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STEEL DENT OUTPUT OF A NUMBER OF COMMON EXPLOSIVES VOLUME I UNCLASSIFIED EXPLOSIVES

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Useful by-products of the output study are the density vs consolidation pressure data. Nomographs have been devised as a compact way of presenting this information.

This report is in two volumes of which this is Volume 1.

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Prepared by:
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Explosions Dynamics Division
Explosions Research Department
NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

Steel Dent Output of a Number of Common Explosives

The work leading to this report was done under the task "Explosion Initiation and Safety," ORD-332-004-092-1-UF-354-314. The effort was carried out to obtain background output data needed for both the design of explosive trains and the assessment of their safety and reliability.

The identification of commercial materials implies no criticism or endorsement of them by the Naval Ordnance Laboratory. This report is divided into two volumes of which this is Volume I.

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Captain, USN
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By direction

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1. INTRODUCTION, BACKGROUND AND SCOPE

1.1 The Small Scale Gap Test (SSGT)[1] has been used in the past decade (1960 to date) to determine the sensitivity of explosives to hydrodynamic shock when fabricated in dimensions comparable to those of explosive components used in explosive-train detonators and leads. The SSGT is also useful in characterizing newly synthesized explosive compounds obtainable only in gram-quantities. Each shot of an SSGT is assessed for response (go or no-go) by the indentation produced in a steel block. The observed indentation is compared with that obtainable from the same explosive when initiated under maximum-input (zero gap) conditions. The zero-gap* indentations (which are a measure of the brisance of the explosive) are the values reported as output data in this report. The data are published in two volumes--the first for unclassified and the second for classified information.

1.2 Both the output and the sensitivity of an explosive in the SSGT configuration depend upon the loading density. The usual practice to explore these dependencies is to load the acceptor explosive at five different densities. As a sort of "spin-off", density vs loading-pressure data are generated. These are useful in computing charge weights for specific dimensions during the design of detonators and leads. Often, the density vs loading-pressure data can be reduced to a very simple nomograph (Section 8.0).

1.3 The main objective of this report, however, is the presentation of steel-dent output data. We point out that the steel-dent output is not one of the more precise measurements of explosive performance. The standard deviation(s) can be expected to run from 3 to 6% of the mean (X), occasionally as high as 10%. It should be remembered that the SSGT configuration measures the output of a relatively long, highly-confined, bare-ended explosive charge with the explosive column in direct contact with the dent plate. Under such conditions, the performance might differ considerably from that of the same explosive in a small, light-walled explosive component.

*For some explosives the indentations observed for "go's", when the input stimulus is not greatly higher than the 50% response level, are appreciably less than when initiated at zero gap.

1.4 Nonetheless, we have found output data valuable in characterizing explosives and comparing candidates for use in particular explosive systems. Also, output data are used to establish accept/reject criteria in specifications for new high-performance high-temperature explosives.

1.5 The following sections will describe in detail the experimental, statistical, and data-reduction techniques used. We have tried to "squeeze out" as much as there is in the information. We have attempted a realistic study of the sources and magnitude of errors in our determinations.

2. TEST PROCEDURES AND ARRANGEMENT

2.1 The test arrangement used to measure the output of the explosives is shown in Figure 1. This arrangement is identical to the SSGT arrangement, except that the lucite barrier used to attenuate the donor shock is omitted.

2.2 To minimize scatter, five shots were made at each loading pressure to give a total of 25 test shots for each explosive. The depths of the resulting dents were measured using the equipment specified in MIL-STD-331, Test 301.1. The dial indicator is set at zero when the probe is at lowest point in the dent cavity. Then the probe is removed from the cavity and four depth-of-dent readings are made, one on each edge of the block, approximately 90° apart. The average of these four readings is the observed depth of dent. From previous work*, it has been found that the depth of dent is a function of block hardness, and that this relationship is in accordance with the following empirical equation:

$$\delta_c = \delta_o + 0.67(H-83). \quad (1)$$

Where: δ_c is the corrected dent (mils)
H is the Rockwell block hardness on the B scale
δ_o is the observed dent (mils)

Hence, the observed data were corrected to reflect changes due to block hardness. This dent/hardness correction equation applies only for 1018-1020 steel and for a steel hardness range between 60-95 Rockwell B. In our tests, the steel dent blocks had hardnesses in the range of 80-90 Rockwell B.

2.3 Statistical data--the mean, ($\bar{\delta}$), and standard deviation, (s),--were calculated for each explosive at each density. This was done for the observed or uncorrected dent data, the corrected dent data, and for hardness of the blocks.

3. DISCUSSION AND ANALYSIS OF RESULTS

3.1 Previous work by Stresau and Slie[2] shows that for highly confined charges the following relationship exists between the depth

*NOLTR 71-137, 8 Sep 1971, (Task, Explosive Initiation and Safety; pp C-3 to C-16), L. A. Roslund, "Chemistry and Explosives Research Departments Technical Progress Reports on Explosives Research", 1 Apr - 30 Jun 1971, Conf of dent and detonation velocity

$$\frac{\delta}{r_c} = k_2 \rho_c D_c \left(D - \frac{S_1}{\rho_o D}\right) \tag{2}$$

Where: δ = depth of dent
r_c = radius of the charge
ρ_c = density of confining material
D_c = shock velocity in the confining medium
D = detonation velocity
ρ_o = density of pressed explosive
S_1 = elastic limit of the steel block divided by a constant
k_2 = constant

3.2 It can be seen from a plot of the Stresau-Slie data (Figure 2) that for the explosives tested (PETN, RDX, Tetryl, TNT) the depth of dent varies nearly linearly with detonation velocity (See the experimental line, Figure 2) for the following conditions:

a. the radius of explosive charge is 0.075 or greater
b. the explosives are the C-H-N-O type
c. the detonation velocity of the explosive is 5000 m/sec or greater

3.3 Hence, a linear equation can be obtained for the experimental curve line, and this depth of dent/detonation velocity relationship would be:

$$\delta = K_1 (D - 2.15) \tag{3}$$

Where: δ = depth of dent (mils)
D = detonation velocity of the explosive (mm/sec)
K_1 = proportionality constant estimated from experimental data

3.4 In the test arrangement used within to measure the steel dent output of the explosive, the conditions mentioned above were met. That is, the 0.2 diameter explosive column was highly confined in a 1.0 diameter brass sleeve, the explosive column radius of 0.1 was greater than the 0.075 R minimum stated, and all the explosives tested (except Lead Azide) were the C-H-N-O type. In addition, the detonation velocity of these explosives is probably greater than the 5000 m/sec at the minimum test density. Hence, the detonation velocity/depth of dent equation given above in (3) is assumed valid; and will be used to assess the steel dent output properties of the explosives.

3.5 Also, reference 3 shows that the detonation velocity of an explosive varies linearly with the density as follows:

$$D = G\rho + F \tag{4}$$

Where: D = detonation velocity (mm/μsec)
ρ = density of the explosive (gm/cm^3)

and F and G are explosive constants. Substitution of "$G\rho + F$", for D in Equation (3) gives

$$\delta = k_1 \ (G\rho + F-2.15) \qquad (5)$$

3.6 For the explosives listed in Table 2 or Table 3, the largest F value observed is for RDX and is 2.44*, (Lead Azide is not a C-H-N-O explosive), and the smallest observed values are 1.85* and 1.86* for TNT and PETN. Hence, the quantity (F-2.15) of Equation (5) falls inside the band of $-0.30<|F-2.15|<0.29$. This quantity (F-2.15) is at most 10% of the G value observed (see Table 2) for the same explosive. If we assume that the quantity F-2.15 = 0, then, the error will be no greater than 10%, and Equation (5) can be reduced to:

$$\delta = k_1 G\rho \qquad (6a)$$

or for any one explosive $\qquad \delta = k_2\rho \qquad$ (6b)

Where: δ = depth of dent (mils)
ρ = density of the explosive (gm/cm^3)
k_2 = portionality constant estimated from experimental data

3.7 Hence, one can conclude that the depth of dent for an explosive varies nearly linearly with the density of the explosive, and the line describing this relationship passes through the origin (0,0).

3.8 Since the depth of dent should vary linearly with explosive density, one can apply least squares fits to the data. In addition, since b, the y intercept is zero, the point (0,0) can be used as a point in a least squares fit of the explosive density/depth of dent data.

3.9 The depth of dent (corrected) - density data obtained for each explosive are tabulated and are shown graphically in Tables 4 to 30. Also shown are the least squares fit of the plotted data. In most cases, the depth of dent - density data fit the least squares line rather well.

4.0 DATA COLLECTION

4.1 Normally, in conducting the SSGT Test one hardness measurement is made on each block prior to testing, and the set of four dent readings is averaged for each explosion on each block. However, as the program progressed and the raw data were collected, it was noted that there were large variations in the depth of dents. Investigations revealed that the dent measurements varied with the individual operator. To study this effect, the depth of dent measurements were repeated. Unfortunately only one-third of the steel dent blocks were retrievable, but this number was sufficient to illustrate the dispersion that exists in the depth of dent measurement. The analysis of these data will be given later in paragraph 7.1.

*Average of cited literature values.

4.2 In addition, the block hardness measurement value is also a variable. For example, four independent block hardness measurements were made on 25 blocks (see Table 31), and the block hardness values obtained varied by as much as 5%. This measurement variation can be attributed to the following:

a. true hardness variations in the block
b. the operator's procedure in measuring the block hardness.

These factors were lumped together, and the total variation was called the block error. It has been decided that henceforth output measurements would require two independent block hardness values and two independent depth of dent measurements. In this way, the scatter in the dent data due to different operators would be reduced. Repeating measurements has in most cases reduced the observed dent scatter and has made the corrected dent data fit more closely the linear line as determined by the least squares fit.

5.0 ANALYSIS OF VARIANCE

5.1 For some explosives (see Table 32), the depth of dent and the block hardness measurements were repeated. An analysis of variance[4] (ANOVA) was applied to these data to test whether or not operator and block error produced significantly different results in the variable being tested. The data fit a two-way classification between the block error and the operator with one depth of dent observation per cell. The following mathematical model can be set up:

$$x_{ij} = \bar{x} + B'_j + C'_i + z_{ij}$$

Where: $\bar{x}$ = general mean of all data
B'_j = bias of the j factor (block)
C'_i = bias of the i factor (operator)
z_{ij} = random error
i = no. of operator, and $i \to a$, a = 3
j = no. of blocks, and $j \to b$, b = 5

Each combination of i and j determines a cell, and the total number of cells equals $a \cdot b$ or 15. To analyze the effects of any factor on a given variable, the following information was necessary:

$$\sum_i \sum_j x_{ij}^2 - \frac{T^2}{N} \qquad (7)$$

where: x = any given observation
i and j = the cells as $i \to a$ and $j \to b$ (for our problem a = 3 and b = 5)
$T = \Sigma x_{ij}$
$N = i \cdot j$ as $i \to a$, $j \to b$

$$\sum_{j} \left[\frac{(T_j)^2}{n_j}\right] \cdot \frac{T^2}{N} \qquad (8)$$

where: T_j = sum of each i factor for each j as j→b
n_j = no. of j factors

$$\sum_{i} \left[\frac{(T_i)^2}{n_i}\right] \cdot \frac{T^2}{N} \qquad (9)$$

where: T_i = sum of each j factor for each i as i→a
n_i = no. of i factors

The residual or random error, Z_{ij}, is then equal to total error (Equation (7)) minus the sum of block mean squares (Equation (8)) and the operator mean squares (Equation (9)). (See Tables 33-35.)

5.2 When each of these sums of squares is divided by the appropriate degrees of freedom, the quotient represents the mean square and is the unbiased estimate of the population variance. The resulting F* values from the data are compared to the F_α value from the F distribution at an assumed significance level (for our case we assumed 95%) for the degrees of freedom involved. If F-calculated is less than the book value of F_α, then there is no significant difference in the variable being tested. If F-calculated is greater than F_α, then the variable being examined is significantly different.

5.3 This analysis was done for three different explosives at one pressure. Inspection of Tables 33-35 shows that in two of three cases the value of F-calculated for operator effect exceeded the $F_{.05}$ (95% level of significance) and, hence, one can deduce that there is an operator effect. In addition, for block effect, the calculated F also exceeded the measured $F_{.05}$ in two cases out of three, and thus there probably is also a block error effect.

6.0 DISCUSSION OF RESULTS

6.1 A linear equation was obtained by applying the least squares fit to the depth of dent - density data of the explosives for the following data groupings:

*The F value obtained here is not the same as the F term of the previous equation (see section 3.5) which was a constant for the explosive. The F value calculated here is obtained by dividing the source mean square by the mean square of the random error.

(i) For the average of the Group I data. (These data were the original data, and have only one block hardness and depth of dent measurement.)

(ii) For the average of Groups I, II, and III data. (Each group is by a different operator, and each has a block hardness and depth of dent measurement.)

For each grouping (see (i) and (ii) above), the least square fit was applied to the five depths of dent (corrected for block hardness differences) - density points, and the point (0,0). The resulting linear equations are given in Table 36.

6.2 Comparison of these linear functions for the two groups shows that the slopes (m) are similar, and that in the worst case (see results of Comp B) agreed to within 3% of one another. The y intercept (b) is, of course, more random.

6.3 There is a minimum density below which dents will not occur because the explosion pressure will be insufficient to overcome the strength of the steel block. One should be aware of this and thus should use the data below the density listed at 4 kpsi only with caution.

6.4 As a first approximation, the output dent for a given explosive can be predicted by use of the following relationship:

$$\text{Dent} = k\rho$$

where: k is the slope of the least square fit line (see Table 36)
ρ is the density (gm/cm^3) of the explosive

The y intercept term is omitted, but this intercept value is normally less than 0.5 mils, and the expected error in the predicted dent will be less than 5%. The largest y intercept value calculated is 2.6, (see TACOT-T; Table 36) and even for this explosive the error is only approximately 8%.

