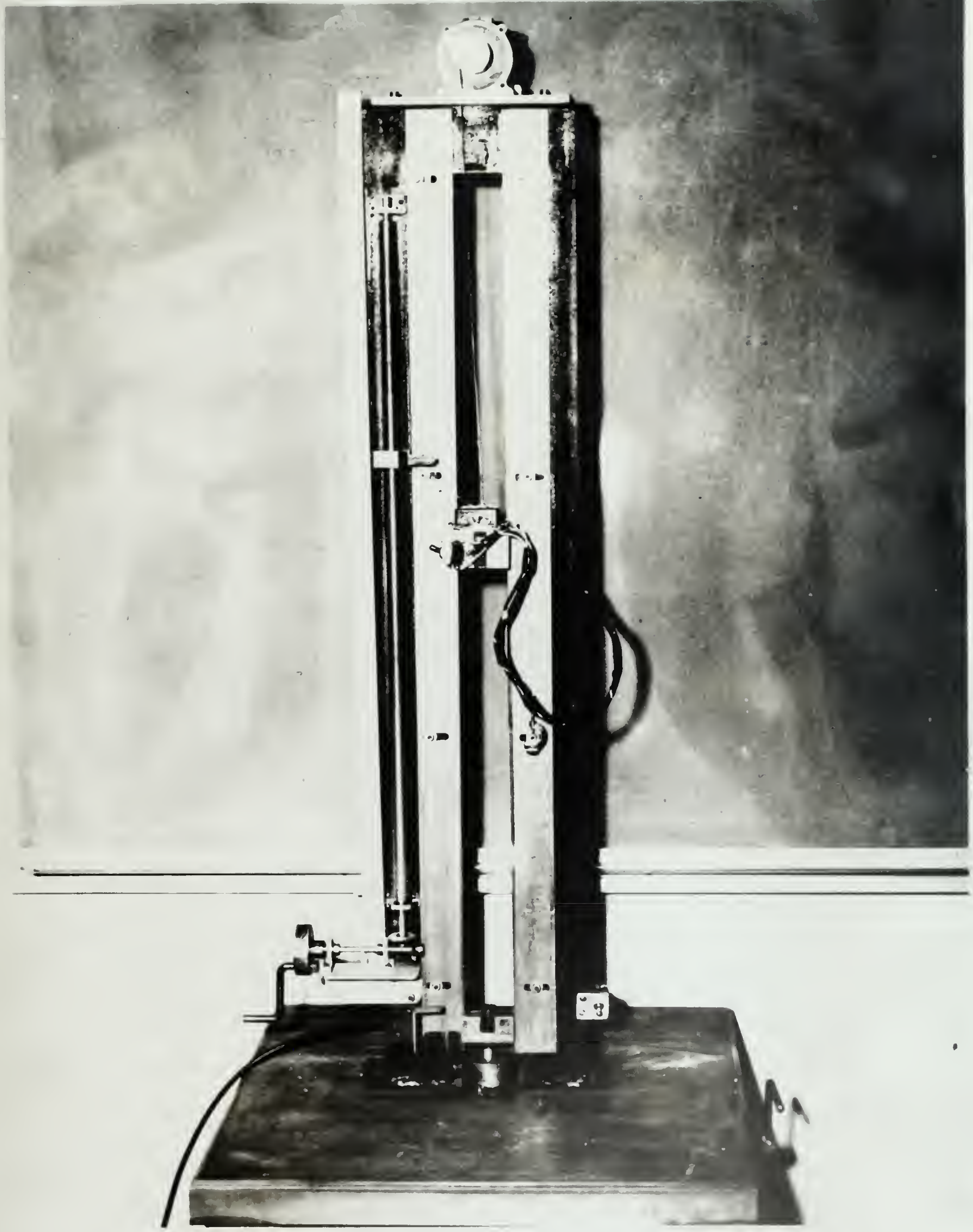


Fig. I Impact Machine

2. THE IMPACT MACHINE

The impact machine was designed and built with the following requirements in mind:

a. miniaturized as practicable

b. as near automatic as practicable

c. accurate and adjustable release height

d. easily replaceable weights, to be in the order of 200, 500, 1,000 grams

e. free fall of weight assured

f. fixed and rigid base

g. smooth striking surface

h. easily replaceable sample

The impact machine (fig. 1) drops a fixed weight from a predetermined fixed but adjustable height. The weight is dropped along a verticle track that is lubricated and smooth and is as near frictionless as possible. The base of the machine is 30 inches from the deck giving a proper height for ease of operation. The steel base is square 30 inches by 30 inches by 2 inches and is of sufficient rigidity to provide an excellent base to absorb the repeated pounding of the drop weight and to assure that the material being tested receives the full impact of the drop weight. The base also provides a working table for the necessary equipment to carry on the tests.

