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U. S. PARTICIPATION IN THE CANADIAN
HIGH EXPLOSIVE FIELD TRIALS, 1959

30 October 1961

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U. S. PARTICIPATION
IN THE CANADIAN HIGH EXPLOSIVE FIELD TRIALS, 1959

PART I

CALIBRATION OF FIVE-GALLON CANS
(PROJECT 1.2)

Prepared by:
J. F. Pittman

ABSTRACT: This report presents the results of an attempt to calibrate empty 5-gallon cans so that they could be used to measure the peak overpressures of long-duration shock waves from the 0.5- and 5.0-ton HE explosions conducted by the Canadians in 1959. The ultimate objective of the experiment, to obtain data on the reliability of peak overpressure measurements made by the cans, was not met. The cans used for this investigation were rectangular in shape and had physical properties unsuitable for pressure measurements of this type in that when they reached a minimum volume under hydrostatic pressure, they failed to retain this volume upon release of the pressure. Also, it was found that the opening in the can was not large enough to allow the compressed air inside the can to escape rapidly and prevent reinflation. Although it is thought that an extensive theoretical and experimental investigation of rectangular, thin-walled cans could lead to the development of a "gauge" suitable for measuring peak blast overpressure, this course of action is not recommended.

Approved by:
J. F. Moulton, Jr., Chief
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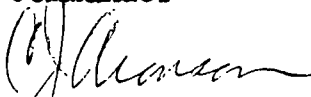
PART I - CALIBRATION OF FIVE-GALLON CANS
(PROJECT 1.2)

NOL participation in the Canadian 0.5- and 5.0-ton HE Test Program, September, 1959, was accomplished as part of Task Number RE01 ZA 732/2129/F008-21-003 (formerly designated 701-267/76002/01073). The experiments reported herein were conducted on both shots and were designated U. S. Project 1.2.

The invitation for NOL to participate in these tests came originally from the Suffield Experimental Station (SES), Ralston, Alberta, Canada, through the Ballistic Research Laboratories (BRL), Aberdeen, Maryland.

The reader should note that this project was conceived in haste, performed in haste, and concluded in failure. Had there been sufficient time prior to the field tests to check the response of the instrumentation when subjected to forces simulating those to be expected in the field, there is every reason to believe the project would have resulted in success. This report is published to serve, first, as a documentary of the work done and, second, as an example of what may befall the experimenter who goes into the field before he is fully prepared or adequately equipped.

W. D. COLEMAN
Captain, USN
Commander



C. J. ARONSON
By direction

CHAPTER I

INTRODUCTION

1.1 OBJECTIVES

The immediate objective of Project 1.2 was to calibrate 5-gallon rectangular cans in terms of volume change due to the distortion caused by subjecting the cans to external overpressures. The ultimate objective was to expose such cans to long-duration shock waves and evaluate them as devices for obtaining reliable peak overpressure measurements.

1.2 BACKGROUND INFORMATION

When attempts were made to correlate the air blast data from nuclear test Baker of Operation CROSSROADS (reference 1) with other more recent nuclear data, numerous difficulties were encountered. The immediate reaction was to discredit the Baker data because the instrumentation employed was comparatively crude. The instruments were, for the most part, mechanical devices that were designed to suffer permanent deformation when subjected to the blast; included were such objects as gasoline cans, beer cans, oil drums, arrays of vertical steel pipes, and aluminum-foil diaphragms. All of these "instruments" were calibrated in various ways, but the short preparation time in advance of the CROSSROADS tests precluded the adequate calibration of the larger can-type instruments. The various possible modes of failure (deformation), especially, were poorly understood.

The investigation conducted as U. S. Project 1.2 in the Canadian large-scale explosion trials of 1959 was undertaken as part of a new program to evaluate the 5-gallon can as a device for measuring peak overpressures in long-duration shock waves. It was hoped that the knowledge gained might be applied to reevaluate CROSSROADS Baker data obtained with similar cans.