7.0 STEEL DENT OUTPUT OF CAST EXPLOSIVES

7.1 The steel dent output of six cast explosives (same as six of the pressed explosives previously tested) were measured. The explosives and their steel dent outputs are given in Table 37. In addition, these values are also given on the tables showing the output test results of the same explosives pressed into the acceptor body. The density of some of these cast explosives in the brass acceptor body varied considerably. This variation in the density was probably due to voids in the explosives caused by pouring the molten explosive into the relatively small acceptor cavity. The acceptor bodies were heated to approximately 150°F to minimize this. The cast bodies were divided into various density groupings. All units were fired, but the output dent ($\overline{\delta}$) was based on the acceptor pieces which had reasonable and uniform explosive densities. Of the cast explosives, the steel dent output of TNT was variable, even though the densities were uniform.

8.0 LOADING PRESSURE/DENSITY RELATIONSHIP

8.1 In designing explosive components it is often desirable to know the density of an explosive for a particular loading pressure. For each explosive, (See Tables 4 to 30) a graph of explosive density as a function of loading pressure can be constructed. As an example, such a graph was constructed for two explosives; PETN and HNS-II (see Figure 3). A simple nomograph can be used to present density/pressure data in a very compact and handy form (Figure 4). The nomograph is applicable at loading pressures in the range of 4,000 to 32,000 psi. Below 32,000 psi the pressure/density relationship fits very well the linear relationship[8] (see Figure 3) of

$$\rho = A \log \frac{P}{1000} + B$$

where: ρ = density of the explosive (gm/cm^3)
P = consolidation pressure (kpsi)
A and B = constant for the explosive.

At consolidation pressures above 32,000 psi, where the density of the explosive being pressed is approaching the theoretical maximum density, the logarithmic plot is no longer linear.

8.2 The nomographs were constructed by estimating the intersection of the four lines one gets when one matches the loading pressure (4, 8, 16 and 32 kpsi) with the calculated density (gm/cm^3).

8.3 By using different density scales, the point that represents the intersection of the four lines is constructed on the scale that minimizes line intersection scatter. The estimate of the density for a particular loading pressure was generally well within 5% of the observed data given within.

9.0 CONCLUSIONS

9.1 The steel dent output has been determined for a number of explosives. The data show that the density - depth of dent data collected for the explosives fit, in most cases, a linear relationship. Since the minimum density required to produce a steel dent was not determined, one should use with caution the steel dent data at densities lower than those obtained at consolidation pressures of 4 kpsi.

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Table 1

Explosives Tested for Steel Dent Output

Explosive	Table Number	Remarks
Lead Azide (Dex.)	4	
Nitromannite	5	
PETN	6	
RDX	7	
CH-6	8	
Tetryl	9	
Tetryl/Graphite	10	
HMX	11	
PBXN-5	12	
HNS-I	13	
HNS-II	14	
HNS-II/Tef (95/5)	15	
HNS-II/Tef (90/10)	16	
DIPAM	17	
DATB	18	
TATB	19	
TACOT-T	20	
KHND	21	
Octol (75/25)	22	Pressed and Cast
Octol (65/35)	23	Pressed and Cast
Pentolite (50/50)	24	Pressed and Cast
TNT	25	Pressed and Cast
Comp-B	26	Pressed and Cast
TNB	27	
TNETB	28	
Nitroguanidine (LBD)	29	Low Bulk Density
Nitroguanidine (HBD)	30	High Bulk Density
NONA		Classified, see Vol 2. Table 2
ONT		Classified, see Vol 2. Table 3
ABH-I		Classified, see Vol 2. Table 4
ABH-II		Classified, see Vol 2. Table 5
TPT		Classified, see Vol 2. Table 6
HNAB		Classified, see Vol 2. Table 7
PBXN-4		Classified, see Vol 2. Table 8

Table 2

Some F and G Values for Common Explosive

	F			G		
	Cook[5]	Fickett and Cowan[6]	Dunkle[7]	Cook	Fickett and Cowan	Dunkle
TNT	1.78	2.36	1.30	3.23	2.80	3.50
PETN	1.60		2.12	3.95		3.50
RDX	2.49	2.51	2.33		3.46	3.57
Tetryl	2.37			3.25		
Lead Azide	2.86			0.56		

$$D = F + G\rho$$

D = detonation velocity (mm/μsec)
ρ = density of the explosive (gm/cm^3)
F and G are constants

Table 3

Some F and G Values Calculated for
Several Heat Resistant Explosives

	F [(1)]	G [(1)]
HNS-I	2.15	2.93
DIPAM	2.03	3.05
HNS-R/Teflon 95/5	1.85	3.0

(1) Calculations based on detonation velocity values of explosive listed in NOLTR 66-94, E. E. Kilmer, "Annual Report On Investigation of High and Low Temperature Resistance Explosive Devices", Unclas, 24 Aug 1966, Conf

EXPLOSIVE	Lead Azide (PbN_6), Dextrinated	X NO.	Lot #2
TMD	4.38 gm/cm^3	I. D. NO.	1072

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	2.549	0.0257	33.2	3.51	32.7	3.75	32.9	1.98	32.3	2.33	82.3	0.47
8,000	2.792	0.0190	36.2	1.54	35.9	1.83	37.0	1.15	35.0	1.54	82.6	0.64
16,000	3.012	0.0323	44.9	1.71	44.5	1.59	42.4	1.39	41.6	1.60	82.5	0.60
32,000	3.332	0.0171	43.9	1.36	43.2	1.95	45.0	0.85	44.3	1.28	81.9	1.73
64,000	3.664	0.0024	51.3	2.54	50.5	3.10	49.4	1.68	48.6	2.17	81.9	0.96

NOTES: (1) **Dextrinated Lead Azide is not a C-H-N-O explosive, hence the line drawn is an eye-fitted line and not a least squares line.**

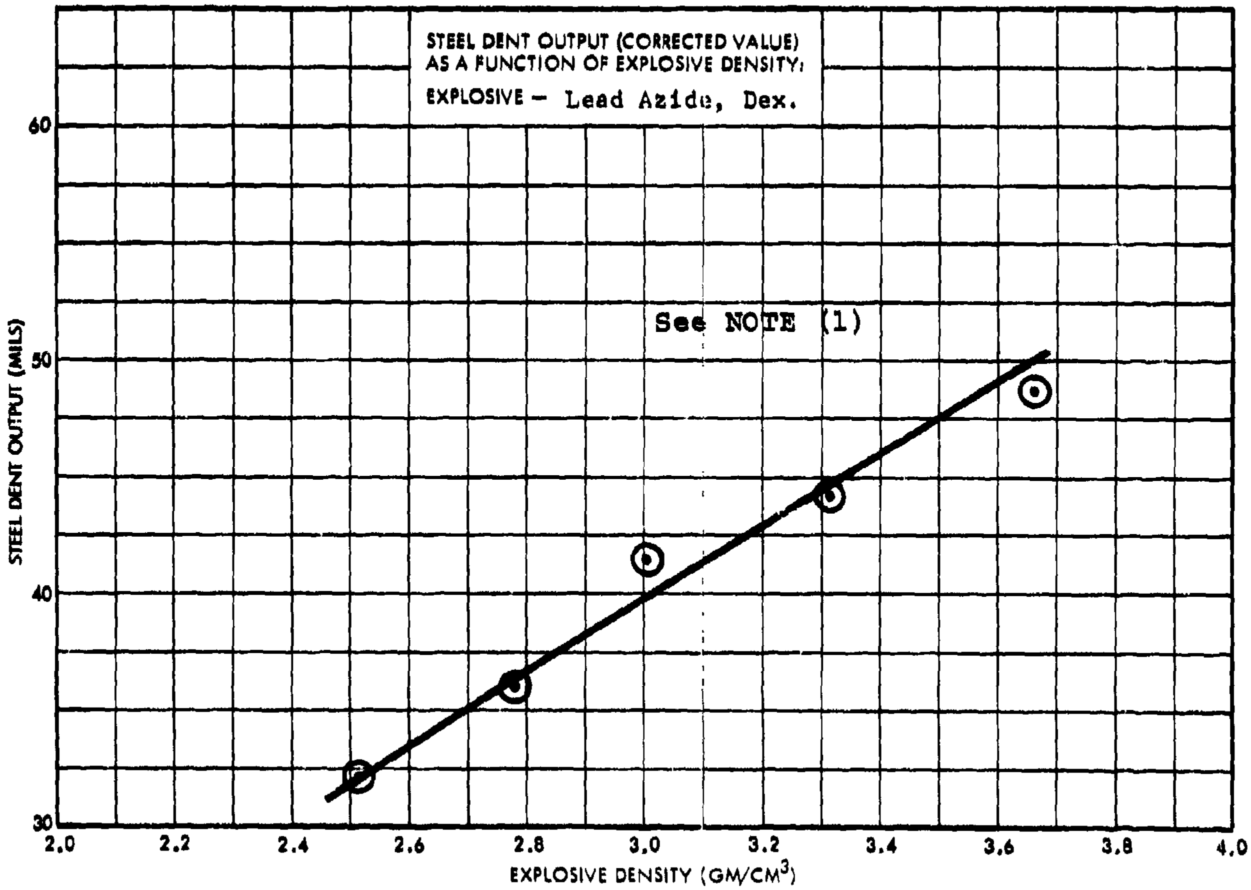


TABLE 4 STEEL DENT OUTPUT DATA FOR Lead Azide (Dex)

EXPLOSIVE	Nitromannite	X NO.	601
TMD	1.73 gm/cm^3	I. D. NO.	311

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.315	0.0037	48.8	1.63	48.0	1.92	48.4	1.19	47.8	1.62	81.8	0.92
8,000	1.504	0.0030	59.9	2.13	59.3	2.54	57.7	3.27	57.0	3.55	82.1	1.43
16,000	1.645	0.0021	63.3	2.05	62.3	2.62	65.6	1.26	65.1	1.67	81.4	0.96
32,000	1.764	0.0039	64.3	2.00	63.7	2.06	67.7	1.75	66.7	1.54	82.1	0.55
64,000	1.809	0.0019	70.1	1.89	69.3	2.13	69.6	1.98	68.5	2.41	81.7	0.56

NOTES:

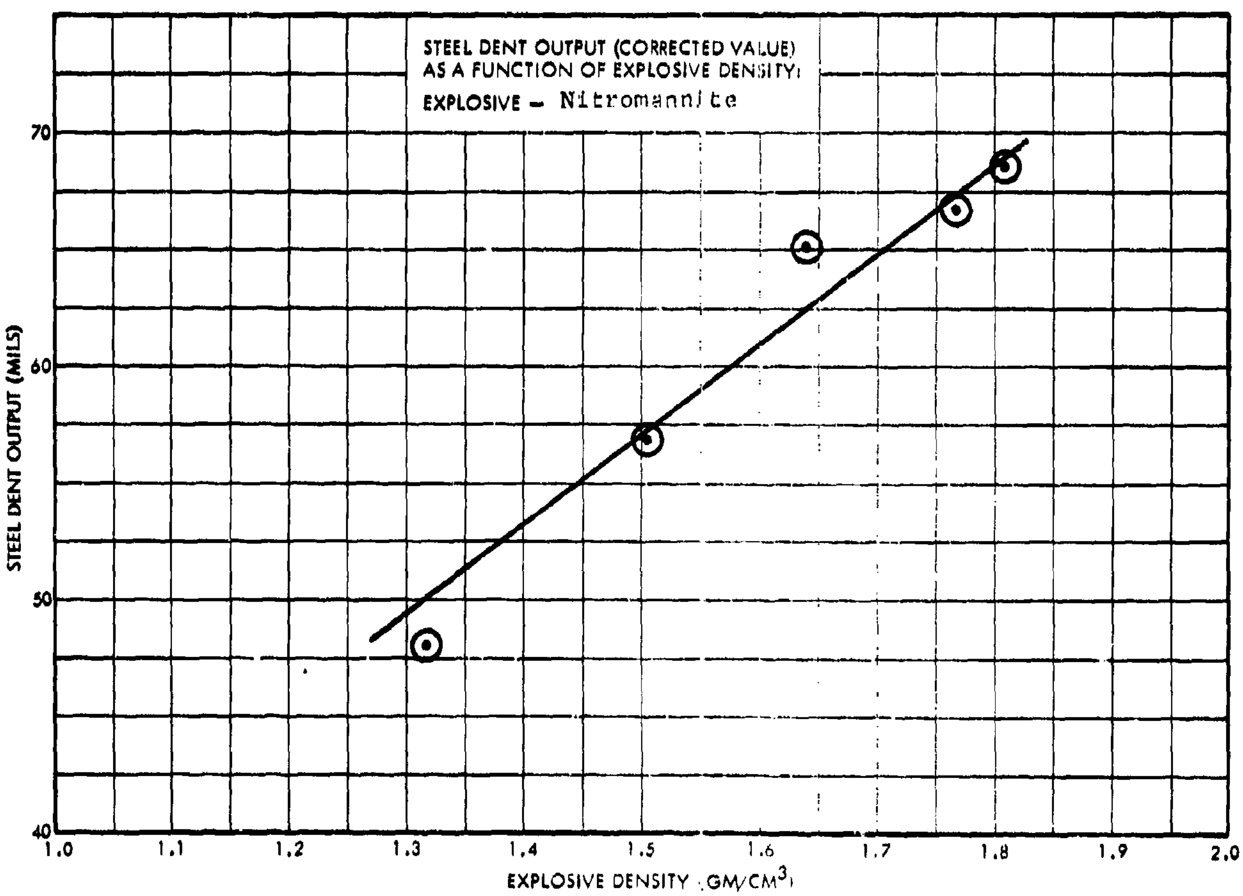


TABLE 5 STEEL DENT OUTPUT DATA FOR NITROMANNITE

EXPLOSIVE	PETN	X NO.	321
TMD	1.77 gm/cm³	I. D. NO.	85

LOADING PRESSURE (PSI)	DENSITY (GM/CM³)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.362	0.0034	53.2	1.84	55.3	1.92					86.1	1.20
8,000	1.492	0.0043	59.9	2.59	61.1	2.25					84.7	1.66
16,000	1.593	0.0124	63.5	1.71	63.2	3.65					82.6	4.60
32,000	1.702	0.0081	68.4	0.70	69.5	1.01					84.6	1.06
64,000	1.769	0.0079	74.0	2.87	75.1	2.74					84.6	1.21

NOTES:

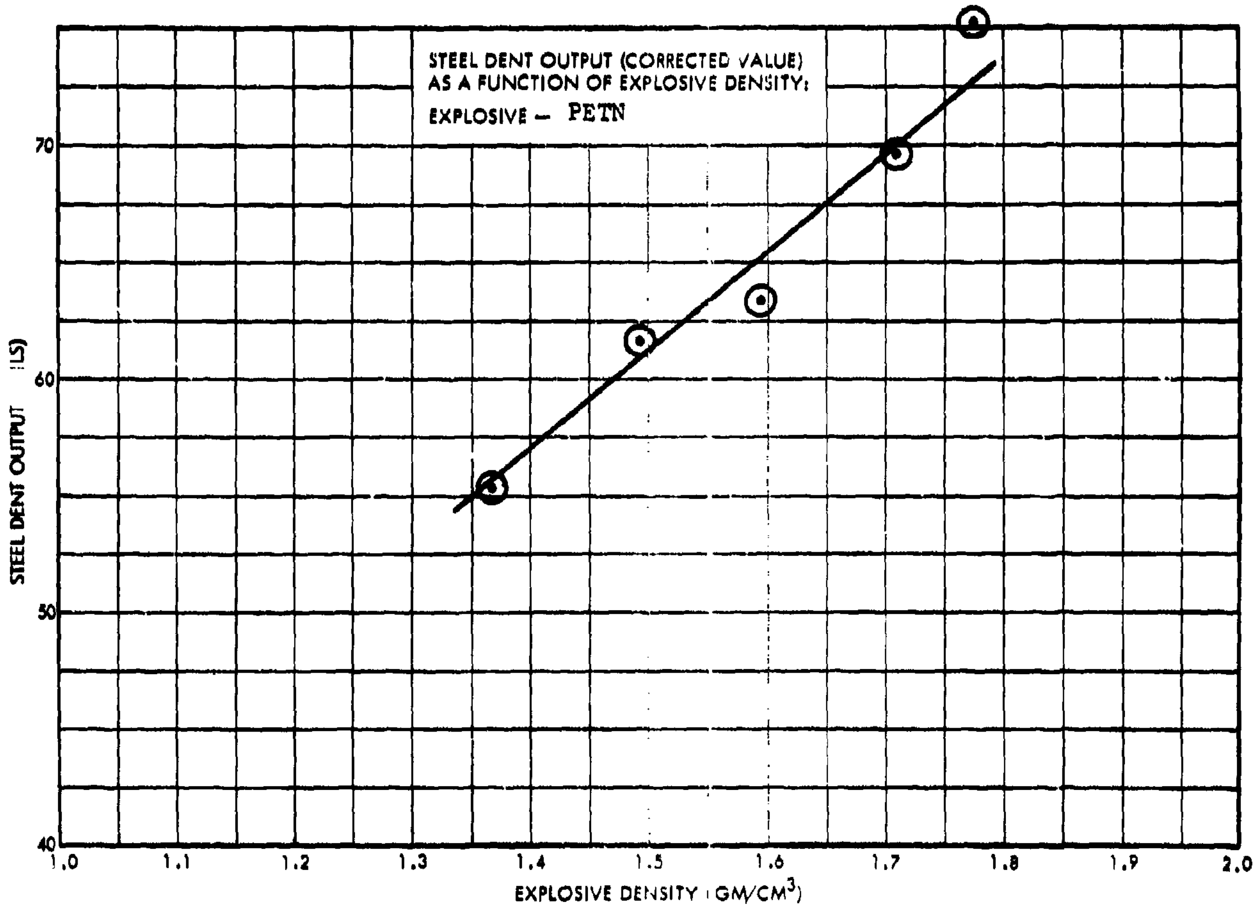


TABLE 6 STEEL DENT OUTPUT DATA FOR PETN

EXPLOSIVE	RDX	X NO.	334
TMD	1.82 gm/cm3	I. D. NO.	998

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.450	0.0060	59.5	1.58	61.4	0.92					85.8	1.10
8,000	1.553	0.0046	63.0	1.46	64.2	0.93					84.8	1.35
16,000	1.631	0.0056	65.1	1.04	66.7	1.03					85.5	1.22
32,000	1.714	0.0042	68.4	2.70	70.1	2.24					85.5	1.41
64,000	1.785	0.0005	70.8	3.03	71.8	2.65					84.5	1.41

NOTES:

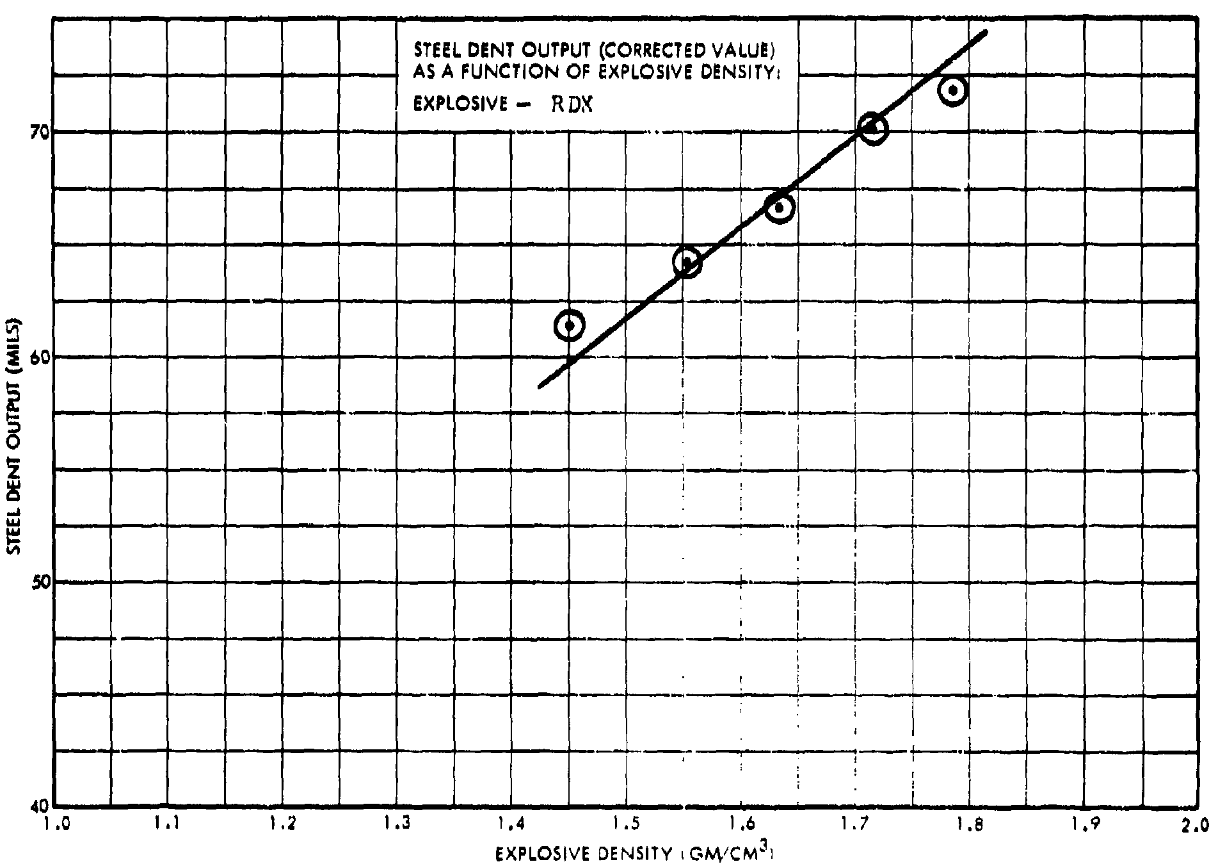


TABLE 7 STEEL DENT OUTPUT DATA FOR RDX

EXPLOSIVE	CH-6	X NO.	267
TMD	1.77 gm/cm^3	I. D. NO.	115

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.526	0.0067	60.9	0.88	61.5	0.96					84.0	1.23
8,000	1.611	0.0033	63.4	1.14	64.2	1.99					84.2	1.79
16,000	1.693	0.0018	67.6	1.81	68.4	1.66					84.1	0.82
32,000	1.744	0.0010	67.5	2.19	68.7	2.79					84.8	1.44
64,000	1.766	0.0017	69.2	2.83	70.7	2.16					85.3	1.07

NOTES:

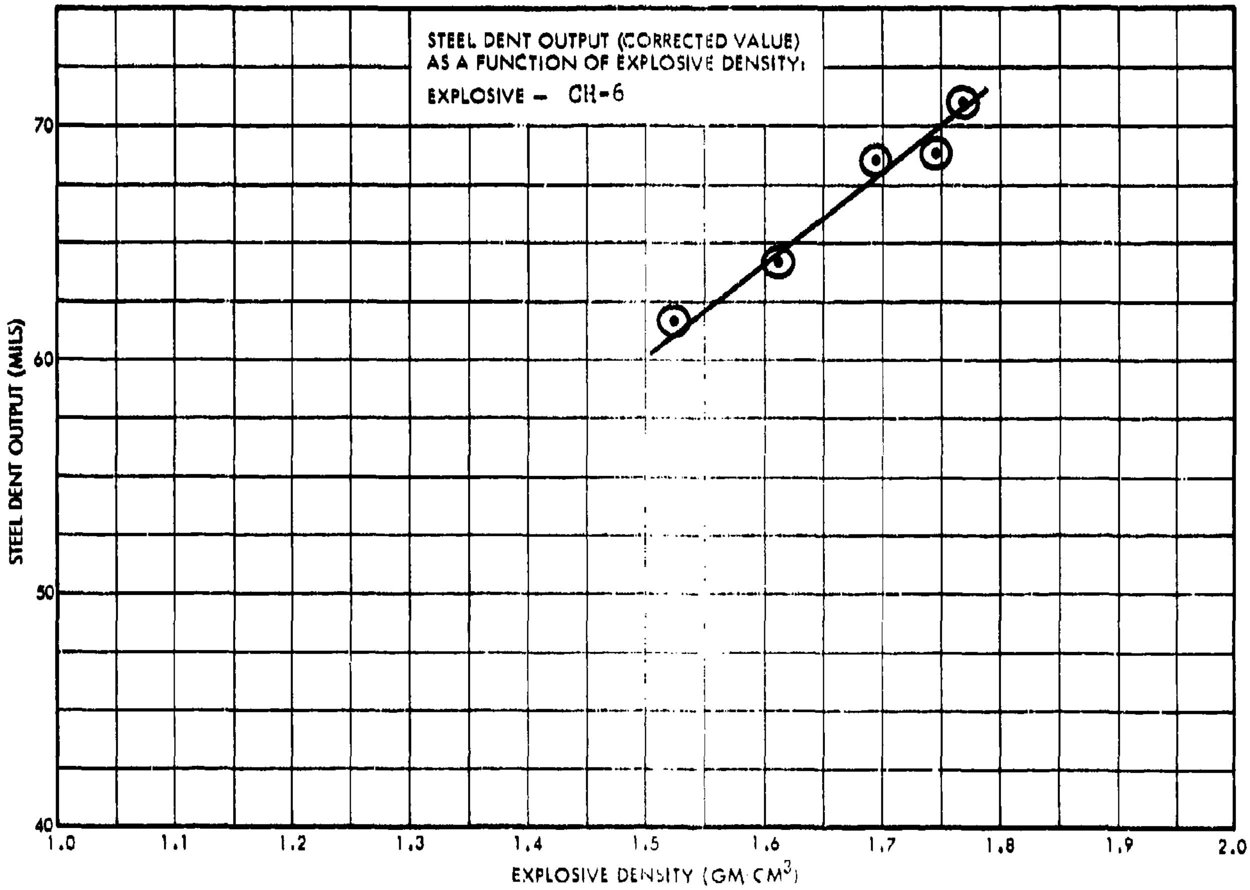


TABLE 8 STEEL DENT OUTPUT DATA FOR CH-6

EXPLOSIVE	Tetryl	X NO.	436
TMD	1.73 gm/cm³	I. D. NO.	1054

LOADING PRESSURE (PSI)	DENSITY (GM/CM³)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.432	0.0023	50.9	0.76	51.3	0.91					83.6	1.34
8,000	1.523	0.0050	53.2	2.60	54.3	2.42					84.7	1.10
16,000	1.607	0.0024	56.1	0.56	56.6	1.82					83.7	2.08
32,000	1.677	0.0023	63.6	1.99	64.4	1.81					84.2	1.89
64,000	1.732	0.0023	62.5	1.61	63.3	0.50					84.2	1.82

NOTES:

