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USA SMALL-SCALE COOKOFF BOMB (SCB) TEST

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ABSTRACT

This report describes the use of a Small-Scale Cookoff Bomb (SCB) for the UN Classification of explosives with regard to their thermal response. The SCB test simulates transport and storage situations involving external heating of substances. (A similar report has been written for inclusion in a compilation of test methods to be published as an addendum to the UN Orange Book, ("Transport of Dangerous Goods.")

INTRODUCTION

At the August 1979 meeting of the UN Group of Experts on Explosives, a general set of test procedures was established to determine to which hazard class various substances and articles should be assigned. UN Test Series 1 is part of the acceptance procedures used to determine whether or not a substance is accepted into Class 1. UN Test Series 2 is used to determine whether or not an explosive substance is too insensitive for acceptance into Class 1. UN Test Series 5 is being established to determine whether or not an article can be assigned to 1.5 hazard classification. These test procedures were agreed upon and published in UN Paper ST/SG/AC.10/C.1/R.51. The paper herein presented discusses a thermal response test that can be used in these series of tests for hazard classification of explosives.

Among the tests proposed for the thermal response tests were the Koenen test, the United States (US) Internal Ignition test, the US External Heat test, the United Kingdom Time/Pressure test, the United Kingdom Sealed Vessel test, and the US Deflagration-to-Detonation Transition (DDT) test. The External Heat test (Refs. 1 and 2) used by the US Department of Defense (DOD), has been proposed and accepted as an alternate to the present in-use Koenen test. A report on the SCB test will be published with other test methods as an addendum to the UN Orange Book. (The External Heat test is also known as the SCB test.)

The SCB test can be used to assess the severity of the cookoff reaction by examination of the SCB case and witness plate damage caused by the test substance when subjected to external heating. Criteria are provided herein for rating each test result as a burn, deflagration, explosion, or detonation based on the degree of damage sustained by the test fixture. This rating is described below and is suggested for use in relating the severity of the cookoff reaction to the UN criteria for thermal response.

EXPERIMENTAL PROCEDURE

Apparatus and Materials

The SCB experimental arrangement is shown in Figure 1. The sample to be tested is contained in a 400-milliliter steel vessel with walls 3 millimeters thick. Two 400-watt electric heater bands are fastened to the steel vessel, as shown in Figures 1 and 2.

The vessel has a threaded steel cover with two feedthrough fittings for thermocouple leads and for a pressure take-off. The complete fixture consists of the capped steel vessel clamped between two 13.5- by 13.5- by 1.27-centimeter thick steel witness plates held in place with four 1.27-centimeter diameter bolts. The SCB is instrumented with one or two plate-type thermocouples. When only one substance is being tested, a thermocouple is spot welded to the inside center of the vessel wall (see Figure 1). When two substances are tested, i.e., a liner material and an explosive material, a second thermocouple is used between the two substances. The plate-type thermocouples consist of a 0.3-millimeter thick nichrome ribbon approximately 1-centimeter square, with the thermocouple wires fanned out and individually spot welded to the nichrome. The welder used should be designed for thermocouple welding, or should be a welder that is current-limited for use with small wire or thin metal. Plate-type rather than bead-type thermocouples are used for this test since plate-type thermocouples respond faster and provide a more representative measurement of the temperature at the interfaces.

Procedure

The substance of interest is loaded into the SCB steel vessel to within 1 centimeter (approximately) of the top. The space remaining above the substance of interest allows for thermal expansion. The substance of interest can be a solid, liquid, slurry, powder or a gas under modified assembly and fill conditions. The test unit is assembled complete with the 400-watt heater bands and placed in a safe testing bay for remote firing. At the test bay, the thermocouple leads are connected to a strip-chart recorder which is used to record the temperatures and the time to cookoff. The two heater bands are wired in parallel and then connected to either a 110-VAC or 220-VAC safety-key controlled firing line. Which voltage selected depends upon which heating rate is desired. Once the test setup is completed and the site cleared of all personnel, the units are "fired" by turning the key to activate the heaters. The test is completed when a cookoff reaction occurs.