1.3 THEORY

A simple method for measuring the overpressure in a shock wave is to observe the crushing of a suitable container, such as a can with an opening of appropriate size. The can, subjected

to the sudden increase in pressure in the shock wave, is caused to collapse. The air inside the can is compressed adiabatically to a point such that the pressure inside is less by a certain amount than the pressure outside, this pressure being the maximum pressure that the container can withstand without further yield. In the compressive stage, no air must enter the can through any opening. During the decay of the external pressure, the air must be allowed to escape from inside the can fast enough to prevent the inside pressure from "reinflating" the can. Assuming that the above conditions have been met, then the observed volume in the collapsed condition, V_2 , is a true register of the collapsed volume due to the blast, and the over-pressure, Δp , that caused collapse is

$$\Delta p = P_0 \left[\left(\frac{V_1}{V_2} \right)^\gamma - 1 \right] + P_c, \quad (1)$$

where V_1 is the initial volume of the container, P_0 is the atmospheric pressure, P_c is the yield strength of the can in the collapsed condition, and γ is the ratio of specific heats of air.

A flapper valve is placed over the opening (spout) in the can in a manner such that excess exterior pressure cannot enter the can, but excess interior pressure can escape. As previously stated, the opening in the can must be sufficiently large to allow the air inside the can to escape quickly as the pressure in the blast wave decreases; otherwise the walls of the can will be blown out, again and spoil the reading.

CHAPTER 2

PROCEDURE

2.1 EXPERIMENTAL PLAN

This investigation was undertaken as a minimum effort task in conjunction with other NOL projects on the Canadian 5.0- and 0.5-ton HE shots. Five-gallon rectangular cans of the type commonly used for shipping paint were obtained from the Continental Can Company. These cans were modified by soldering light phosphor-bronze flapper valves to the tops of the cans in a position to cover the openings of the cans. The valve operated to prevent entry of air into the can initially, while later allowing escape of the compressed air inside the can as outside pressure decayed.

The cans were placed at five positions along the ground where peak shock overpressures of 5, 10, 15, 20, and 25 pounds per square inch (psi) were expected. Three cans were used at each of the five stations. Two cans at each station were placed on top of the ground and one can was placed in a shallow excavation, deep enough so that the highest position of the can, lying on its side, was level with the ground surface. The cans were secured in position by a loose harness of banding straps that was fastened to a stake driven into the ground 18 inches in front of the cans. The five stations were located in a line parallel to and 10 feet away from the Ballistic Research Laboratories' (BRL) gage line. A typical station is shown in Figure 2.1-1.

2.2 CALIBRATION OF CANS

To determine the peak shock overpressures to which the cans had been subjected during the Canadian trials, it was necessary to determine the yield strength, P_c , of the cans. This was accomplished statically by gradually evacuating a number of cans by means of a vacuum pump. A manometer was used to determine the differential between the interior and exterior pressures. In general, as the cans were slowly evacuated, the differential pressure increased steadily with minor relapses, as the sides yielded by buckling, until edge failure occurred between 1.4 and 2.0 psi. With edge failure, the differential pressure

dropped to between 0.5 and 0.8 psi, and then gradually increased to 1.5 to 2.5 psi as the can was compressed from 1/2 to 1/3 its original volume. If evacuation were stopped at any point and the pressure differential removed, the can would spring back to a considerably larger volume, i.e., the deformation corresponding to a particular pressure differential was not retained upon release.

Static calibration data obtained for four unused cans plus two cans used in the Canadian tests are shown in Figure 2.2-1.* It was noted during calibration that as the cans were evacuated, periodic buckling of the sides would occur, amounting to a slight inward dishing of the side. However, no measurable deformation was retained upon release of the pressure differential unless the evacuation proceeded to the point where one of the edges of the can failed. Therefore, the first datum point on the runs with the unused cans represents the value of P_c , the differential pressure at which edge failure occurred, and the associated volume to which the can returned after the pressure differential was removed. This volume is not particularly significant since it depends primarily on how quickly the pressure differential is released following edge failure. The subsequent points were then obtained by slowly evacuating the cans until some further deformation occurred, after which the pressure differential was released and the volume of the can measured. The points shown in Figure 2.2-1, not connected by lines, are single datum points, each obtained from a separate unused can. In all cases except for those indicated in Figure 2.2-1 by encircled data points, considerable expansion of the can was observed following release of the pressure differential.