On top of the base are located two verticle tracks, along which the drop weight falls. At the top of the tracks is a reversible motor which raises and lowers an electromagnet arrangement. The electromagnet holds the drop weight until a microswitch command is given at a predetermined height and the weight is dropped.

The motor at the top is then reversed and the electromotor assembly is lowered to retrieve the weight. A stop switch is located near the base which will stop the motor to allow for inspection of the sample and removal and replacement of a new sample.

The sample is placed on a piece of special garnet paper on an anvil of hardened steel. With slight modifications the anvil can be made to hold liquid explosives. The anvil rests on the base and inside a steel cylinder. The steel cylinder has a threefold purpose:

(1) it keeps the anvil and sample in the desired position.

(2) it confines the explosive, making no safety precautions necessary other than the wearing of safety glasses.

(3) The cylinder provided a means whereby temperature can be controlled.

Due to the fact that the tests were all conducted over a relatively short period, and due to the fact that the explosives laboratory remained at fairly constant temperature, no special effort on the part of the writer was made to control the temperature variable.

The falling drop weight does not strike the explosive material sample. A floating weight or hammer of hardened steel is placed on top of the sample. This provides a level and smooth surface for the drop weight to strike. The arrangement within the steel cylinder is shown in fig. 2.

Some method of determining whether or not there was an explosion had to be used. Several laboratories use some type of audio machine or acoustimeter but due to the complications and calibrations necessary with this type of procedure, a simpler system is used in the Postgraduate School Laboratory. The system here is to place a piece of paper, cut to

fit, inside the steel cylinder and around the sample. The anvil and the hammer are built to make room for the paper and since the paper does not touch the explosive it has no effect on the explosive being tested. After each drop the paper was inspected and if there was any indication of burns or tear resulting from blast, the test shot was considered an explosion. In most cases the report or flash was sufficient to determine explosion or not but the paper was used on each shot. Where cases of doubt resulted, the indication from the paper was the determining factor.

A plunger arrangement was fixed to the base which enabled the operator to remove the anvil and the floating hammer from the cylinder. This enabled the surfaces of both the hammer and the anvil to be cleaned. The inside of the cylinder could also be cleaned. It became apparent that cleanliness of the inside of the cylinder and between the anvil and the base was very important. Several of the earlier "runs" had to be discarded due to the effect of "trash" in the cylinder. The plunger assembly was also used to raise and lower the anvil during the loading and unloading of the samples.