Data Reporting

Time and temperature of the cookoff reaction are taken from the strip-chart records, and an assessment of the severity of the reaction is made from the number and condition of the vessel fragments and the condition of the witness plate. Levels of reaction severity and the associated rating usually identified are given in Table 1.

TABLE 1. Thermal Response Rating of SCB Tests.

Vessel Condition	Witness Plate Dent	Cookoff Reaction	Rating
No change	No change	Burning	R-0
Intact, but bulged	No change	Burning	R-1
Open, one piece	<0.05-inch (0.13 cm)	Deflagration	R-2
Two pieces	<0.05-inch	Deflagration	R-3
Three/four pieces	<0.05-inch	Deflagration	R-4
Five+ large pieces	<0.05-inch	Explosion	R-5
Many pieces	<0.05-inch	Explosion	R-6
Many pieces	<0.20-inch	Explosion	R-7
Many small pieces	>0.20-inch (0.5 cm)	Explosion	R-8
Many small pieces	Almost punched	Partial Detonation	R-9
Many small pieces	Punched hole	Detonation	R-10

The time-temperature record is suggested for use in determining whether or not the substance of interest has met a minimum temperature requirement to be established for the UN Test Series 2(b). The minimum temperature requirement would be used to determine if a substance is too hazardous for thermal reasons (thermal stability criteria).

Figure 3 shows the experimental results used in evaluating the cookoff data and for assigning cookoff ratings of R-1 through R-10. The witness plate damage provides the strongest argument as to whether or not a substance has undergone a deflagration-to-detonation transition. *If the witness plate is flat with no apparent bending or concavity, then the reaction is considered not-a-detonation nor a reaction that would lead to a detonation. If, on the other hand, the witness plate has a measurable dent, then this is a strong indication that a detonation might develop if a larger sample were used.*

Criteria

A. *For UN Test Series 1(b)* (Suggested)

The test is considered positive if deflagration (R-2 or greater), as defined in Table 1, occurred.

B. *For UN Test Series 2(b)* (Suggested)

The test is considered positive if an explosion (R-5), as defined in Table 1, occurred prior to 100°C at the interface between the case and the substance.

C. *For UN Test Series 5(b)* (Suggested)

The test is considered positive if a partial detonation or detonation (R-9 or greater), as defined in Table 1, occurred. This test series is suggested for use for consideration of articles to be placed in Division 1.5.

DISCUSSION OF RESULTS

Test results for some typical explosives are given in Table 2. The SCB is a technique that has been used to empirically predict the time to cookoff and the severity of the cookoff reaction for a given explosive in hardware. The technique has been used to evaluate a large number of military high explosive compositions and their ingredients for predicting their reaction in a fuel fire under the confined condition of a munition. Since a liner material is usually used with a high explosive fill in a munition, the steel vessel can be lined with the selected liner material, explosively filled, and tested. In this manner, the effect of the liner material on the high explosive can be determined with regard to its influence on the cookoff time and the severity of the cookoff reaction. Studies have shown that certain liner materials can make the cookoff reaction of a given high explosive more *or* less severe.

Another factor which must be considered when using this technique is that the actual heating rate is nonlinear and averages out to be approximately 0.2°C/s when connected to 110 VAC. When the same heaters are connected to 220 VAC, the heating rate averages out to be approximately 3°C/s. When an item is heated in a fuel fire, the heating rate is nonlinear in the same manner as has been described for the SCB. The approximate heating rate will depend on the heat given off by the fire in relationship to the mass of the item and the thickness of the wall through which the temperature is measured. The 3°C/s rate is approximately that experienced by a high explosive (HE) fill in a heavy wall steel munition subjected to a fuel fire test. The 0.2°C/s heating rate is representative of that experienced by a HE fill in a thermally protected heavy wall steel munition subjected to a fuel fire. In general, cookoff reactions become more severe as the heating rate decreases.

It is proposed to use the SCB to determine if a substance has any significant explosive properties when subjected to a thermal stimulus (UN Series 1(b) Test). It is further proposed that substances that yield only a burning reaction (i.e., see those listed in Table 2) should be considered too insensitive for inclusion in Class 1. Although the cookoff reaction listed as a deflagration does show some explosive properties for a given substance, this reaction should also be considered too insensitive for the lower limit of thermal sensitivity in the UN Series 2(b) Test. It is thus proposed that the cookoff reaction listed as a deflagration should be considered too insensitive for Class 1, unless retained in Class 1 based on the results from another test (such as those listed in UN Series 1(b)).