The static calibrations on cans 5-A and 5-DEF were obtained after these cans had been subjected to 5-psi overpressure shock waves from the Canadian 0.5- and 5.0-ton shots, respectively. Can 5-DEF is seen to be considerably stronger than the other cans initially, but its P_c vs V_1/V_2 curve ultimately falls in with the curves for the other cans. This behavior is apparently due to the manner in which failure occurred. Initial edge failure occurred about 1 inch from a corner of this can. The subsequent discontinuous drop in yield strength occurred as the edge failed at a second point about 1/3 of the length of the can from the bottom. A more typical pattern of

*In Fig. 2.2-1, the calibration curves labeled 5-A and 5-DEF are for the cans so identified in the 0.5- and 5.0-ton field tests (see Tables 3.1-1 and 3.1-2). Curves labeled 10-13 represent virgin cans randomly selected from the supply available.

behavior was for the edge nearest the spout to fail about mid-way along the length of the can. In almost every case of static calibration, the first permanent deformation resulted from the buckling of the edge nearest the spout.

The average of the calibration curves in Figure 2.2-1 is plotted in Figure 2.2-2. This average curve was used in equation (1) to calculate Δp , the shock overpressure measured by the cans.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 RESULTS

The final volume, V_2 , of the cans exposed to the 0.5- and 5.0-ton shots and the calculated peak shock overpressure, Δp , calculated using equation (1), are given in Tables 3.1-1 and 3.1-2. Also given, for comparison, are the best available values for the peak shock overpressures, Δp_s , taken from mechanical and electronic pressure-time measurements reported in reference (2). The percentage differences between these values, Δp_s and Δp , for the one can placed in a hole at each position, are also shown.

3.2 DISCUSSION OF RESULTS

It may be noted that the Δp values in Tables 3.1-1 and 3.1-2 are considerably lower than the corresponding values of Δp_s , the peak shock overpressure from the more reliable recording equipment, reference (2). The fact that Δp is lower than Δp_s indicates that the cans underwent post-shock inflation. Evidence of this is seen in the following: The time necessary for the pressure inside the can to equalize with the outside pressure is controlled by the size of the opening in the can. In using the cans to indicate peak overpressures in a shock wave, the time allowed for the can to vent is a function of the positive duration of the shock wave. Generally, the positive duration of a shock wave is a function of the charge size and the distance from the charge, increasing as either is increased. Note that, in Tables 3.1-1 and 3.1-2, the difference between Δp_s and Δp decreases as the duration of the shock wave is increased, either by increasing the distance to the charge or by increasing the size of the charge. This indicates that the opening in the can was not large enough to prevent post-shock inflation. It may also be noted in the tables that at each station on both shots, the can in the hole yielded the greatest value of Δp . While no sure explanation for this can be offered, it is probable that these cans were subjected to a greater pressure, owing to reflections of the initial shock within the holes.

It is obvious that the improper employment of the cans as discussed above precludes any evaluation of the CROSSROADS Baker data based on this experiment. Data from the Baker shot indicate that the openings in the cans were large enough to prevent post-shock inflation in the case of the long duration shocks in that there was no trend for the cans to indicate lower pressures close in to the charge. Moreover, the cans used on SANDSTONE shots Yoke and Zebra, reference (3), gave pressures reasonably close to theoretical values as well as those from other peak pressure indicators.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The ultimate objective of this project, to determine the reliability of 5-gallon cans as peak overpressure indicators, was not met. Two negative conclusions were reached:

- a. The cans used for this investigation were unsuitable for measurements of this type in that they would not retain full deformation upon pressure equilization
- b. The openings in the cans were too small to allow the compressed air inside the cans to escape rapidly enough to prevent inflation of the cans following passage of the shock

As a result, the volume change measured after a shot would be less than the maximum volume change; hence, the indication of the "peak" overpressure would be unreliable.

4.2 RECOMMENDATIONS

Undoubtedly, extensive theoretical and experimental investigations could be conducted that would lead to the practicable use of weak-walled containers as peak overpressure measuring devices. Other more sophisticated and reliable instrumentation is now available for the purpose, however. Therefore, further pursuit of such work is not recommended.

The results obtained in this investigation are inconclusive as to the reliability of the CROSSROADS Baker data. However, the results from the SANDSTONE shots Yoke and Zebra indicate that when properly used, 5-gallon cans give reasonable peak pressure results.