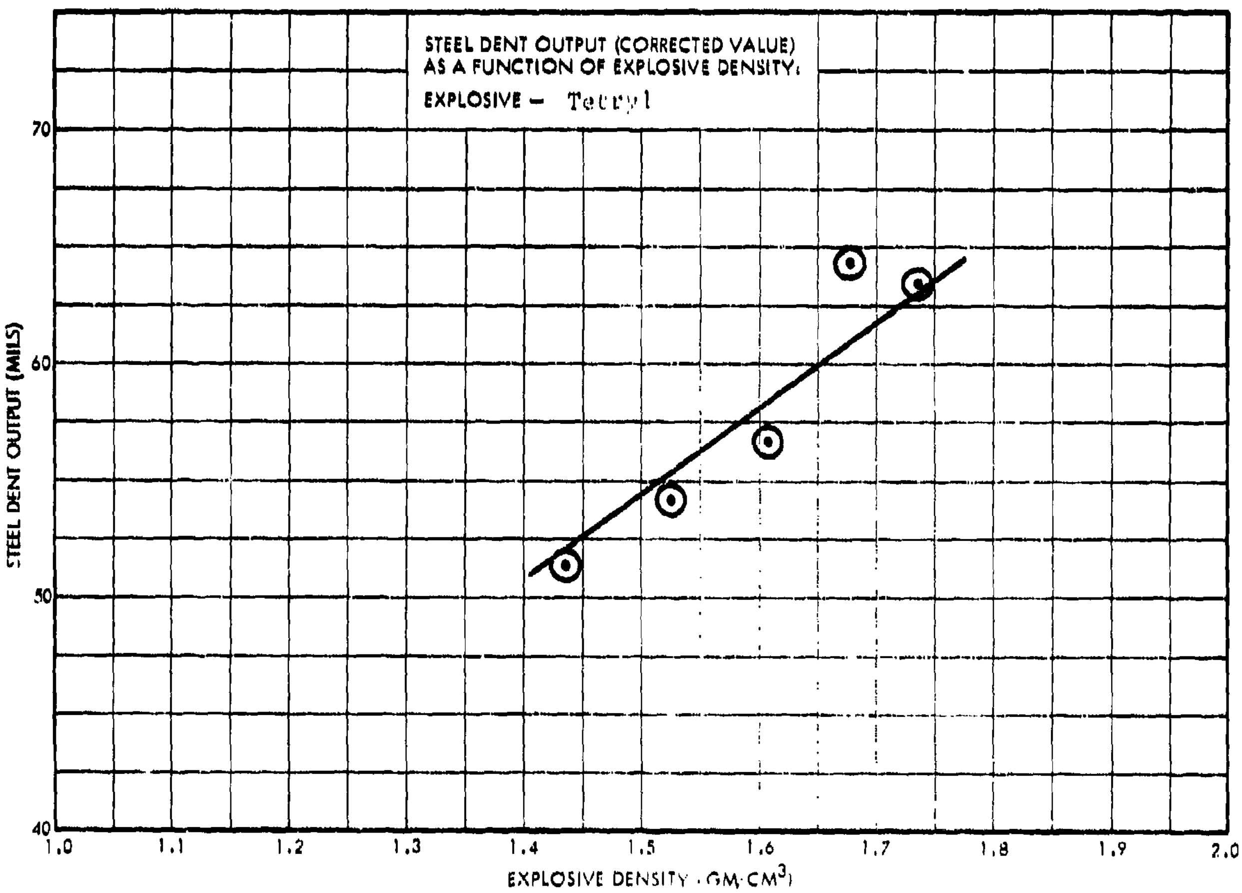


TABLE 9 STEEL DENT OUTPUT DATA FOR Tetryl

EXPLOSIVE	Tetryl/Graphited	X NO.	460
TMD	1.73 gm/cm^3	I. D. NO.	374

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.446	0.0042	52.6	1.99	54.1	1.67					85.2	0.57
8,000	1.531	0.0028	56.3	1.83	57.5	2.61					84.8	1.35
16,000	1.611	0.0022	58.9	1.09	59.9	1.63					84.6	1.14
32,000	1.691	0.0015	61.7	3.36	62.4	2.48					84.1	1.78
64,000	1.737	0.0018	61.8	2.04	63.1	2.08					85.0	1.23

NOTES:

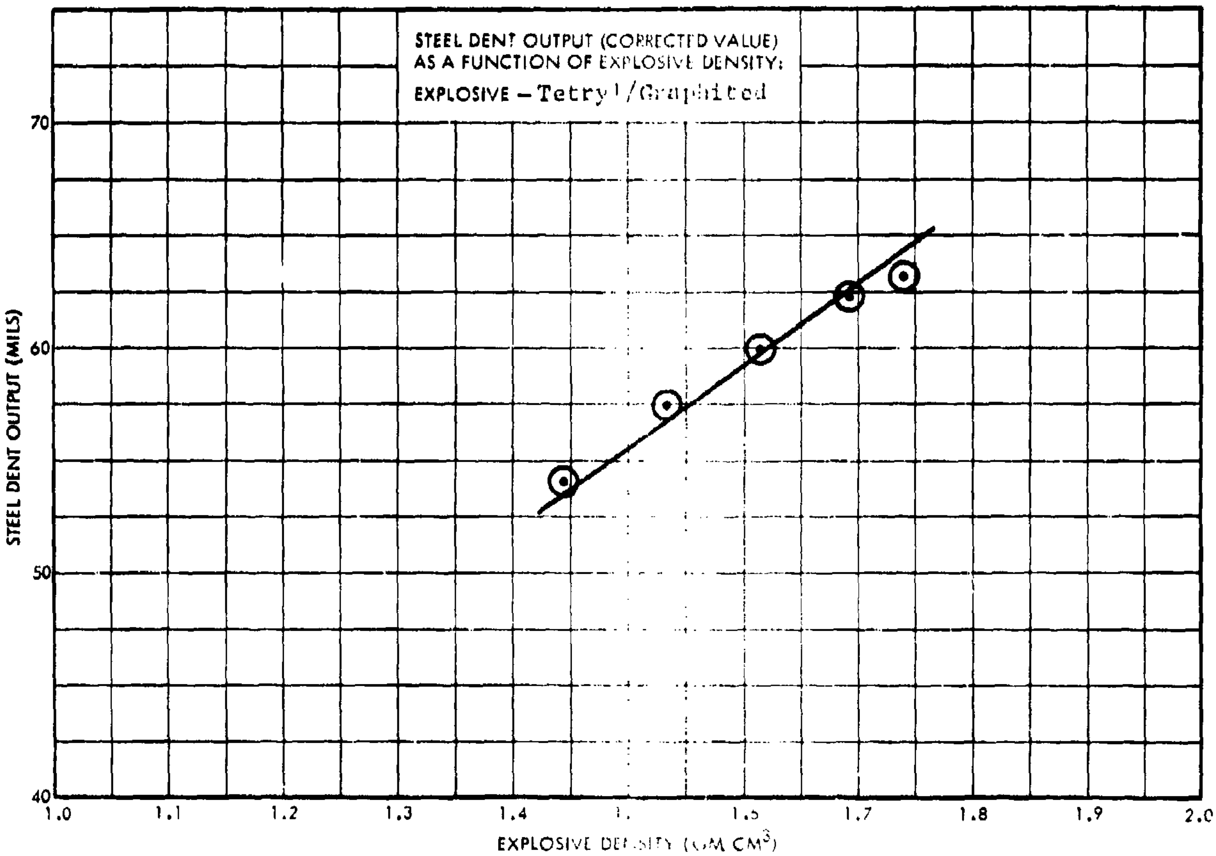


TABLE 10 STEEL DENT OUTPUT DATA FOR Tetryl/Graphited

EXPLOSIVE	HMX	X NO.	4[illegible]
TMD	1.90 gm/cm^3	I. D. NO.	439

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.473	0.0083	60.0	2.94	60.6	3.04					84.0	1.08
8,000	1.561	0.0062	64.6	4.12	64.7	4.56					83.1	0.79
16,000	1.661	0.0045	71.8	1.46	72.8	1.14					84.4	0.76
32,000	1.761	0.0031	66.9	4.44	68.6	4.14					85.5	1.83
64,000	1.841	0.0009	73.3	1.79	74.3	1.89					84.4	1.26

NOTES:

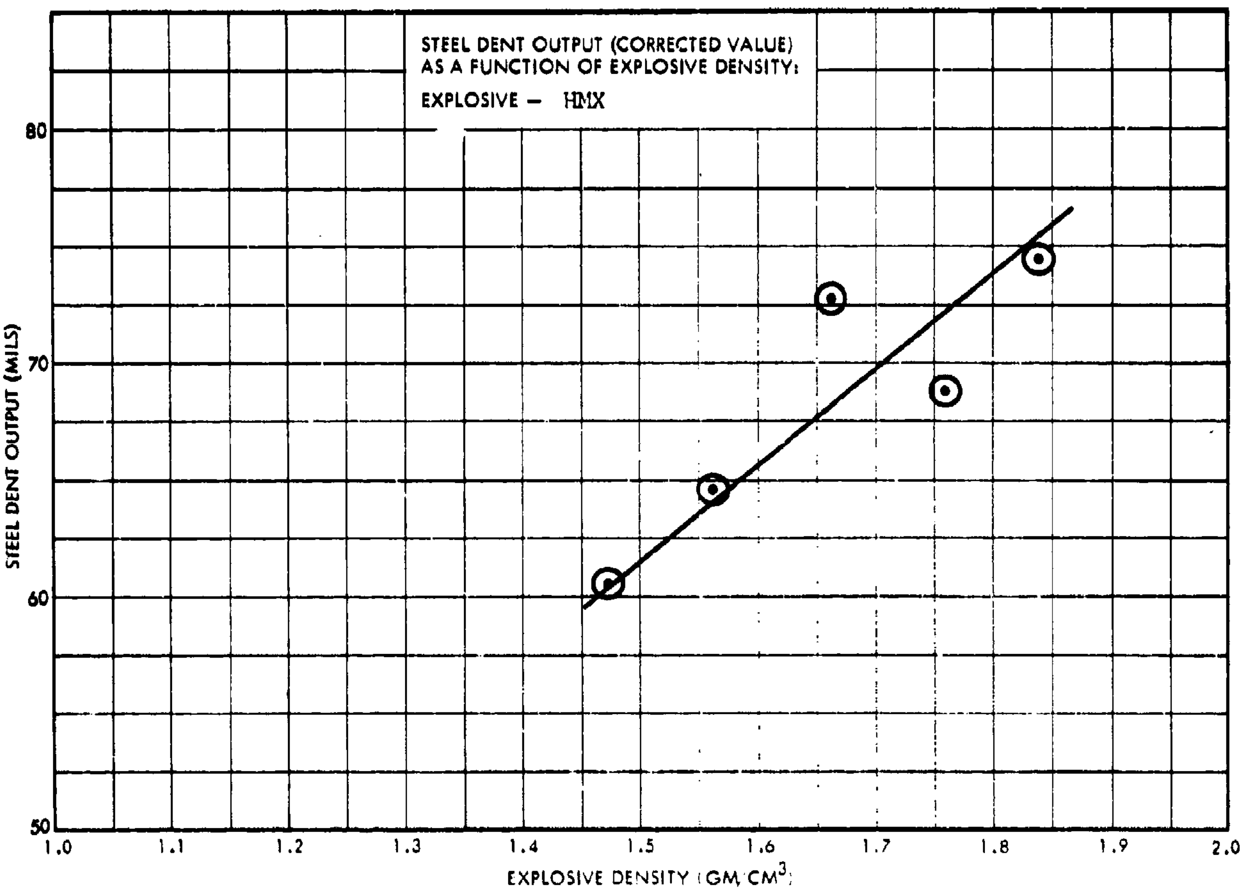


TABLE 11 STEEL DENT OUTPUT DATA FOR HMX

EXPLOSIVE	PBXN-5	X NO.	618
TMD	1.91 gm/cm^3	I. D. NO.	579

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.385	0.0074	56.4	1.01	58.4	1.14	56.3	1.26	57.6	1.48	86.0	1.14
8,000	1.465	0.0042	57.7	1.61	57.9	1.92	57.9	1.20	58.4	1.52	83.4	2.43
16,000	1.567	0.0072	61.5	2.67	62.4	3.15	61.0	2.31	61.6	2.64	84.3	0.77
32,000	1.709	0.0010	67.1	1.00	68.2	1.21	67.5	0.95	68.2	1.19	84.6	1.02
64,000	1.824	0.0024	72.3	4.81	73.3	5.23	72.1	4.62	72.8	4.69	84.5	2.28

NOTES:

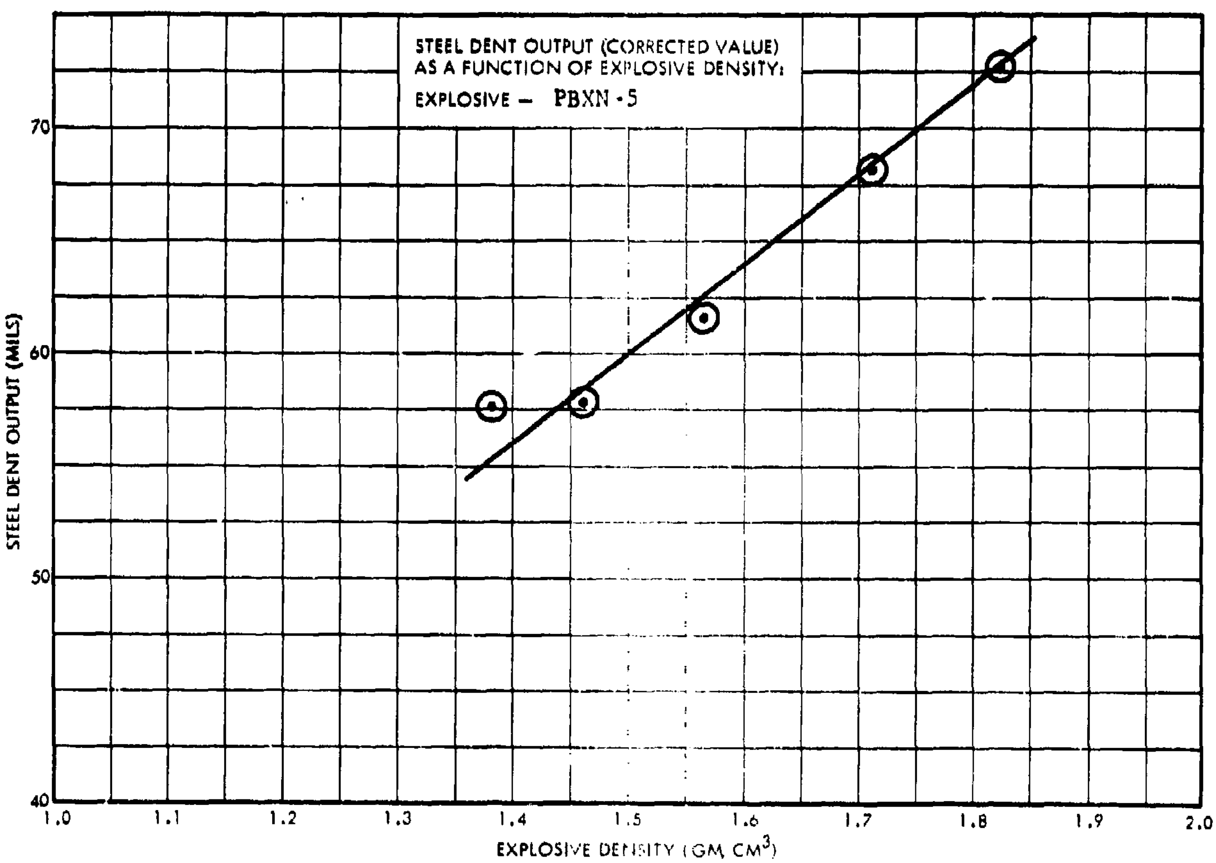


TABLE 12 STEEL DENT OUTPUT DATA FOR PBXN-5

EXPLOSIVE	HNS-I	X NO.	537
TMD	1.74 gm/cm³	I. D. NO.	714

LOADING PRESSURE (PSI)	DENSITY (GM/CM³)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.119	0.0069	38.5	1.81	40.5	0.97					86.0	1.87
8,000	1.260	0.0111	41.2	0.86	42.5	1.04					85.0	0.89
16,000	1.407	0.0042	48.5	0.98	49.7	1.35					84.8	0.56
32,000	1.560	0.0045	48.2	2.42	50.6	2.72					86.7	0.76
64,000	1.676	0.0013	55.2	1.67	57.1	2.02					85.8	1.97