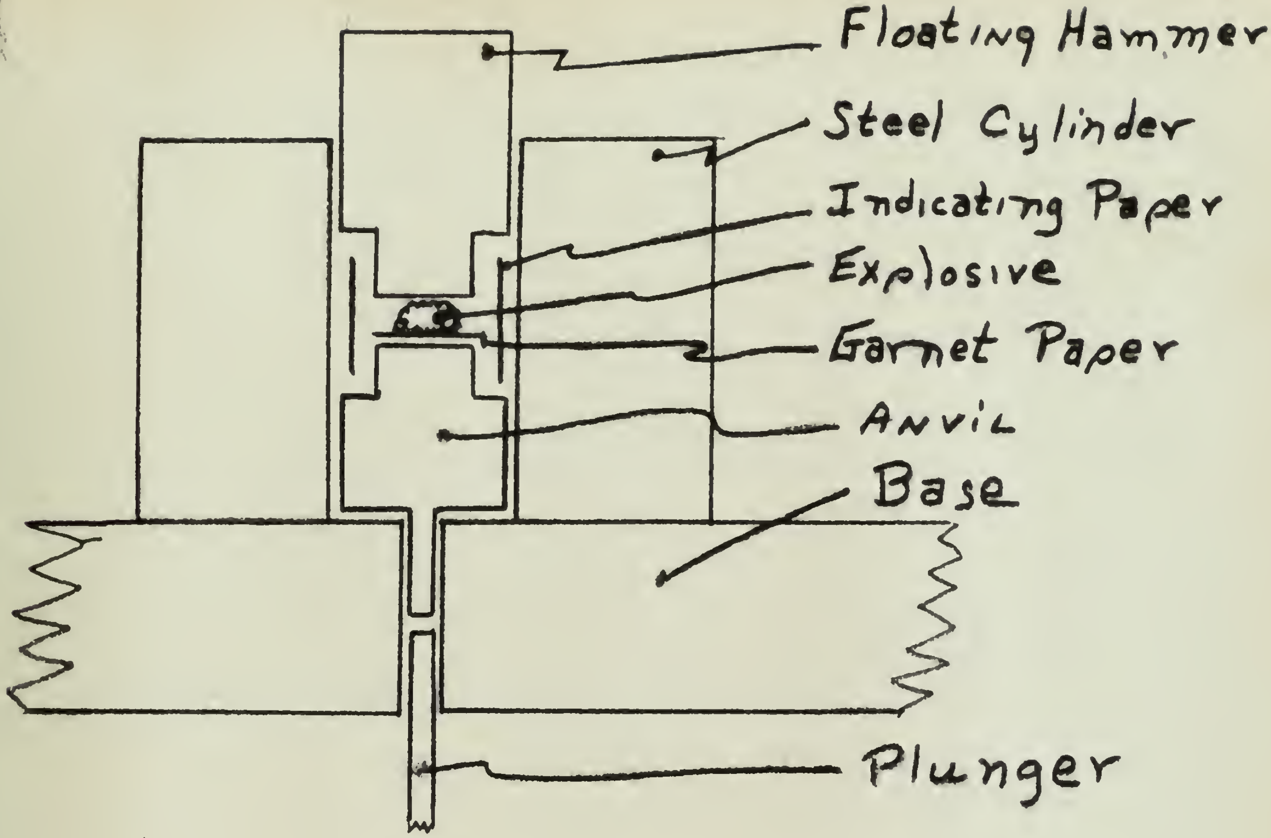


Fig. 2 Diagram of Area Around the Steel Cylinder of the Impact Tester

The drop height was fixed by a bar which was arranged to strike a microswitch that was attached to the electromagnet apparatus. This microswitch controlled the electromagnet. The bar also was arranged to strike a switch which caused the motor to reverse its direction. The height of the bar was controlled by a screw and gear assembly that could be operated by a crank located on the base of the machine.

Several drop weights of various weights were made and all were built so that by removal of a front plate they could be taken in or out of the verticle tracks with ease.

Several tests were conducted with a 200 gram weight but the primary tests were made with the 500 gram weight. Some of the results suggest further work and study with a 1,000 gram weight.

3. PREPARATION OF THE MATERIAL TO BE TESTED

The materials to be tested were lead azide, lead styphnate and pentaerythritoltetranitrate (PETN). The lead azide and lead styphnate were obtained from the Postgraduate School explosive laboratory supply. The PETN was prepared in the local organic laboratory by Captain Charles Treat, United States Army, under the direction of Professor McFarlin of the Postgraduate School.

Grinding, drying and sizing procedure was carried out resulting in a grain size that would pass a Tyler equivalent number 270 mesh U. S. standard sieve with a 0.004 inch opening.

To increase the sensitivity and also as an aid toward protecting the anvil, a piece of garnet paper one-half inch square was placed on the anvil under the explosive to be tested. The paper was 180(5/0) fine garnet finishing paper number OF5R-C manufactured by The Carborundum Company of Niagara Falls, New York.

4. TESTING PROCEDURE.

The following testing procedure was followed closely to remove any operator technique from the final results.

Before any tests were conducted the material to be tested was dried in a vacuum oven and then placed in a dessicator. Particle size was checked and the impact machine made ready for testing. The contact surfaces of the anvil and floating hammer were sanded smooth before any series of tests and the inside of the steel cylinder was wiped and blown clean. The inside of the cylinder was kept free from any obstructions at all times.

Free fall of the drop weight was checked and the drop height was set well above the expected 100% point for an explosion. With the anvil in place and a piece of the garnet paper resting on top of it, the explosive material to be tested was metered onto the garnet paper by specially prepared scoops for either five, ten, or twenty milligrams. The scoops were checked for each explosive tested and corrected accordingly. The floating hammer was placed gently on top of the explosive.