The complete cooperation of the technical staff of Suffield Experimental Station is gratefully acknowledged, as is the assistance received from participating personnel of the Ballistic Research Laboratories and the Waterways Experiment Station.

The field work was carried out by personnel of the Air-Ground Explosions Division under the general supervision of J. F. Moulton, Jr. (Division Chief) and E. M. Fisher (Group Leader). Field personnel were J. F. Pittman (Project Officer), H. B. Benefiel, R. L. Knodle, and J. Mattingly. Laboratory calibration tests were performed after the completion of the field tests by J. Goertner, assisted by R. W. Huff and H. S. Thomas. A more detailed description of the calibration tests than is presented in this report is contained in an NOL internal memorandum designated TN-4907, dated 1 November 1960.

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2. U. S. Visiting Test Team, "Preliminary Results from the 0.5-Ton Air Burst and the 5.0-Ton Surface Shot," Suffield Experimental Station, Ralston, Alberta, Canada, 5 October 1959, Unclassified.
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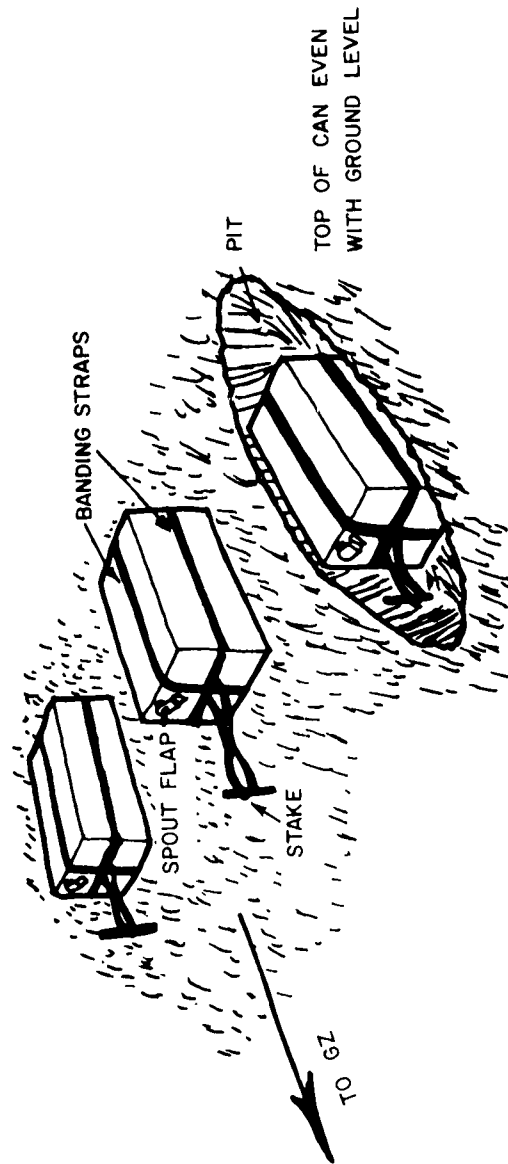