NOTES:

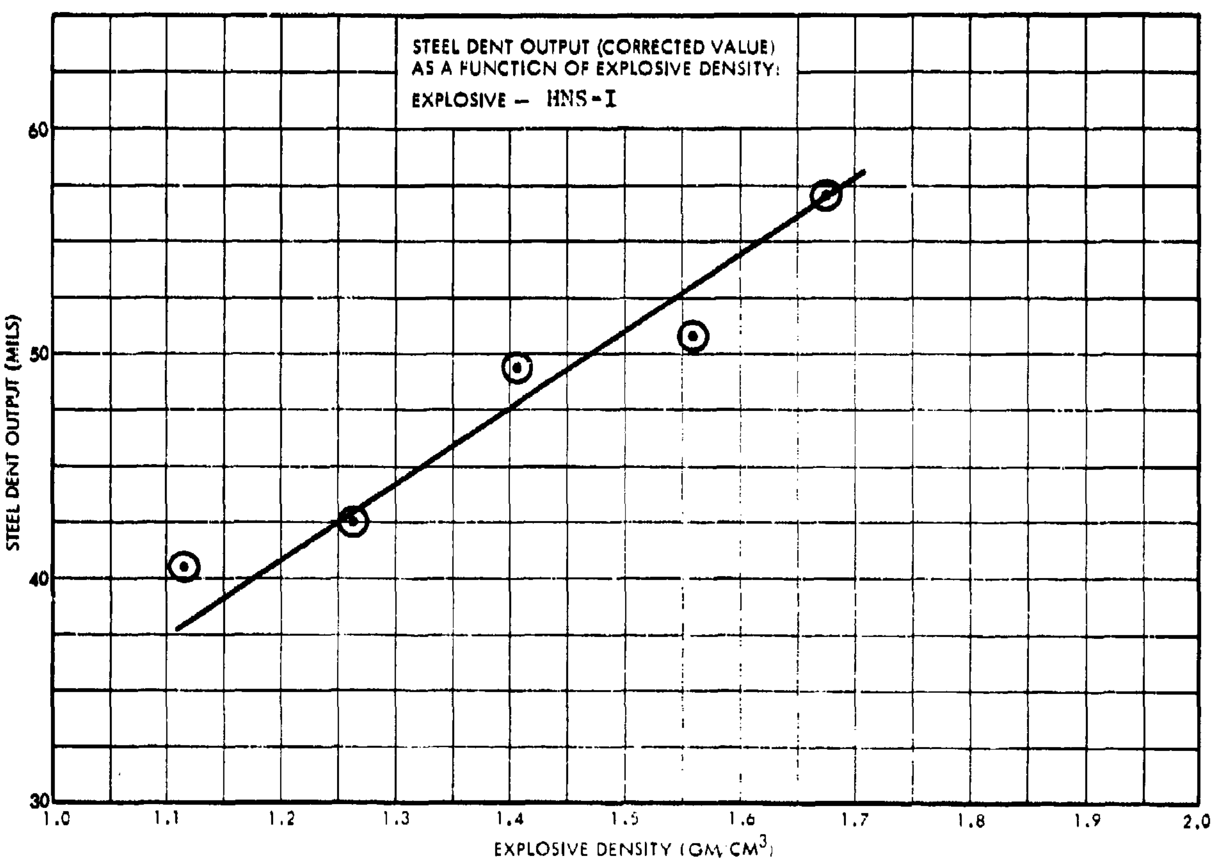


TABLE 13 STEEL DENT OUTPUT DATA FOR HNS-I

EXPLOSIVE	HNS-II	X NO.	567
TMD	1.74 gm/cm^3	I. D. NOS	30&165

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.332	0.0052	45.1	1.14	46.7	0.98					85.5	1.65
8,000	1.443	0.0064	45.1	2.05	46.0	1.44					84.3	1.98
16,000	1.554	0.0025	49.3	1.85	51.6	0.80					86.5	2.92
32,000	1.656	0.0005	54.7	1.28	56.4	1.57					85.5	1.51
64,000	1.723	0.0020	54.0	1.80	55.7	1.03					85.6	1.42

NOTES:

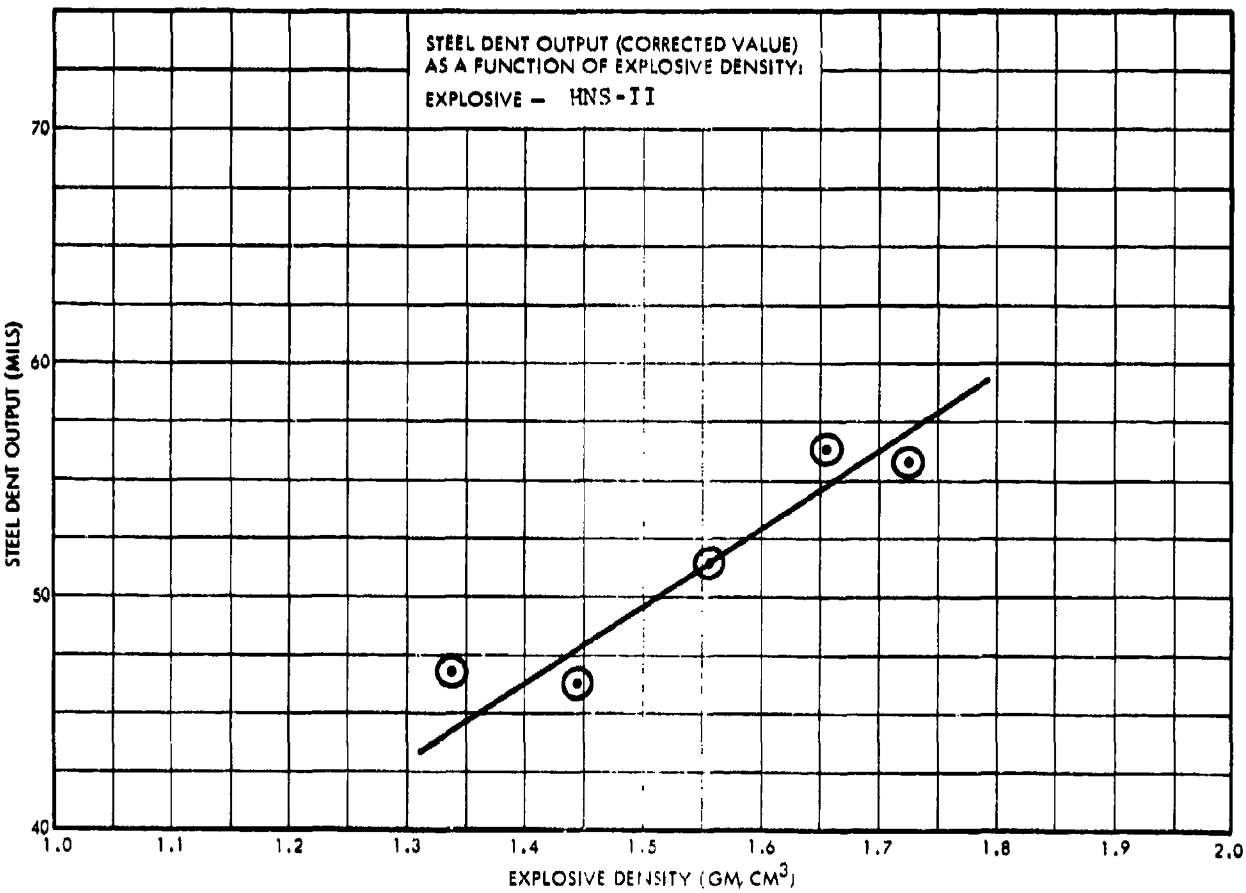


TABLE 14 STEEL DENT OUTPUT DATA FOR HNS-II

EXPLOSIVE	HNS-II/Teflon (95/5)	X NO.	526
TMD	1.76 gm/cm^3	I. D. NO.	212

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.263	0.0078	41.6	1.74	41.3	1.58	41.1	1.14	41.0	1.12	82.5	0.46
8,000	1.405	0.0058	42.8	1.54	42.7	1.85	44.4	0.97	44.3	1.11	82.8	1.04
16,000	1.521	0.0040	51.7	1.76	51.3	1.63	49.6	1.83	49.4	2.26	82.4	0.61
32,000	1.637	0.0025	50.9	1.88	50.4	2.27	51.7	1.29	51.2	1.50	82.2	1.10
64,000	1.715	0.0031	54.9	3.13	53.9	3.38	54.8	1.88	54.3	2.18	81.5	1.00

NOTES:

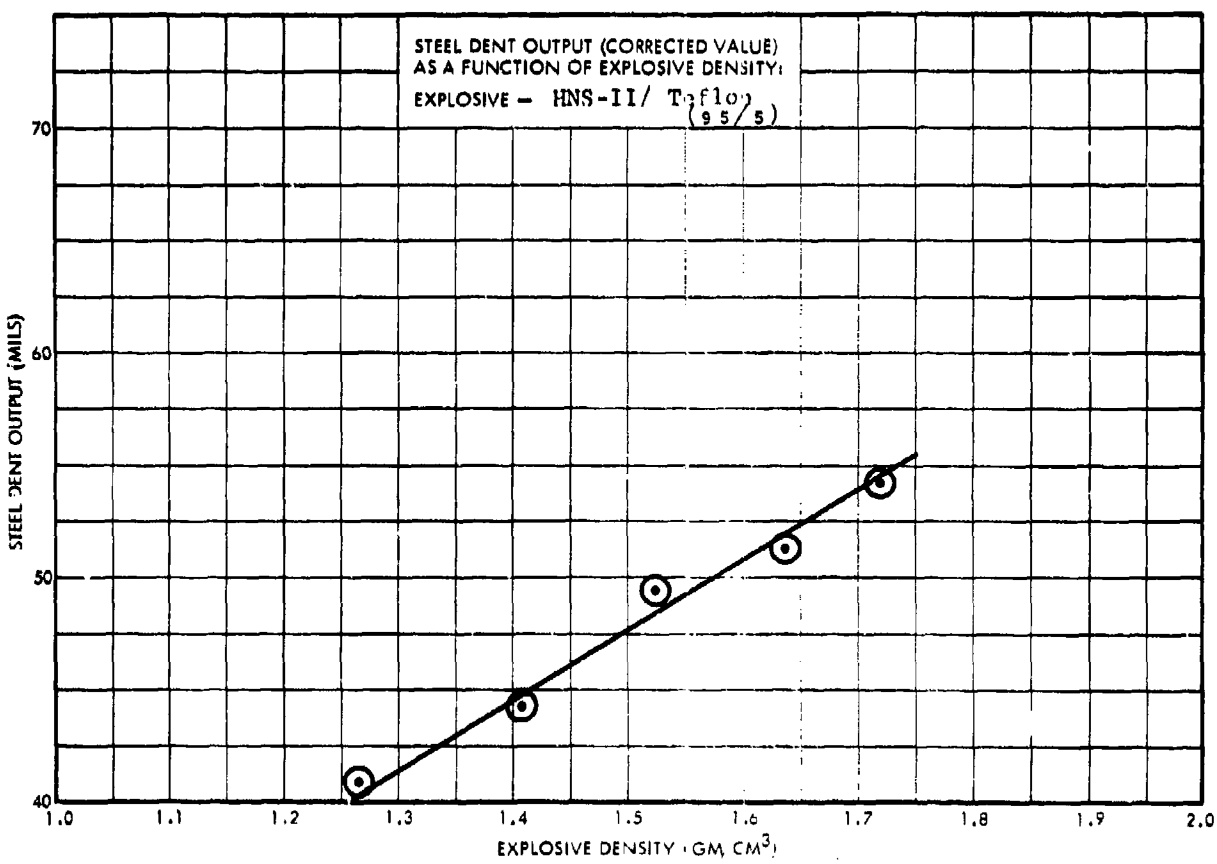


TABLE 15 STEEL DENT OUTPUT DATA FOR HNS-II/Teflon, (95/5)

EXPLOSIVE	HNS-II/Teflon (90/10)	X NO.	581
TMD	1.78 gm/cm^3	I. D. NO.	162

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.426	0.0054	42.6	3.47	42.8	3.24	43.6	2.19	43.4	2.23	83.2	1.26
8,000	1.527	0.0013	43.3	3.11	43.6	3.15	44.4	1.78	44.1	1.86	83.4	0.89
16,000	1.620	0.0039	50.9	2.51	50.3	2.72	49.2	1.94	48.3	1.92	82.0	0.95
32,000	1.700	0.0016	46.7	1.93	46.3	1.68	49.3	1.61	48.5	1.75	82.4	0.92
64,000	1.752	0.0032	52.2	1.99	51.7	2.59	51.6	1.43	50.2	2.09	82.3	1.04

NOTES:

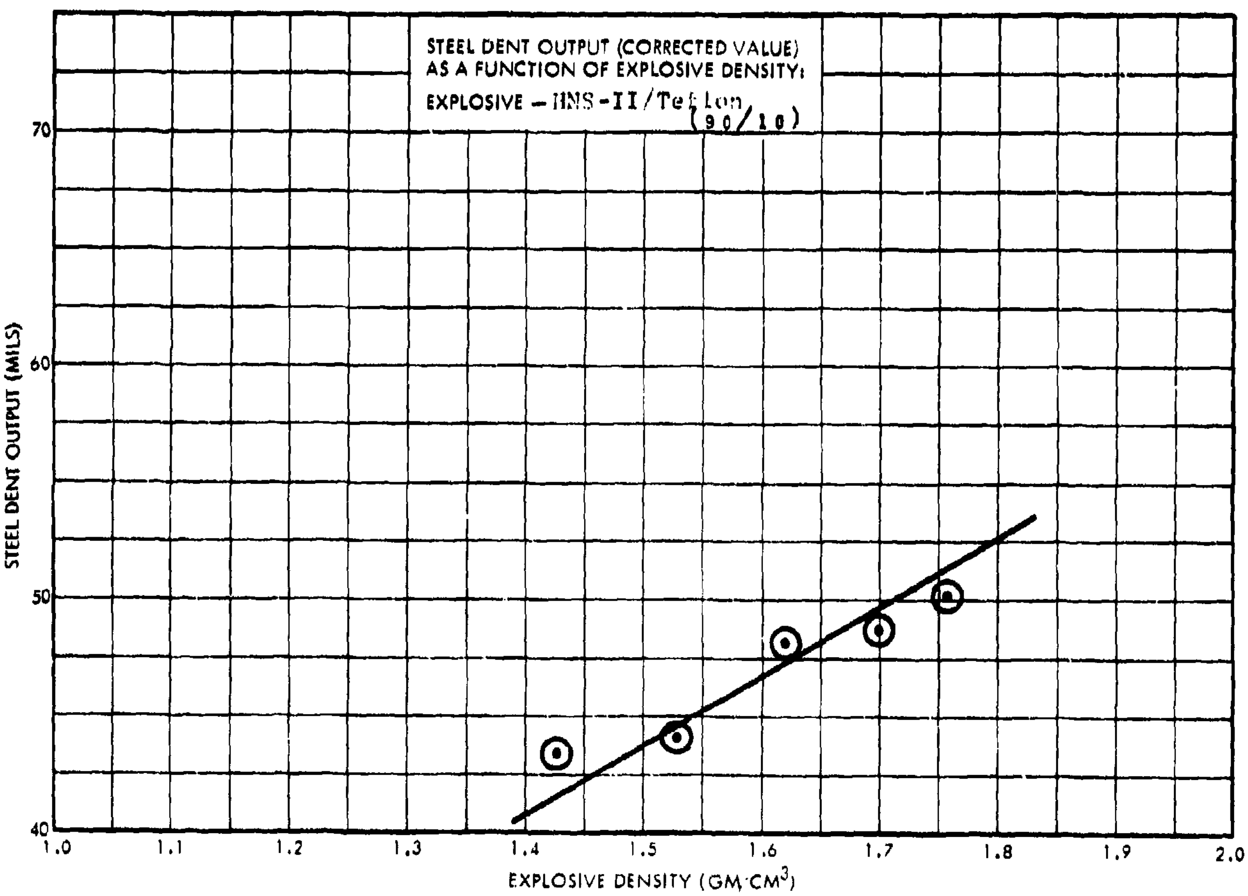


TABLE 16 STEEL DENT OUTPUT DATA FOR HNS-II/Teflon (90/10)

EXPLOSIVE	DIPAM	X NO.	549
TMD	1.79 gm/cm^3	I. D. NO.	223

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.231	0.0096	41.9	2.21	43.2	2.03					84.9	2.72
8,000	1.387	0.0108	45.4	1.25	46.0	1.39					84.0	2.13
16,000	1.503	0.0098	48.4	1.13	50.5	1.38					86.0	0.71
32,000	1.641	0.0042	55.9	1.86	58.1	1.58					86.4	1.94
64,000	1.779	0.0024	57.5	1.89	58.9	1.76					85.2	0.79

NOTES:

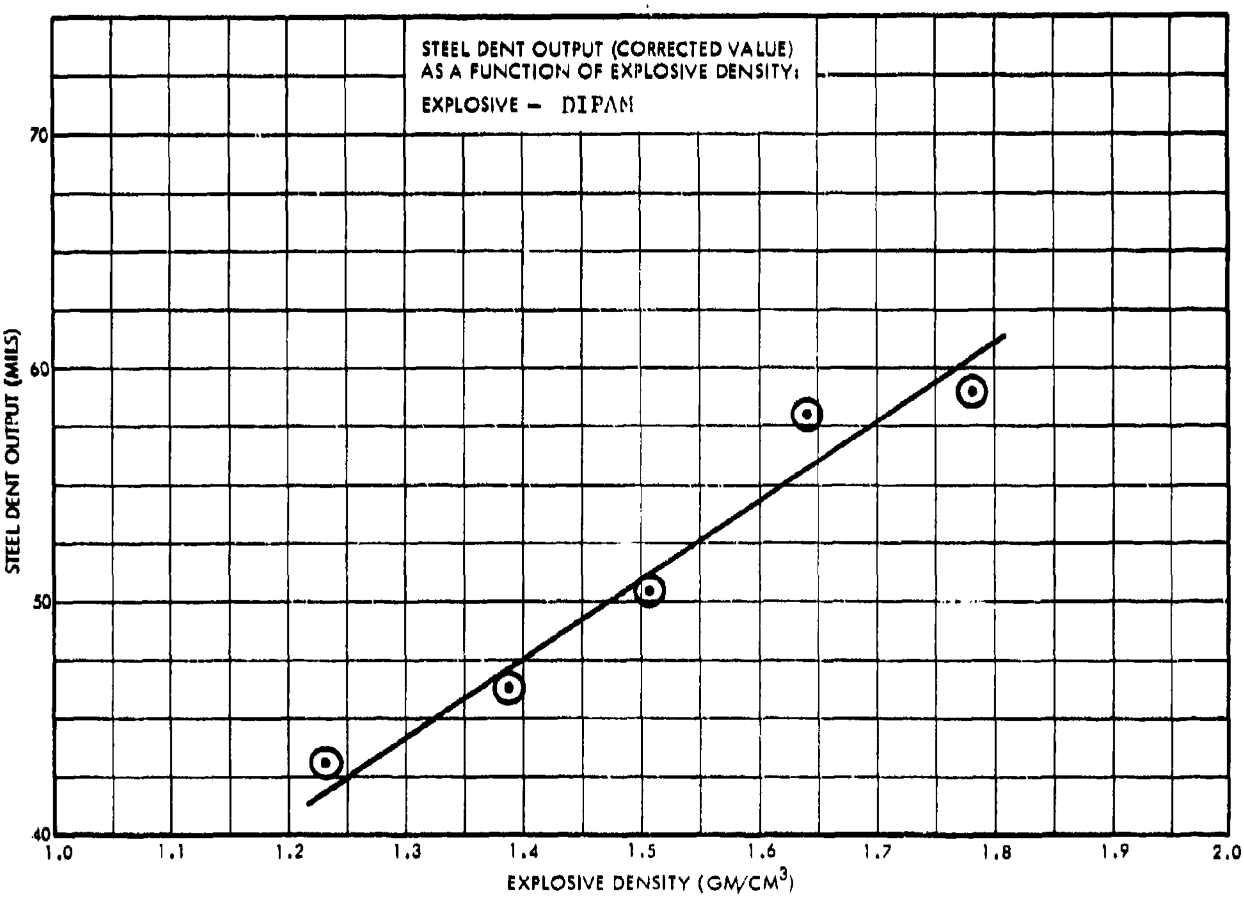


TABLE 17 STEEL DENT OUTPUT DATA FOR DIPAM

EXPLOSIVE	DATB	X NO.	315
TMD	1.84 gm/cm3	I. D. NO.	185

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.257	0.0066	41.4	1.57	42.6	1.49					84.8	1.60
8,000	1.384	0.0028	40.3	3.51	42.2	3.44					85.7	1.55
16,000	1.530	0.0047	49.2	2.54	49.4	3.84					83.3	1.99
32,000	1.663	0.0024	50.9	4.91	52.5	6.43					85.4	2.88
64,000	1.771	0.0041	53.2	2.20	53.7	2.31					83.7	1.72

NOTES:

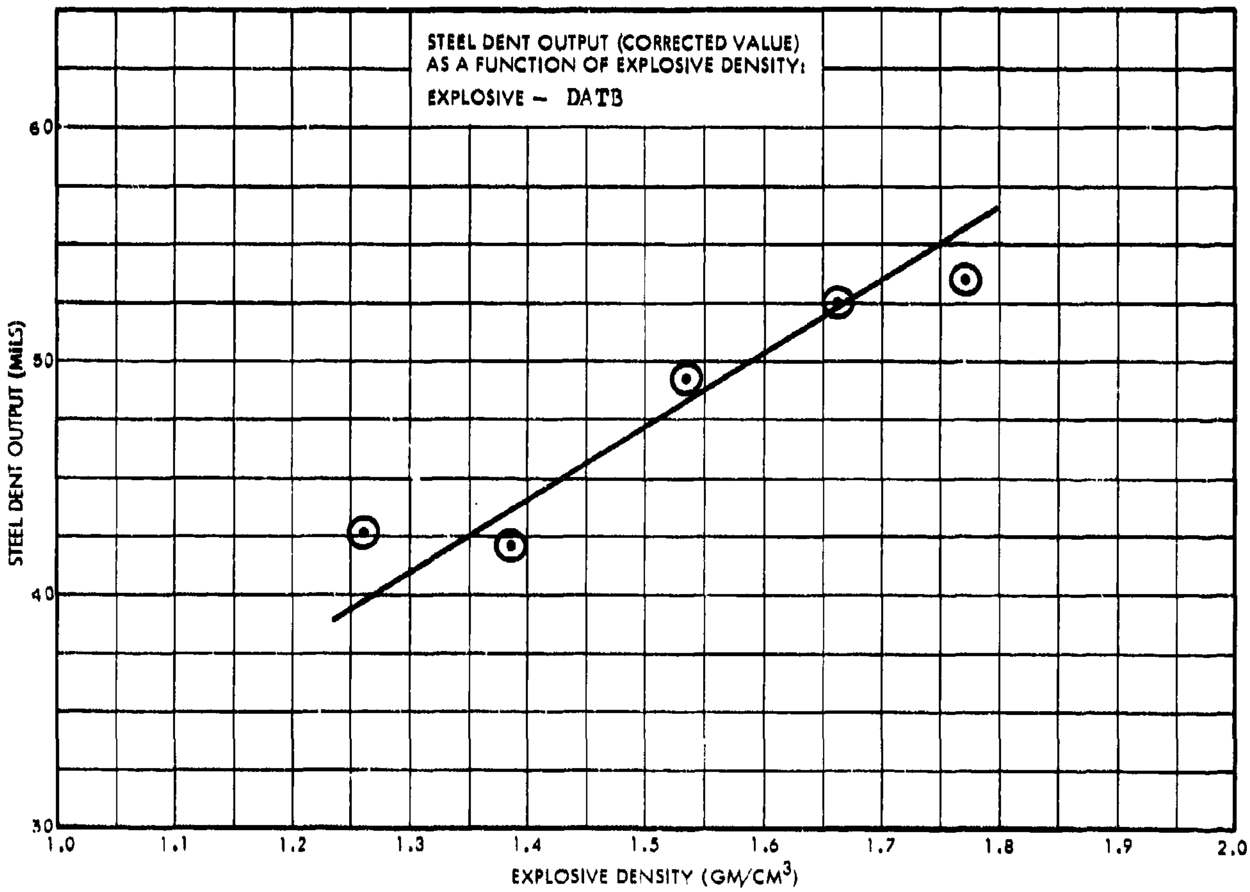


TABLE 18 STEEL DENT OUTPUT DATA FOR DATB

EXPLOSIVE	TATB	X NO.	398
TMD	1.94 gm/cm^3	I. D. NO.	968

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.480	0.0068	48.2	0.96	49.3	0.64					84.7	1.04
8,000	1.616	0.0052	52.1	3.57	53.8	4.10					85.6	1.77
16,000	1.731	0.0038	55.4	1.37	54.9	2.94					82.3	5.09
32,000	1.832	0.0016	52.7	2.90	53.2	3.03					83.8	0.49
64,000	1.888	0.0023	53.2	1.94	53.0	2.55					82.7	1.43

NOTES:

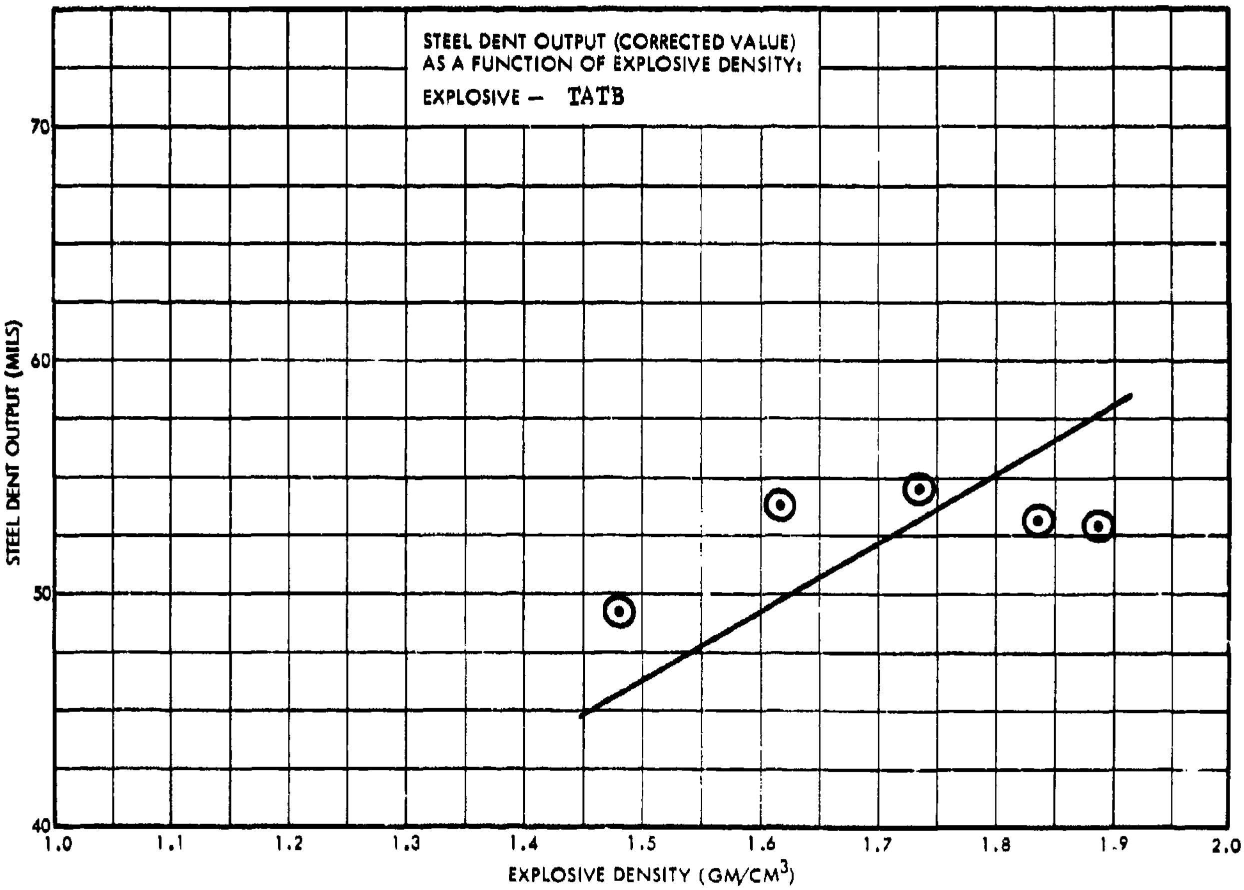


TABLE 19 STEEL DENT OUTPUT DATA FOR TATB

EXPLOSIVE	TACOT-T	X NO.	431
TMD	1.85 gm/cm^3	I. D. NO.	436

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	0.846	0.0110	24.2	1.67	22.9	2.23					81.0	1.09
8,000	0.994	0.0052	29.5	0.90	28.8	1.07					82.0	0.36
16,000	1.196	0.0121	35.0	2.72	33.5	3.13					80.7	1.17
32,000	1.437	0.0101	47.5	1.65	46.4	1.93					81.3	0.80
64,000	1.672	0.0067	55.9	1.05	55.5	1.06					82.4	1.47