The actual starting place for taking data was found by a series of ranging shots. By having the first drop occur well above an assured explosive height, the height bar was lowered two testing intervals until a nonexplosion occured. A testing interval will be defined and discussed later. After the first nonexplosion occured, the bar was raised one test interval and the taking of data begun. By using the ranging method for determining the starting point, a greater percent of the data collected fell near the mean. A series of twenty shots made up a complete test.

5. STATISTICAL DISCUSSION.

An "up and down" or Bruceton method was used for the statistical approach to the testing problem. This method is discussed in full by W. J. Dixon and F. J. Massey Jr. (1).

This method is ideal in that the testing is concentrated about the mean, and therefore fewer tests are required than the ordinary method of testing of groups of equal size at prearranged heights. Each specimen must be tested separately because even though a nonexplosion occurs, the sample is discarded and a new sample is taken. This is done because knowledge of the state of the explosion after having gone through an impact is uncertain.

The final report from impact testing is the 50% point or the point where an explosion will occur 50% of the time. The "up and down" method assumes a normal distribution about the mean. When testing for the mean or 50% point, this assumption is not critical; whereas, testing for some point away from the mean, the assumption of normal distribution does become critical.

In earlier tests (2) with high explosives, such as TNT and RDX, a test interval of five centimeters was found to give acceptable results. The same five centimeter interval was used in these tests and was found to be acceptable. This was due to the fact that on the average the standard deviation was equal to or less than five centimeters. The acceptance of the test interval was not critical due to a good estimate of the mean from which the testing started. This starting point was found by the ranging method.

The "up and down" method consists of a series of shots with the prior shot determining the drop height of the next. If the first shot

is an explosion the drop height is lowered one interval and the next trial is carried out; whereas, if the first shot is a nonexplosion the drop height is raised one test interval for the next shot.

This procedure is carried out for the required number of trials. In determining the percent explosions at a particular height, the assumptions were made that if an explosion occured at a particular height, it would also have occured at a higher level and if there was a nonexplosion, there would also have been a nonexplosion at any lower level. The results are then plotted on probability paper, with drop height as ordinate and percent explosions as absissa. Figure four is an example of the plot.

Massey and Dixon give the following equations for finding the mean ($\bar{X}$) and the standard deviations(s).

$$\bar{X} = y' + d\left(\frac{A}{N} \pm \frac{1}{2}\right)$$

$$s = 1.620d\left(\frac{NB-A}{N} + 0.029\right)$$

y' being the lowest height at which an event occured

d is the test interval

$$A = \sum_{i=0}^{k} in_i$$

$$B = \sum_{i=0}^{k} i^2 n$$

i is the number of the test interval; 0,1,2,3, with 0 being the lowest interval, etc.

n is the observed frequency

N = smaller total either explosion or nonexplosion

(–) sign used when N indicates number of explosions

(+) sign used when N indicates number of nonexplosions

When the plot on probability paper is used, the mean or 50% point can be read directly, and the standard deviation found by dividing the difference between the 5% and 95% points of 3.29. This gives a level of significance or reliability of 10%. Example of probability plot is included below the data plot.