FIG. 2.1-1 FIVE-GALLON CAN STATION

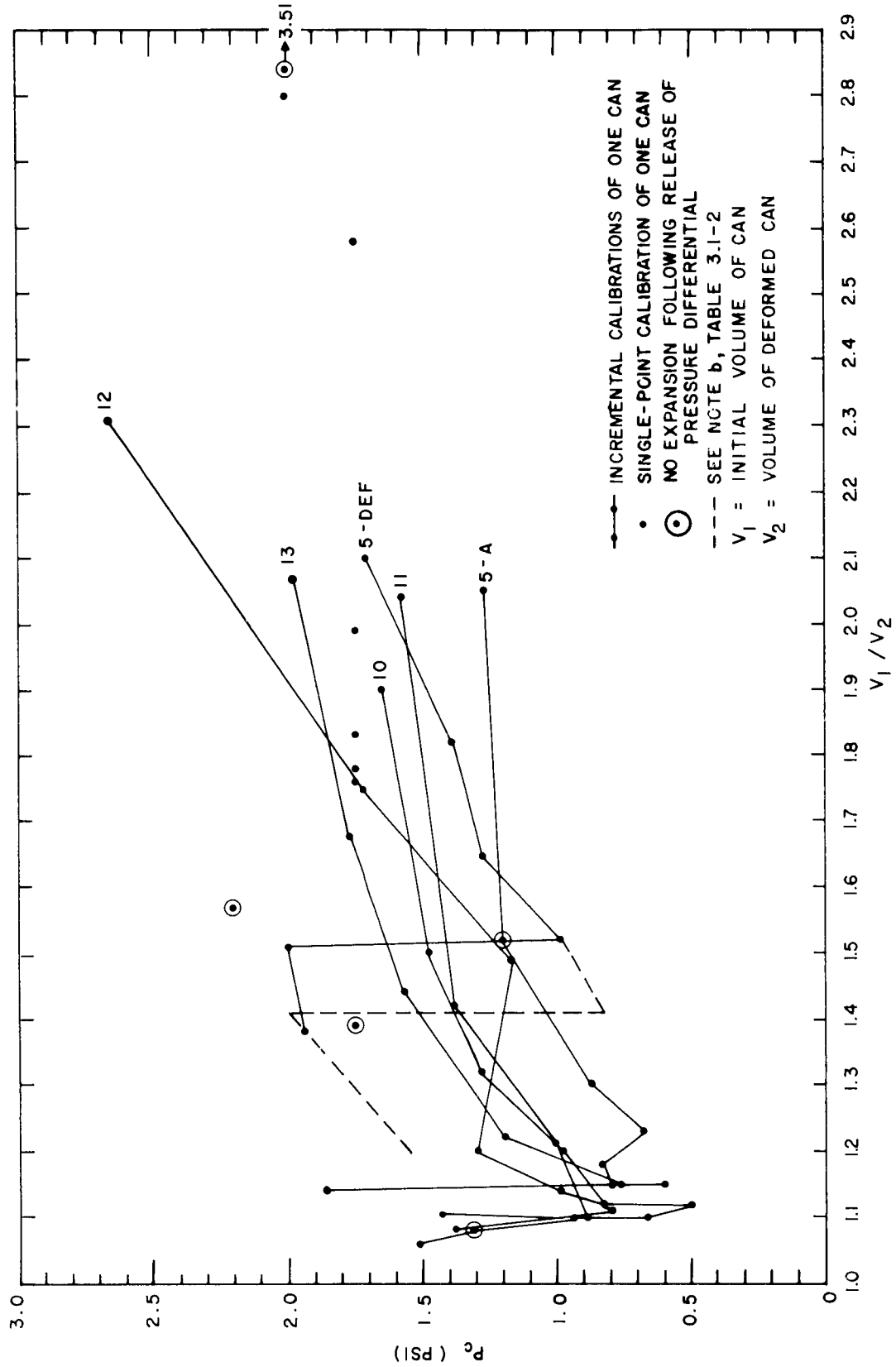


FIG. 2.2-1 YIELD STRENGTH, P_c , VS VOLUME RATIO, V_1/V_2

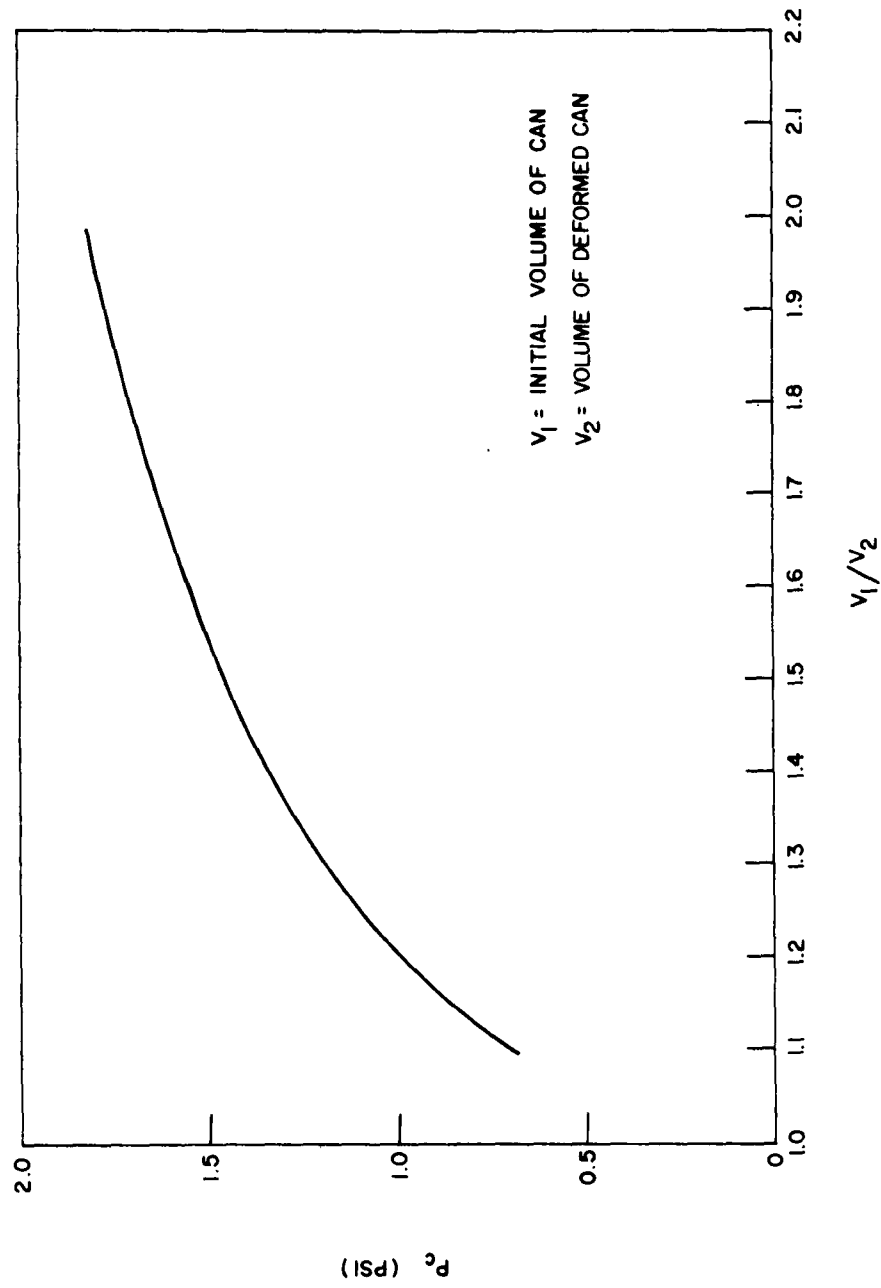


FIG. 2.2-2 AVERAGE YIELD STRENGTH, P_c , VS VOLUME RATIO, V_1/V_2

TABLE 3.1-1 PEAK SHOCK OVERPRESSURE, Δp , CALCULATED FROM 5-GALLON CANS FOR 0.5-TON SHOT

Can Designation	Distance from GZ (Feet)	Final Volume (Liters)	V_1/V_2	Δp^b (psi)	Accepted Value Shock Overpressure Δp_s (psi)	Percent Difference $\frac{\Delta p_s - \Delta p}{\Delta p_s} \times 100$
^a 25A	62	13.70	1.37	9.0	25	64
25AB	62	14.40	1.31	7.5		
25ABC	62	14.40	1.31	7.5		
^a 20A	72	14.20	1.32	7.8	19	59
20AB	72	15.20	1.24	5.9		
20ABC	72	14.50	1.30	7.3		
^a 15A	86	14.55	1.29	7.2	13.5	47
15AB	86	15.60	1.20	5.1		
15ABC	86	15.15	1.24	6.0		
^a 10A	111	15.30	1.23	5.7	8.5	33
10AB	111	16.45	1.14	3.6		
10ABC	111	16.30	1.15	3.9		
^a 5A	160	16.35	1.15	3.9	4.7	17
5AB	160	17.05	1.10	2.7		
5ABC	160	17.30	1.09	2.4		

^a Indicates can placed in hole.^b $\Delta p = P_0 \left[(V_1/V_2)^{\gamma} - 1 \right] + P_c$; $P_0 = 13.82$ psi, $V_1 = 18.80$ Liters, P_c taken from Figure 2.2-1.