NOTES:

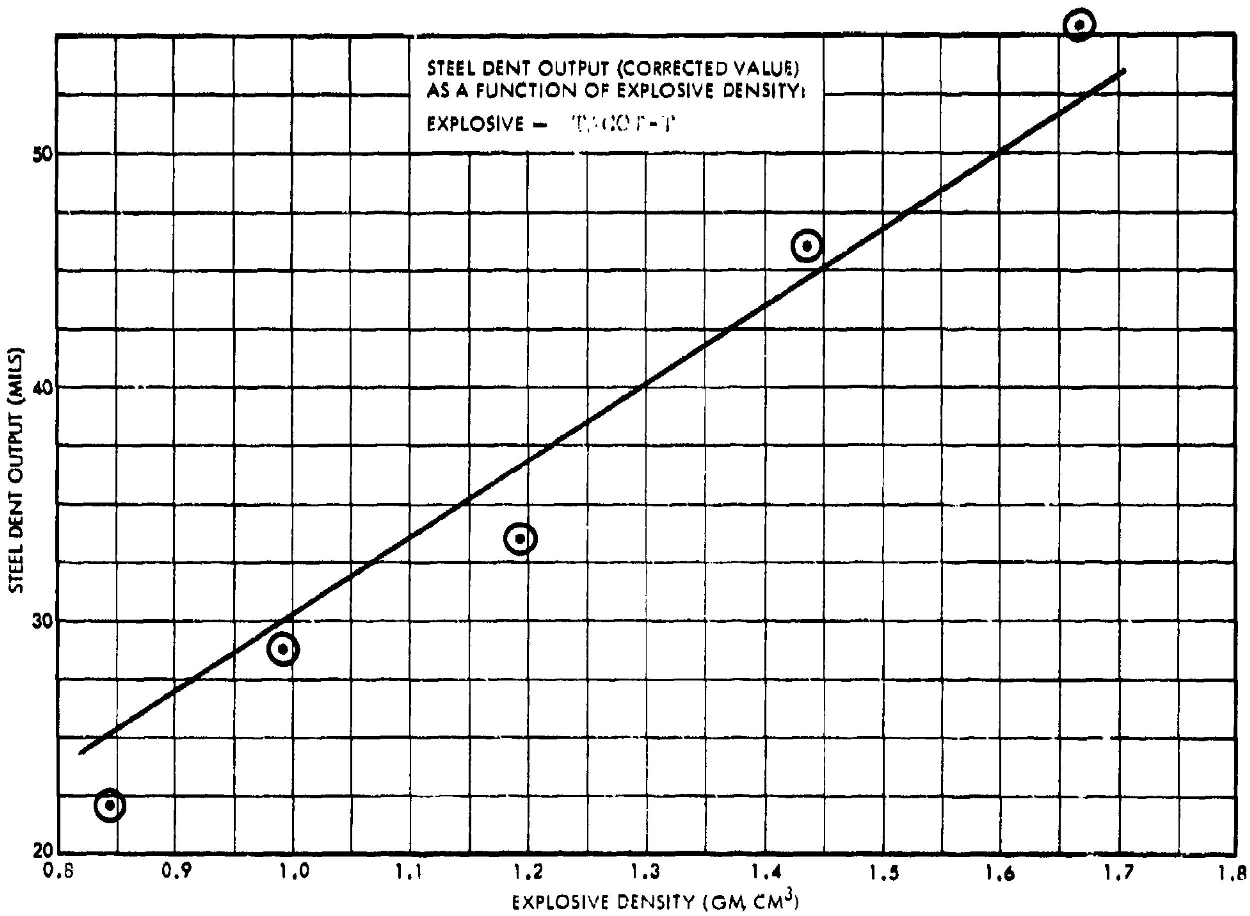


TABLE 20 STEEL DENT OUTPUT DATA FOR TACOT-T

EXPLOSIVE	KHND	X NO.	616
TMD		I. D. NOS	43&1001

LOADING PRESSURE (PSI)	DENSITY (GM/CM³)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.374	0.0085	38.4	3.72	39.2	3.70					84.3	0.78
8,000(1)	1.516	0.0045	46.0	2.99	45.7	3.53					82.5	1.00
16,000	1.601	0.0069	47.3	2.47	46.9	2.89					82.4	1.29
32,000	1.713	0.0067	49.0	2.72	47.9	2.74					81.4	0.74
64,000	1.816	0.0021	54.6	2.72	54.4	2.47					82.7	0.91

NOTES: (1) Sample size = 4

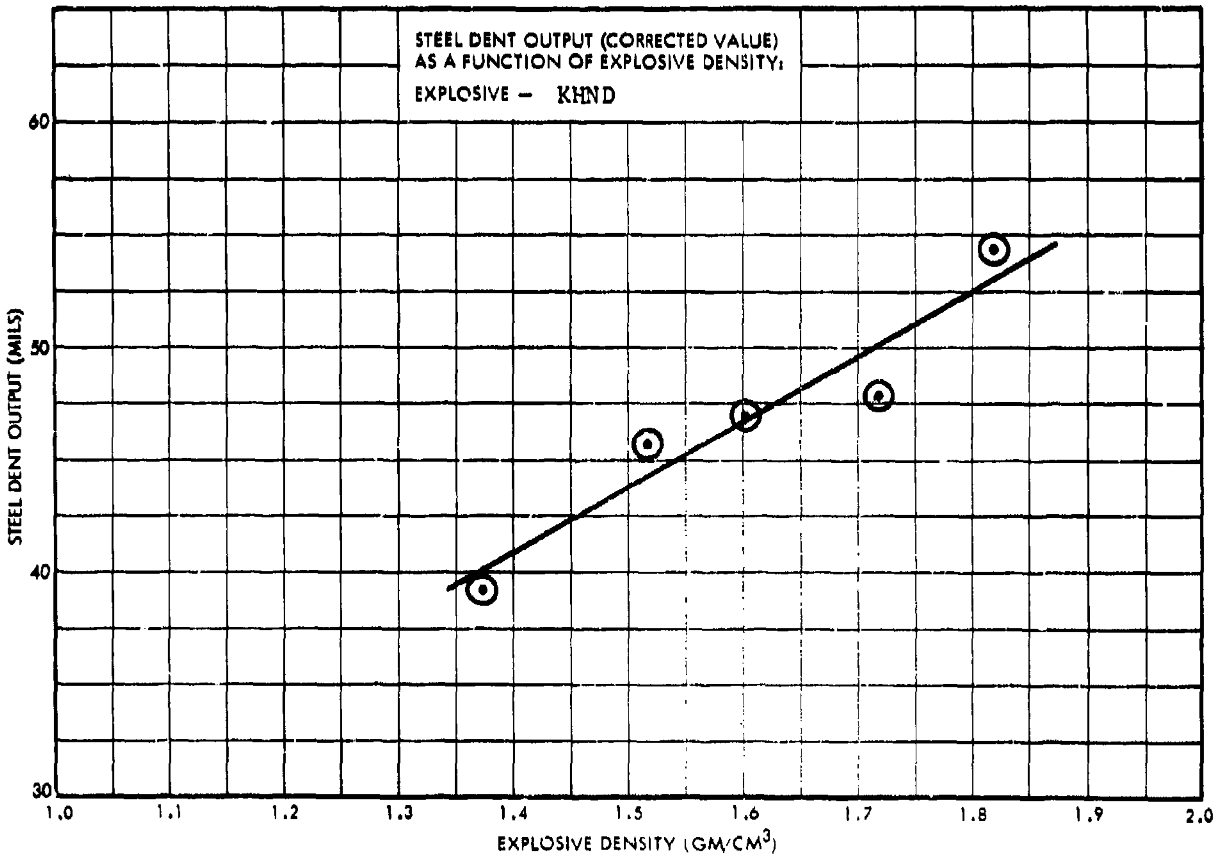


TABLE 21 STEEL DENT OUTPUT DATA FOR KHND

EXPLOSIVE	OCTOL (75/25)	X NO.	577
TMD	1.83 gm/cm^3	I. D. NO.	352

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.545	0.0040	65.6	4.76	66.9	5.22	65.5	3.49	66.2	3.74	84.9	1.16
8,000	1.623	0.0032	[illegible]	3.37	69.4	3.88	67.0	3.03	67.2	3.38	84.7	0.86
16,000	1.680	0.0084	70.1	3.65	71.1	4.03	68.8	3.24	69.0	3.89	84.5	0.77
32,000	1.768	0.0034	72.5	3.19	74.1	3.38	70.6	2.84	71.7	3.07	85.5	1.27
64,000	1.819	0.0049	70.1	2.95	70.4	2.70	70.7	3.84	70.4	3.36	83.5	1.89
CAST (1)	1.792	0.0087	65.9	1.24	66.0	1.55					83.3	1.48

NOTES: (1) Cast explosive X NO-529, I.D. No-1126

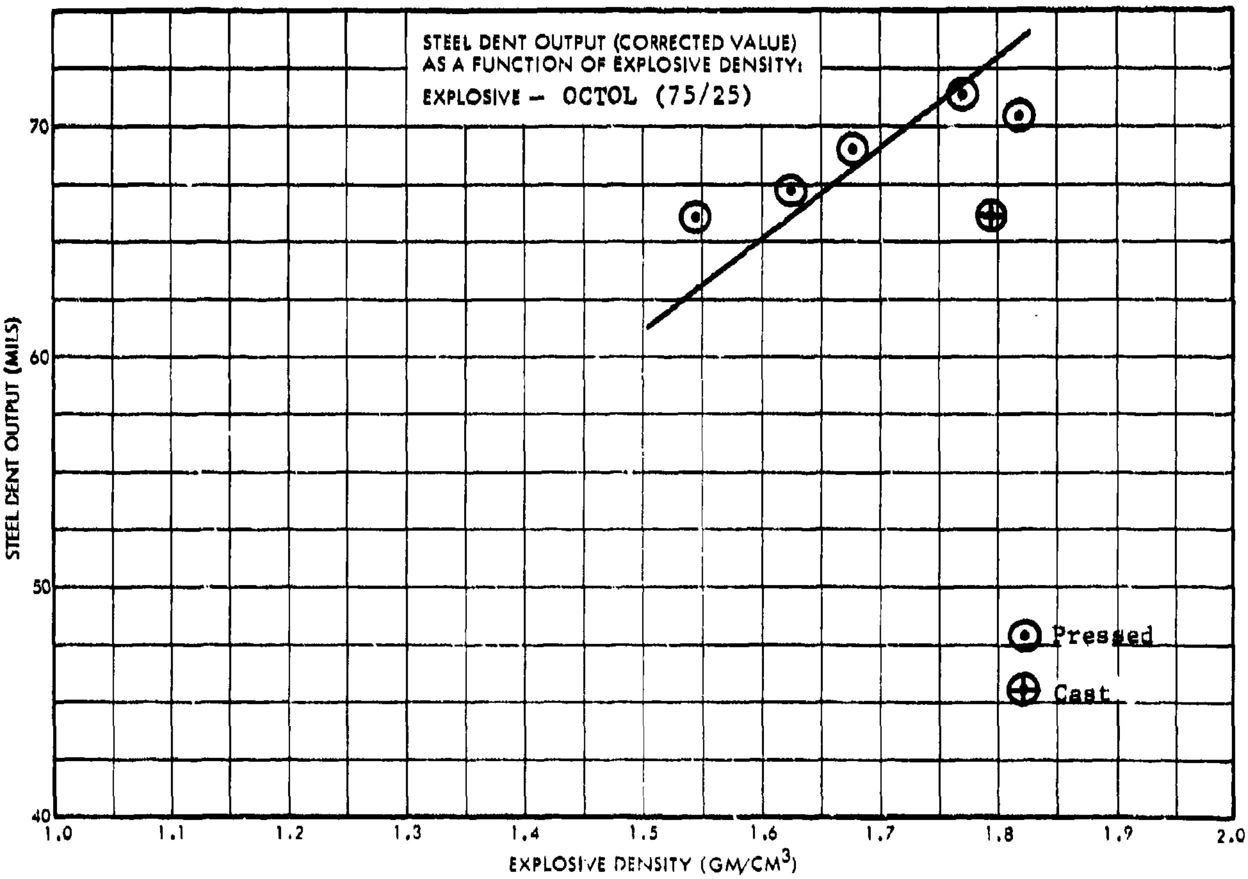


TABLE 22 STEEL DENT OUTPUT DATA FOR OCTOL (75/25)