A number of substances from Table 2 have cookoff reactions listed as deflagrations. One substance that appears to be out of line is the flake TNT. The test with flake TNT would indicate that in a fire the TNT could have a mild cookoff reaction. Once all or most of the TNT is molten, the cookoff reaction can become more severe, leading to a detonation. These data show that the physical state of the substance is important to the reporting of test results.

CONCLUSION

The SCB test fixture has been and will continue to be an excellent technique to determine the thermal behavior of explosives with regard to cookoff time, temperature and the severity of the cookoff reaction. The technique can be used with other laboratory techniques to more fully evaluate the thermal response of confined explosives.

REFERENCES

1. Naval Weapons Center. *NWC Standard Methods for Determining Thermal Properties of Propellants and Explosive*, by Jack M. Pakulak, Jr., and Carl M. Anderson. China Lake, Calif., NWC, March 1980. (NWC TP 6118, publication UNCLASSIFIED.)

2. C. M. Anderson and J. M. Pakulak, Jr., "The Prediction of the Reaction of an Explosive System in a Fire Environment. Coated RDX Systems for Pressed Explosives." *J. of Hazardous Materials*, Vol. 2 (1977/1978), pp. 143-161.

TABLE 2. SCB Test Results on Selected Explosives.

Explosive type	Heater Voltage, VAC	Cookoff Temperature, °C	Cookoff Time, min	Cookoff Reaction
Pressed Composition A-5	110	225	14.0	Detonation
Pressed CH-6	110	222	12.9	Detonation
Pressed RDX/EVA (97/3)	110		12.8	Explosion
Pressed RDX/Estane (95/5)	110		14.6	Detonation
Pressed Composition A-3	110	248	6.8	Detonation
Pressed RDX/PE (91/9)	110		18.6	Detonation
Pressed RDX/EVA (91/9)	110		17.1	Explosion
Pressed Tetryl	110	215	14.5	Detonation
Flake TNT, loose fill	110		11.	Deflagration
Cast TNT	110	>400	6.1	Detonation
Cast Composition B	220	250	1.9	Detonation
Cast EA Eutectic mixture	110	260	14.9	Explosion
Cast EA Eutectic mixture	220	316	1.4	Explosion
Flake TATB, loose fill	220	388	2.8	Deflagration
HBD-powder NQ, loose fill	110	281	4.1	Explosion
Dupont GSX, AAN Sensitized	110	250	6.	Explosion
GSX, TNT Sensitized	110	360	4+	Deflagration
Hercules GSX, Al Sensitized	110	390	8+	Deflagration
5-6 μ powder AP, loose fill	110		33.	Deflagration
200 μ powder AP, loose fill	110		34.	Deflagration
Cast PBCT/Al/AP Rocket propellant	110		7.2	Deflagration
M6 Gun propellant, loose fill	110	201	4.2	Deflagration
M6 Gun propellant, loose fill	220		1.2	Deflagration
Single Base (NC) Gun propellant	220		1.3	Burning
MAN 85% solution	110		23.	Explosion
~ 10 μ powder AN, loose fill	220		3.0	Burning
~ 10 μ powder AN, loose fill	110	339	13.0	Burning
~ 10 μ powder, GN, loose fill	220	~340	3.8	Burning
~ 10 μ powder GN, loose fill	110	368	14.3	Deflagration
p,p'-oxy-bis(benzene sulphonhydrazide), loose fill	220	190	0.9	Burning

Definitions:

AAN = Aliphatic amine nitrate
Al = Aluminum
AN = Ammonium nitrate
AP = Ammonium perchlorate
EA = Ethylene diamine dinitrate/Ammonium nitrate (Potassium nitrate phase stabilizer) eutectic mixture
EVA = Ethylene vinyl acetate copolymer, USI, UE-638-04
GSX = Gelled slurry explosive
HBD = High bulk density
MAN = Methylamine nitrate
NC = Nitrocellulose
NQ = Nitroguanidine
PBCT = Polybutadiene, carboxy terminated
PE = Polyethylene, emulsion, MIL-E-63218
GN = Guanidine nitrate
RDX = Hexogen = cyclo-1,3,5-Trimethylene-2,4,6-trinitramine
TATB = Triaminotrintrobenzene
TNT = 2,4,6-Trinitrotoluene