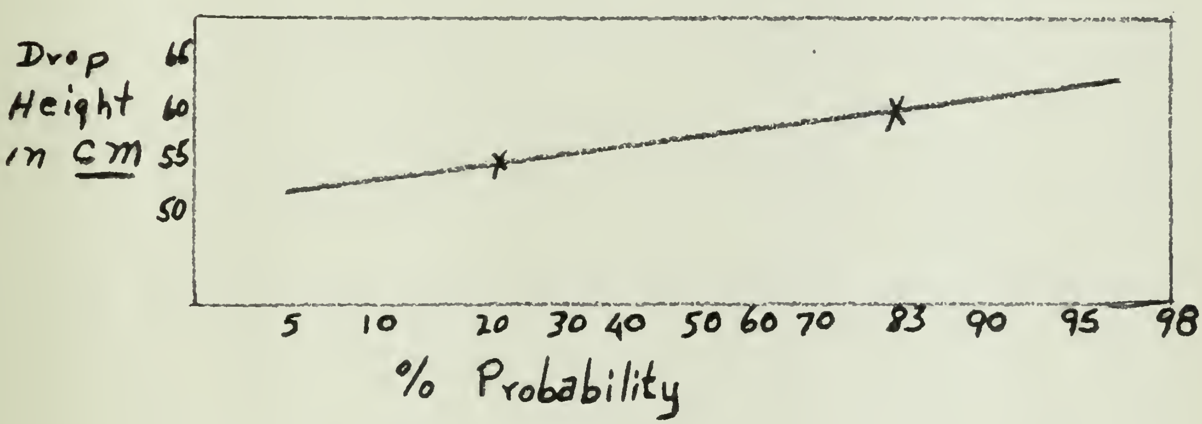
Impact Test Data Sheet

Height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Ratio	%	Remarks
70																							
65	E		E	e		e	e			e		e	e				E	e		e	11/11	100	"Exp" W
60		N		E		E	e			E		E	e			N		E		E	8/10	80	
55		n			N		E		N		N		E		N	n			N		2/9	22	26 mg
50		n			n			N	n		n			N	n	n			n		0/9	0	
45																							

E = EXPLOSION e = ASSUMED EXPLOSION

N = NONEXPLOSION n = ASSUMED NONEXPLOSION

Probability Plot



50% Point = 57 cm.

Standard deviation = 3.04 cm.

Fig. 3

A check of the 50% point was made by setting the drop height at the determined height and dropping a series of shots from this height. The checks all came out within 10% of the determined number. It is felt that these test runs proved the reliability of both the machine and the procedure used.

6. EXPERIMENTAL RESULTS

Before any comparison study between explosives was made, an intensive investigation was made to find the most sensitive size of sample of PETN. The use of grit in the form of a garnet paper is necessary for the sensitizing of the material to be tested. This same grit has a very definite effect on the desensitizing if the explosive when small (five milligrams) samples are taken. A plot of sample size for PETN is included as figure (4).

The reason for the desensitizing effect of the smaller samples is caused by either the grit absorbing too much of the impact or by the fact that with a smaller amount of explosive that there is not enough energy concentrated at any one spot to cause detonation. The reason for the desensitizing effect of the larger samples is believed to be caused by the explosive itself giving a cushioning effect to the impact. The effect of the desensitizing of the larger was made very clear during the testing of the lead azide and lead styphnate when the 20 milligram size samples could not be tested even at maximum height on the impact machine.

Included as figure (5) is a graph showing the comparative results of the sensitivity of ten milligrams of each of PETN, lead azide, and lead styphnate. The ten milligram size was chosen as the test weight because it was the most sensitive size of sample of PETN.

Further examination was made into the effect of a double piece of garnet paper on the sensitivity of PETN and lead azide. The same procedure as before was followed with an additional piece of garnet paper being placed on top of the test sample. This was in addition to the one beneath the explosive. Ten milligram samples were used in the testing.

The PETN 50% point was changed from 35 centimeters to 43 centimeters. The PETN tested was of fine particle size and it is believed that the desensitizing effect was caused by the additional garnet paper absorbing a greater amount of the impact. The 50% point of the lead azide was changed from 76 centimeters to 53 centimeters.