TABLE 3.1.1-2 PEAK SHOCK OVERPRESSURE, Δp , CALCULATED FROM 5-GALLON CAN DATA FOR 5.0-TON SHOT

Can Designation	Distance from GZ (Feet)	Final Volume (Liters)	V_1/V_2	Δp^c psi	Accepted Value Shock Overpressure Δp_s (psi)	Percent Difference $\frac{\Delta p_s - \Delta p}{\Delta p_s} \times 100$
a 25DEF	130	11.95	1.57	13.6	25.0	46
25DE	130	12.80	1.47	11.1		
25D	130	12.70	1.48	11.4		
a 20DEF	143	13.10	1.44	10.4	20.6	50
20DE	143	13.70	1.37	8.9		
20D	143	13.15	1.43	10.3		
a 15DEF	165	13.50	1.39	9.4	15.6	40
15DE	165	14.20	1.32	7.8		
15D	165	13.95	1.35	8.4		
a 10DEF	195	13.60	1.38	9.1	11.5	21
10DE	195	14.95	1.26	6.3		
10D	195	14.17	1.33	7.8		
a 5DEF	285	15.45	1.22	5.9 ^b	6.0	2
5DE	285	17.50	1.07	2.0		
5D	285	16.65	1.13	3.3		

a Indicates can placed in hole.

b Yield strength of 1.6 psi was used for this calculation and was obtained by extrapolating the post-shot static calibration curve for this can back to V_1/V_2 (dashed curve in Figure 2.2-1).c $\Delta p = P_0 \left[\left(\frac{V_1}{V_2} \right)^\gamma - 1 \right] + P_c$; $P_0 = 13.66$ psi, $V_1 = 18.80$ liters, $\gamma = 1.4$, P_c taken from Figure 2.2-2.

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SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Shock wave	SHWV	Minimum	MINM		
Measurement	MEAU	Volume	VOLU		
Cans	CNTA	Testers	TESR		
Calibration	CALB	Gages	GAGE		
Pressure	PRES	Blast	BLAS		
High energy	HIGE				
Explosives	EXPL				
Explosions	EXPS				
Canada	CAND				
Failure	FAIL				
Configurations	COFI				
Hydrostatic	HYRD				

Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 61-122) U. S. PARTICIPATION IN THE CANADIAN HIGH EXPLOSIVE FIELD TRIALS, 1959. PART I - CALI- BRATION OF FIVE-GALLON CANS (PROJECT 1.2), by J. F. Pittman. 30 Oct. 1961. 13p. illus., tables, diagr. Task RE 01 ZA 732/2129/FO08-21- 003. UNCLASSIFIED Presents results of attempt to calibrate empty 5-gallon cans so that they could be used to measure peak overpressures of long-duration shock waves from 0.5- and 5.0ton HE explosions. Ultimate objective, to obtain data on rela- bility of peak over-pressure measurements made by cans, failed. Cans used were rec- tangular and had physical properties unsuit- able for pressure measurements of this type in that after reaching minimum volume under hydrostatic pressure, they failed to retain their volume.	1. Explosions - Pressure 2. Explosions - Measurements 3. Shock waves - Pressure 4. Shock waves - Measurements 5. Gages, Blast I. Title II. Pittman, Joseph F. III. Project
Naval Ordnance Laboratory, White Oak, Md. (NOL technical report 61-122) U. S. PARTICIPATION IN THE CANADIAN HIGH EXPLOSIVE FIELD TRIALS, 1959. PART I - CALI- BRATION OF FIVE-GALLON CANS (PROJECT 1.2), by J. F. Pittman. 30 Oct. 1961. 13p. illus., tables, diagr. Task RE 01 ZA 732/2129/FO08-21- 003. UNCLASSIFIED Presents results of attempt to calibrate empty 5-gallon cans so that they could be used to measure peak overpressures of long-duration shock waves from 0.5- and 5.0ton HE explosions. Ultimate objective, to obtain data on rela- bility of peak over-pressure measurements made by cans, failed. Cans used were rec- tangular and had physical properties unsuit- able for pressure measurements of this type in that after reaching minimum volume under hydrostatic pressure, they failed to retain their volume.	1. Explosions - Pressure 2. Explosions - Measurements 3. Shock waves - Pressure 4. Shock waves - Measurements 5. Gages, Blast I. Title II. Pittman, Joseph F. III. Project