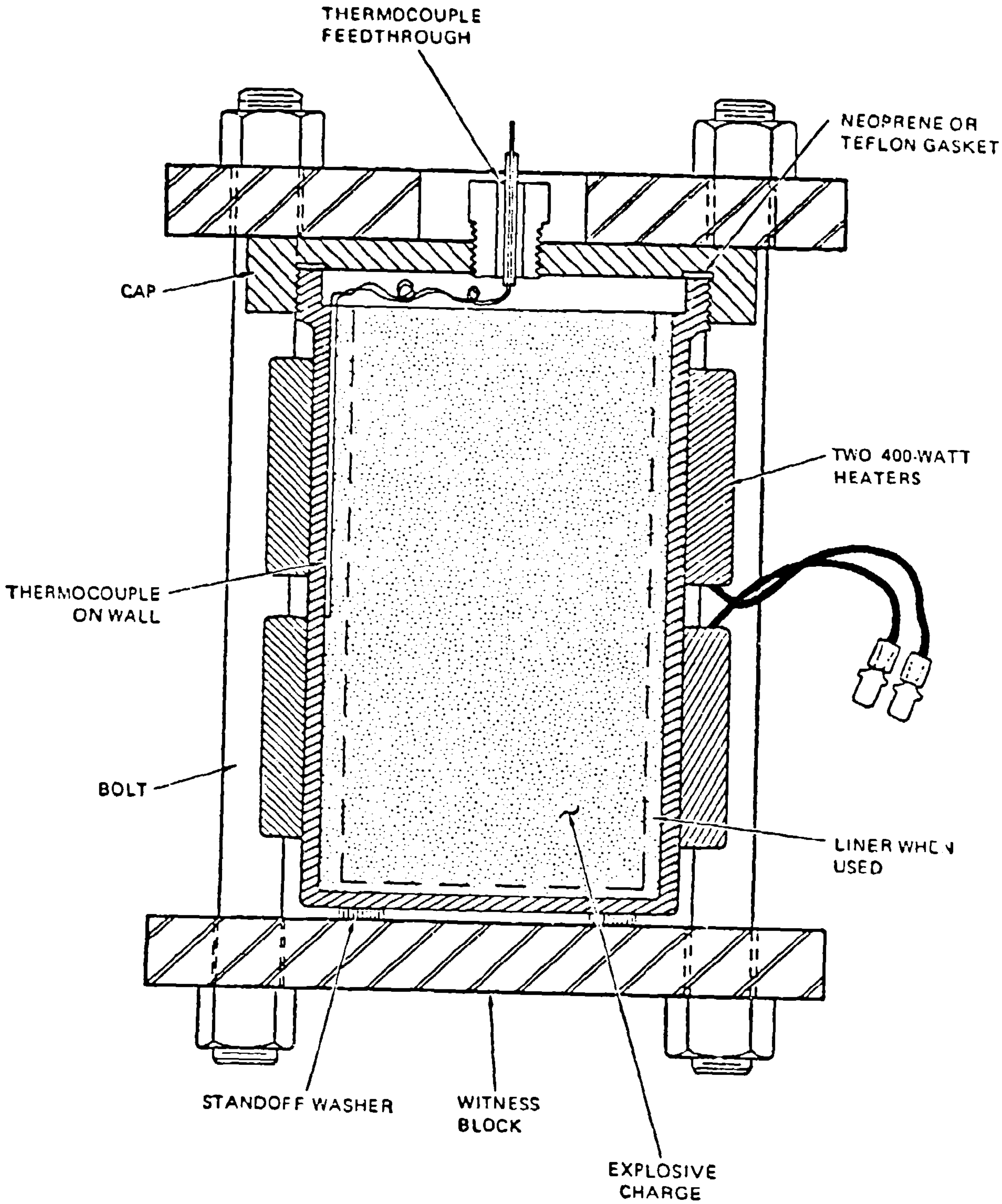


FIGURE 1. SCB Test Fixture.