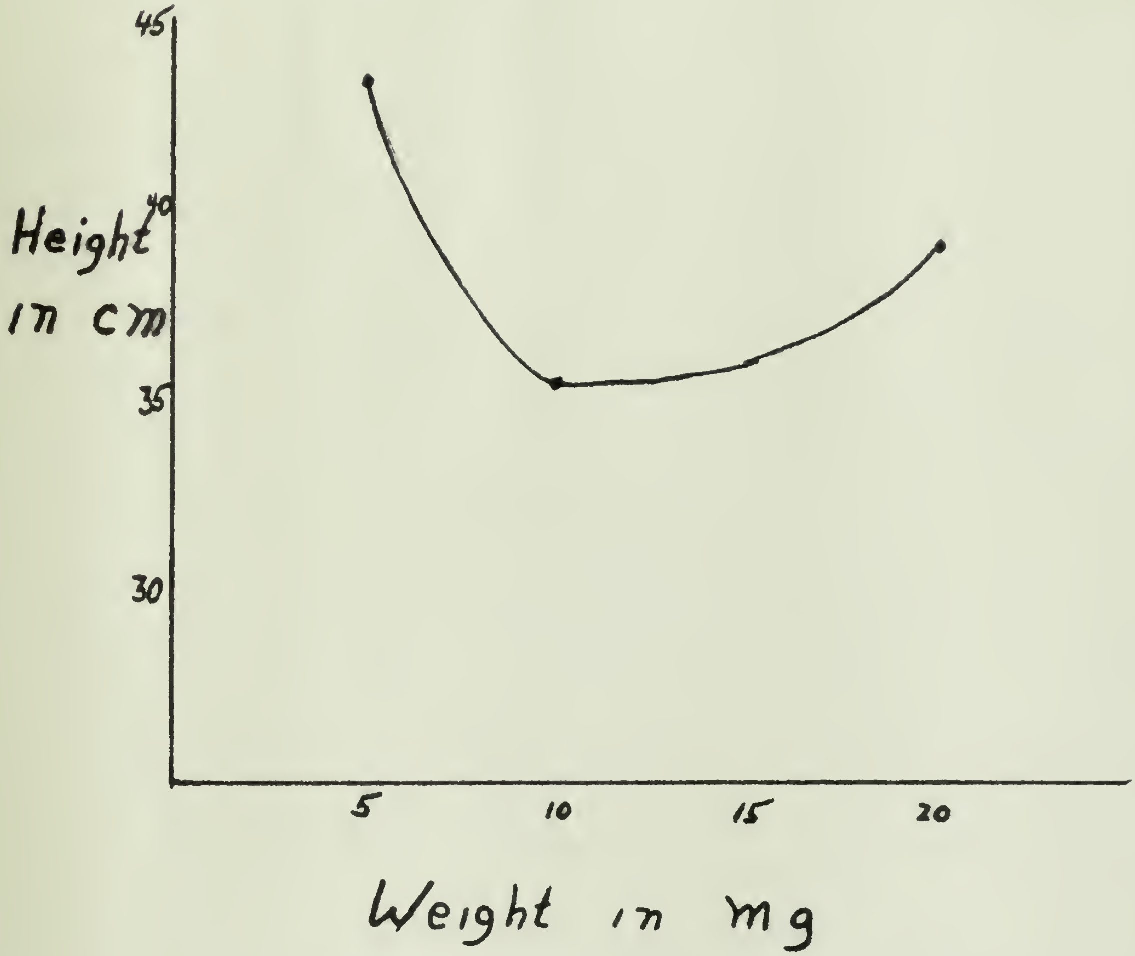


Fig. 4 Study of
Sample Size of
PETN

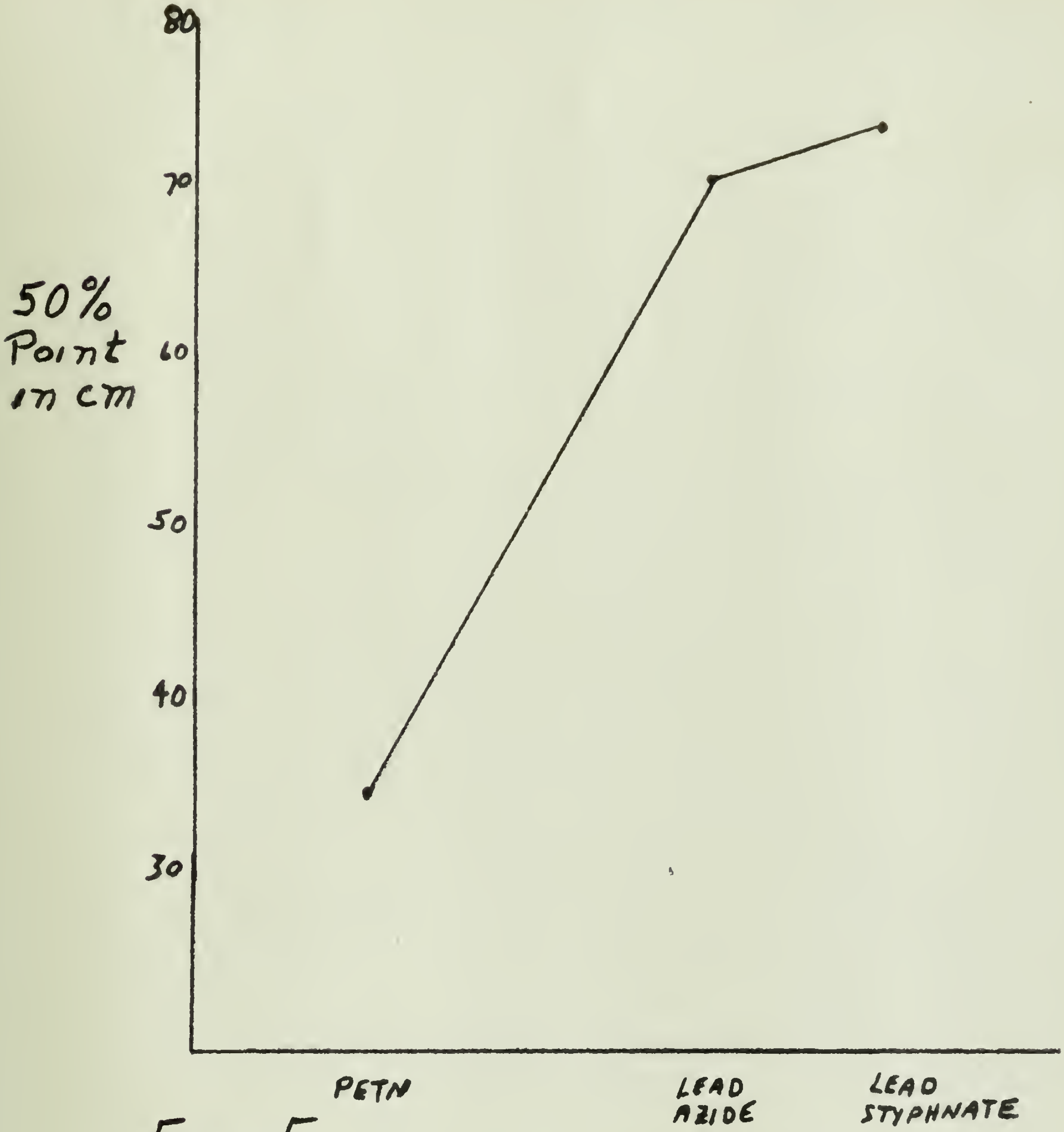


Fig. 5
Comparative Results of Investigation of Impact Sensitivity

7. SCHEDULE OF TESTS

DATE	MATERIAL	WT	50% POINT	REMARKS
1/28/59	PETN	10 mg	37	
1/28	PETN	10 mg	34	
2/2	PETN	20 mg	38	
2/2	PETN	10 mg	30	low wts
2/2	PETN	10 mg	24	low wts
2/3	PETN	20 mg	37	
2/3	Metallic oxide	20 mg	no record	off scale
2/9	lead styphnate	10 mg	73	
2/9	" "	20 mg	no record	off scale
2/12	" "	8 mg	52	
2/12	" "	8 mg	49	
2/12	" "	10 mg	73	
2/12	" "	5 mg	47	
2/18	lead azide	10 mg	76	
2/18	" "	20 mg	no record	off scale
2/18	lead styphnate	10 mg	73	test 50% point
2/19	PETN	10 mg	35	test 50% point
2/19	PETN	10 mg	36	test 50% point
2/23	PETN	5 mg	43.5	
3/2	metallic oxide	10 mg	74	
3/2	" "	10 mg	Failed to test 50% point	
3/2	lead azide	10 mg	76	test 50% point
3/5	metallic oxide	10 mg	Failed to test 50% point	
3/5	lead azide	10 mg	53	two pieces garnet
3/5	PETN	10 mg	43	Two pieces garnet
3/5	lead azide	10 mg	53	test 50% point double garnet
3/5	PETN	10 mg	43	test 50% point double garnet

8. CONCLUSIONS AND RECOMMENDATIONS.

The results obtained have shown the relative sensitivity to impact of the materials tested. The impact machine as designed and built and the outlined procedure give reproducible and acceptable values for this sensitivity data.

Recommendations for further study include the effects of the following on impact sensitivity;

(1) Temperature, particularly in the low ranges and extremely high ranges, results here would be of interest for arctic applications and for high speed missiles,

(2) Grit size, when dealing with sensitivity testing, grit is introduced in the form of garnet paper to increase the sensitivity and to more easily determine the variations in sensitivity. According to grain or particle size and sample weight there should be an optimum grit size.

(3) Mixtures of primer explosives, particularly of importance since primer explosives are quite often used together.

(4) Desensitizing materials such as chalk, moisture or wax.

Further study is also indicated to correlate impact sensitivity to the activation energy of the explosive materials.

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