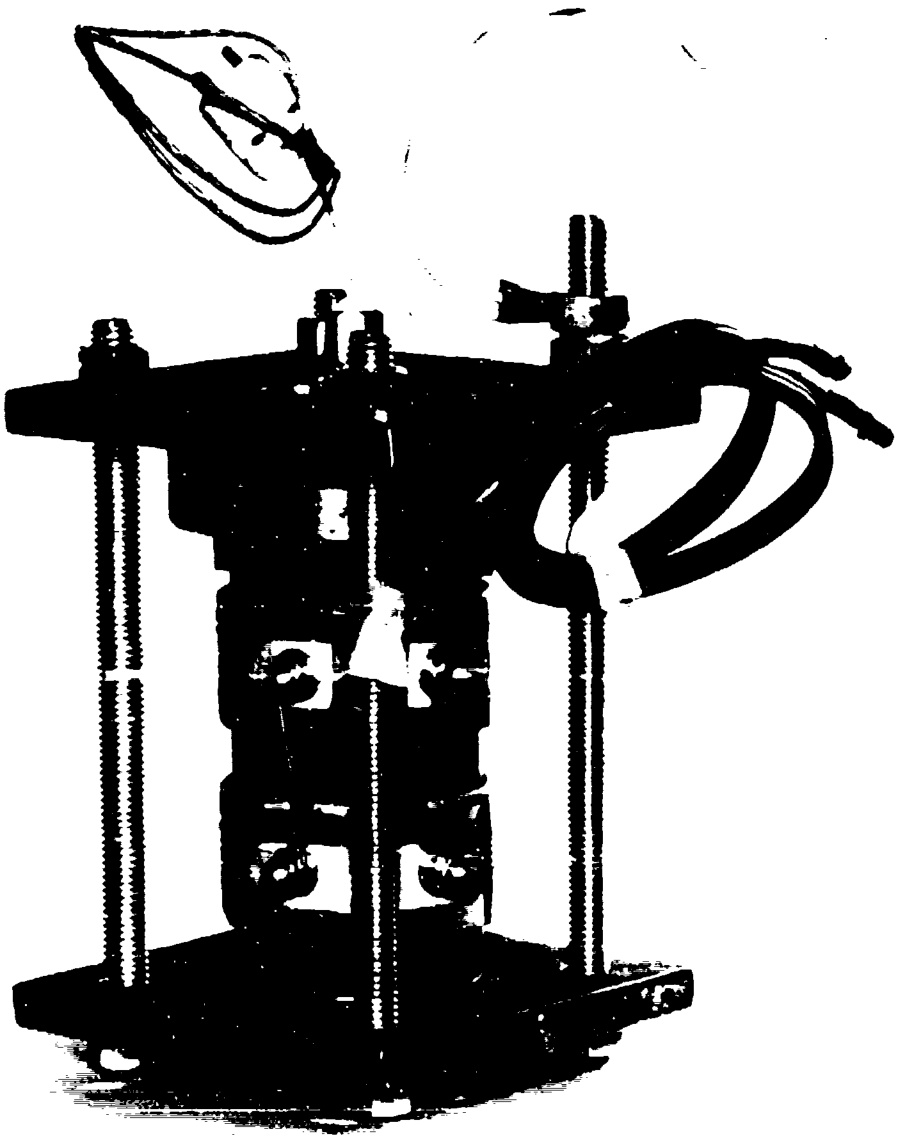
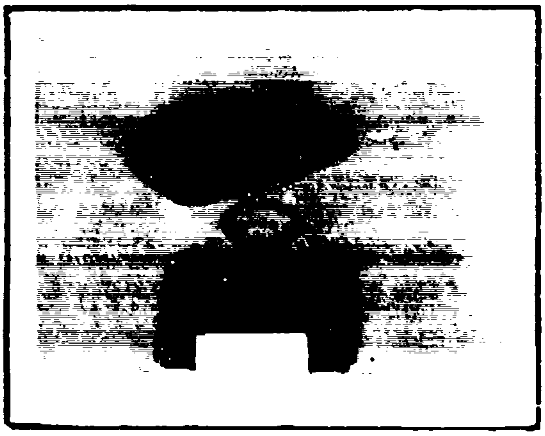
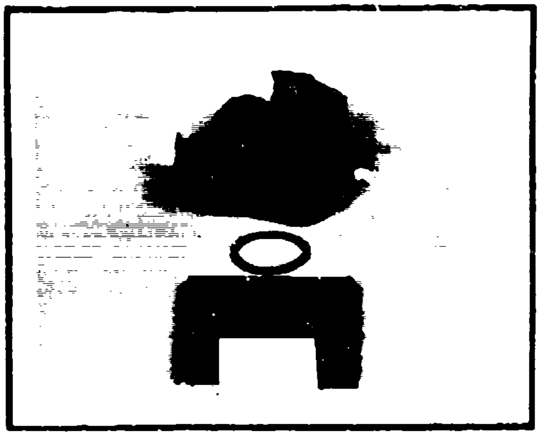


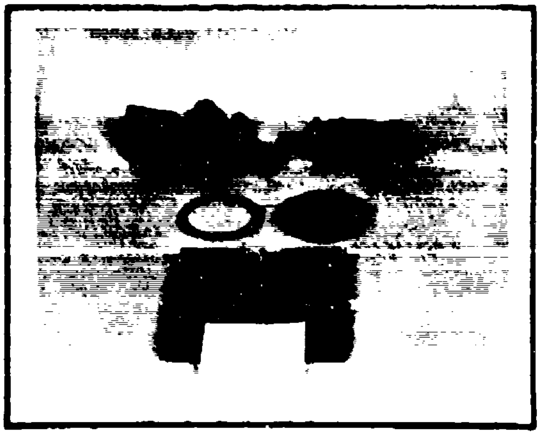
FIGURE 2. SCB Test Setup.



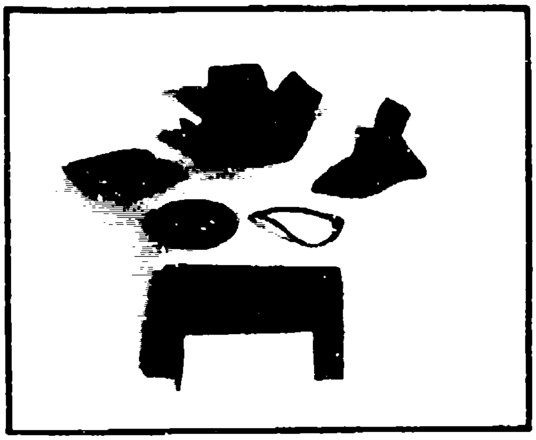
R-1 case intact but bulged, no plate dent, burning.



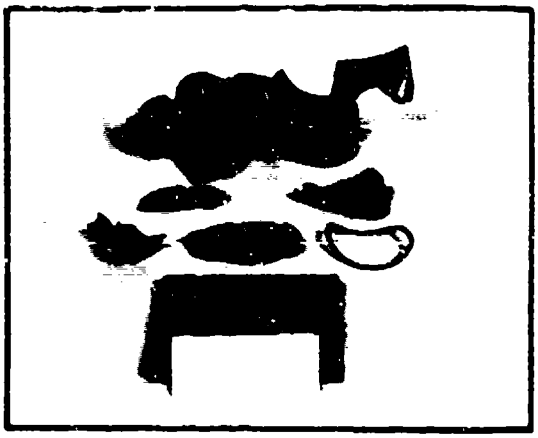
R-2 case open, 1 piece, plate dent 0.05 , deflagration.



R-3 case, 2 pieces, plate dent 0.05 , deflagration.

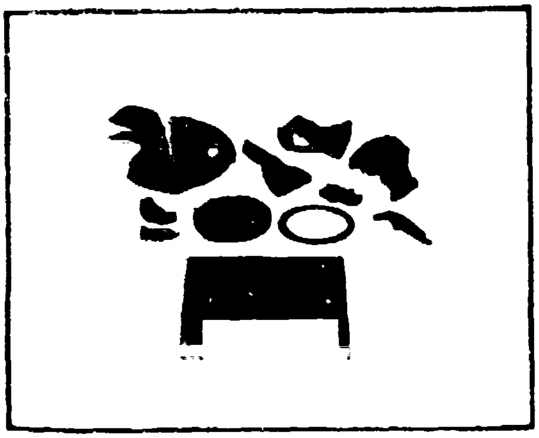


R-4 case, 3/4 pieces, plate dent 0.05 , deflagration.

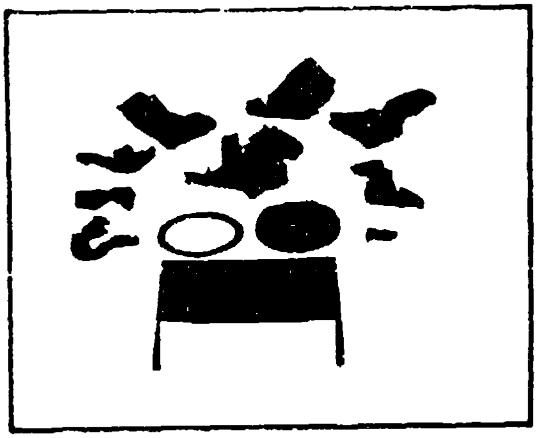


R-5 case, 5+ large pieces, plate dent 0.05 , explosion.

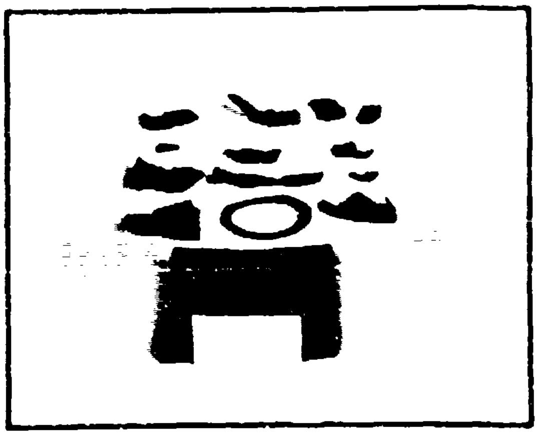
FIGURE 3. Analyzed Reactions.



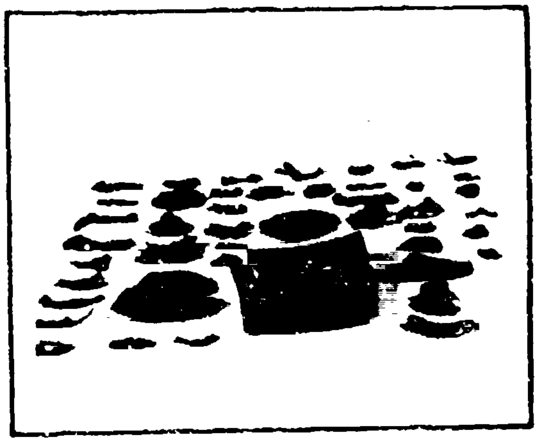
R-6 case, many large pieces, plate dent 0.05 , explosion.



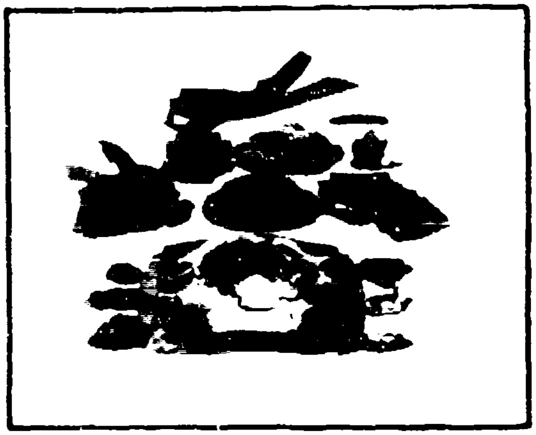
R-7 case, many large/small pieces, plate dent 0.2 , explosion.



R-8 case, many large/small pieces, plate dent 0.2 no punch, explosion.



R-9 case, many small pieces, plate almost punched, partial detonation.



R-10 case, many small pieces, plate punched, detonation.

FIGURE 3. Analyzed Reactions. (Contd)