EXPLOSIVE	OCTOL (65/35)	X NO.	None Assigned
TMD	1.79 gm/cm^3	I. D. NO.	433

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.542	0.0066	63.4	2.63	64.9	2.81					85.3	0.98
8,000	1.627	0.0023	65.8	1.74	68.4	1.90					87.0	1.11
16,000	1.697	0.0037	63.2	2.11	64.7	2.23					85.2	2.26
32,000	1.769	0.0050	62.4	1.83	64.2	1.30					85.8	1.74
64,000	1.806	0.0031	61.7	1.87	63.3	1.67					85.4	1.61
CAST (1)(2)	1.768	0.0097	64.7	0.87	65.2	1.10					83.8	0.96

NOTES: (1) Sample size - 7
(2) Cast explosive x No. 293

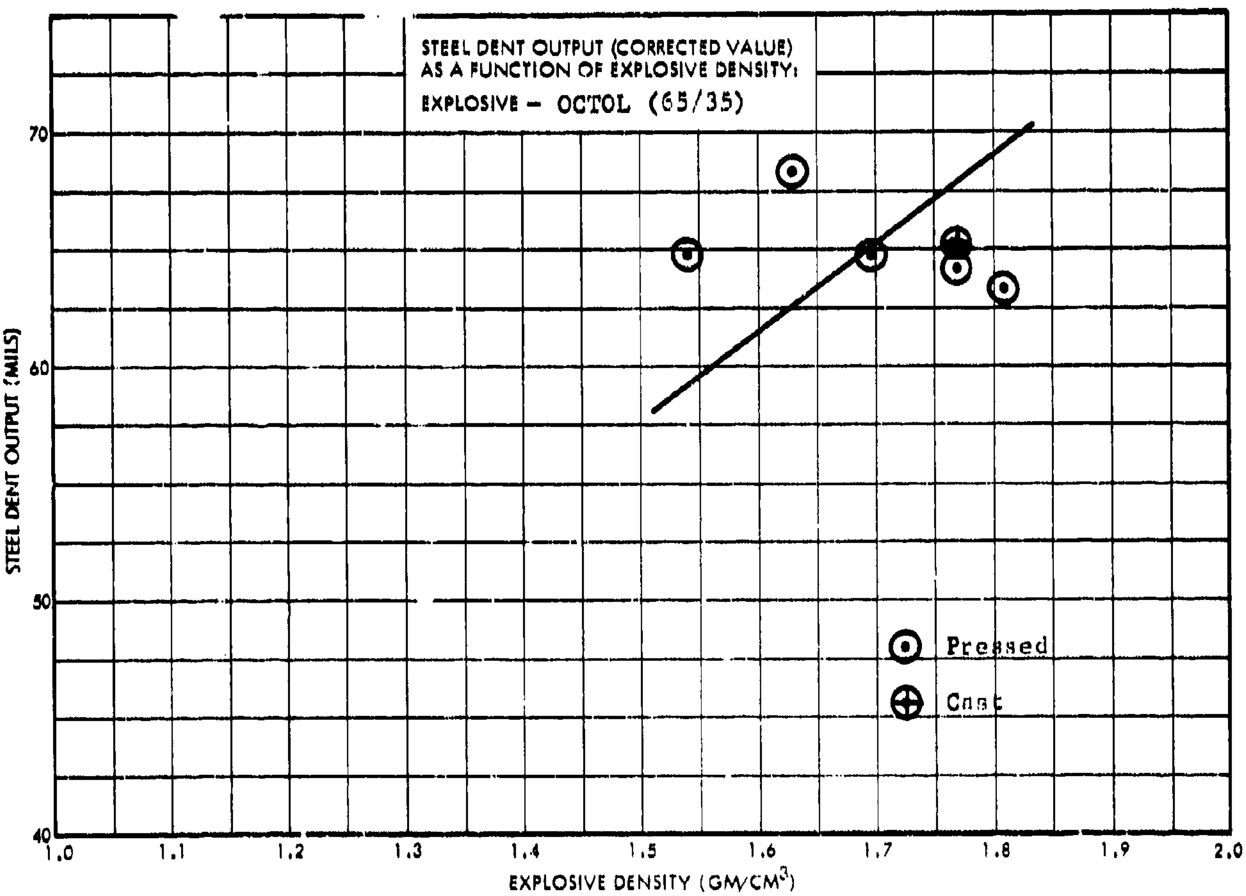


TABLE 23 STEEL DENT OUTPUT DATA FOR OCTOL (65/35)

EXPLOSIVE	PENTOLITE (50/50)	X NO.	551
TMD	1.71 gm/cm^3	I. D. NO.	185

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.372	0.0038	49.1	1.44	49.9	1.27	51.8	1.28	51.8	1.99	84.2	0.84
8,000	1.475	0.0034	52.3	0.71	53.4	1.01	55.3	2.52	55.6	2.33	84.7	0.90
16,000	1.600	0.0026	59.0	3.95	60.9	5.33	61.3	4.25	61.6	5.30	85.9	2.16
32,000	1.691	0.0015	62.8	2.40	63.8	1.85	63.0	1.38	63.5	1.31	84.5	1.80
64,000	1.721	0.0019	62.0	2.34	63.1	3.31	61.4	2.48	61.6	2.74	84.6	1.92
CAST (1)(2)	1.670	0.0047	60.3	1.37	60.5	1.43					83.3	0.88

NOTES: (1) Sample size = 10
(2) Cast explosive X No. 636

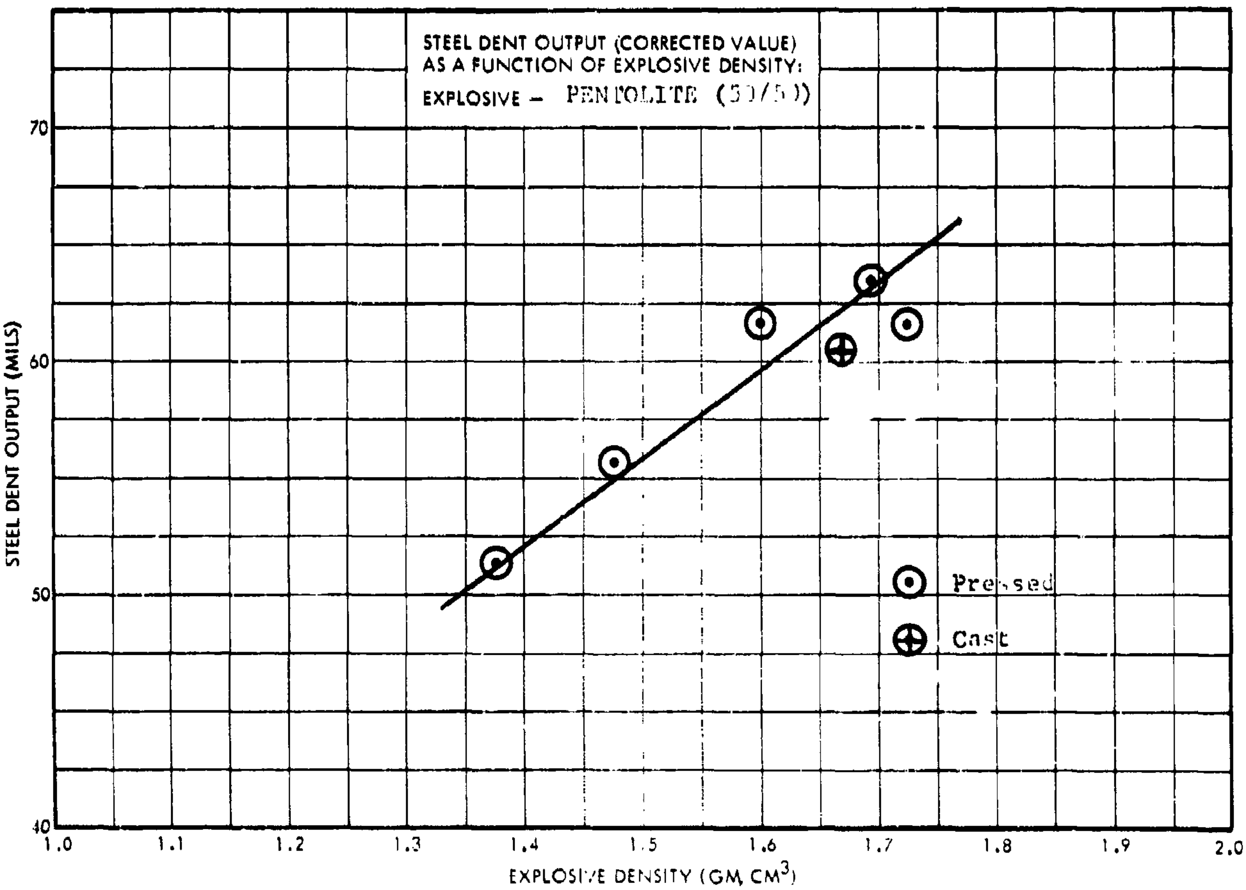


TABLE 24 STEEL DENT OUTPUT DATA FOR PENTOLITE (50/50)

EXPLOSIVE	TNT	X NO.	412
TMD	1.65 gm/cm³	I. D. NO.	369

LOADING PRESSURE (PSI)	DENSITY (GM/CM³)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.350	0.0050	45.8	3.23	44.8	3.60	46.8	1.76	46.1	2.00	81.5	0.97
8,000	1.448	0.0021	48.1	2.90	48.3	3.05	48.7	1.66	48.3	1.73	83.3	0.60
16,000	1.555	0.0020	50.8	2.05	50.8	2.21	50.9	1.53	50.5	1.53	83.0	0.61
32,000	1.624	0.0023	51.8	4.25	52.1	3.79	52.2	2.61	51.6	2.43	83.5	1.14
64,000	1.649	0.0023	54.1	2.58	54.3	2.86	53.5	2.15	53.4	2.27	83.2	1.52
CAST(2)	1.616	0.0046	32.7	15.01	33.0	15.02					83.4	0.64

NOTES: (1) Sample size = 9
(2) Cast explosive X No. 517

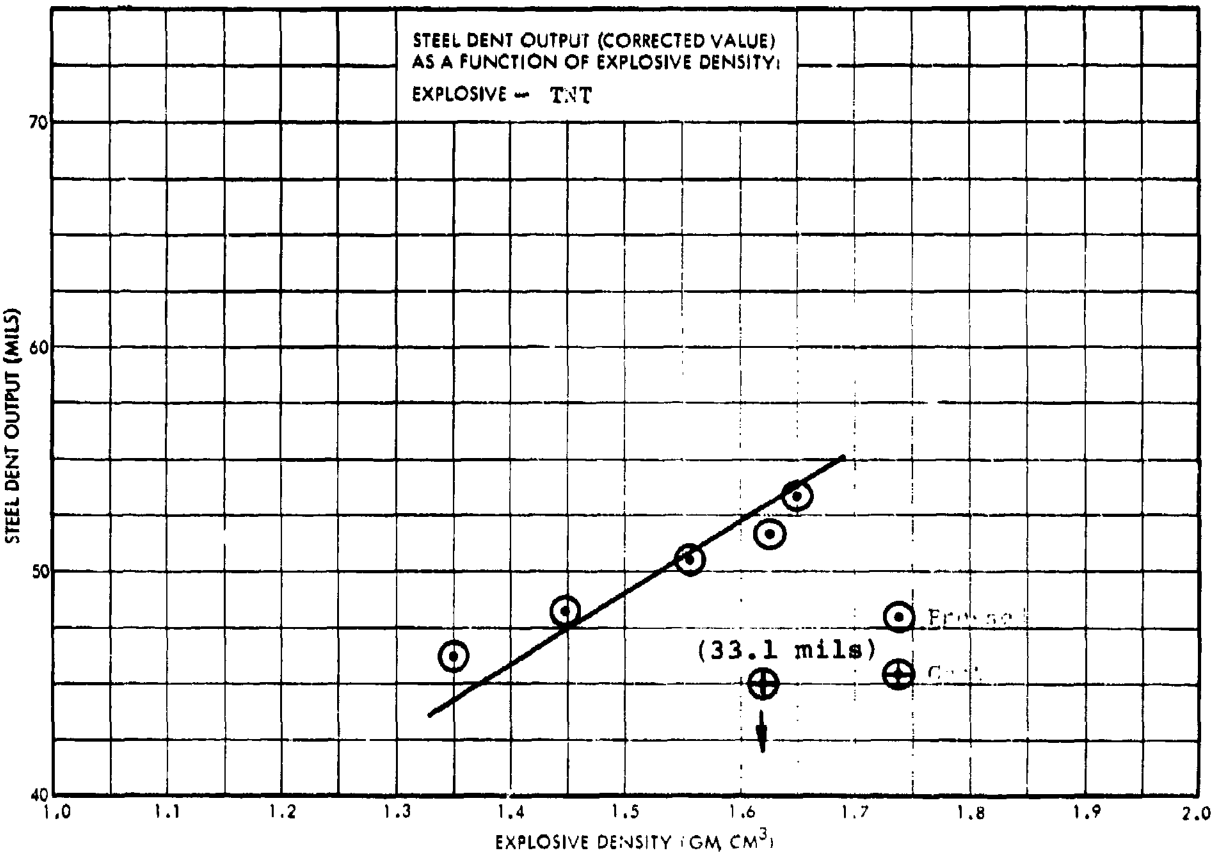


TABLE 25 STEEL DENT OUTPUT DATA FOR TNT

EXPLOSIVE	COMP B	X NO.	576
TMD	1.72 gm/cm^3	I. D. NO.	173

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.473	0.0029	62.9	1.86	62.0	1.73	60.8	1.35	60.5	1.18	81.7	1.15
8,000	1.579	0.0028	60.6	3.52	59.9	3.64	61.3	2.57	61.4	2.89	82.0	2.00
16,000	1.659	0.0024	57.3	1.94	56.4	1.18	60.7	1.95	60.0	1.57	81.7	1.96
32,000	1.714	0.0016	62.1	1.95	61.1	1.61	62.4	1.82	61.7	1.50	81.6	0.82
64,000	1.734	0.0011	59.1	1.63	58.2	1.66	61.2	1.29	60.8	1.29	81.6	0.82
CAST (1)	1.667	0.0263	58.6	0.77	59.3	1.28					84.0	0.98

NOTES: (1) Sample size = 4
Cast explosive X No. 522

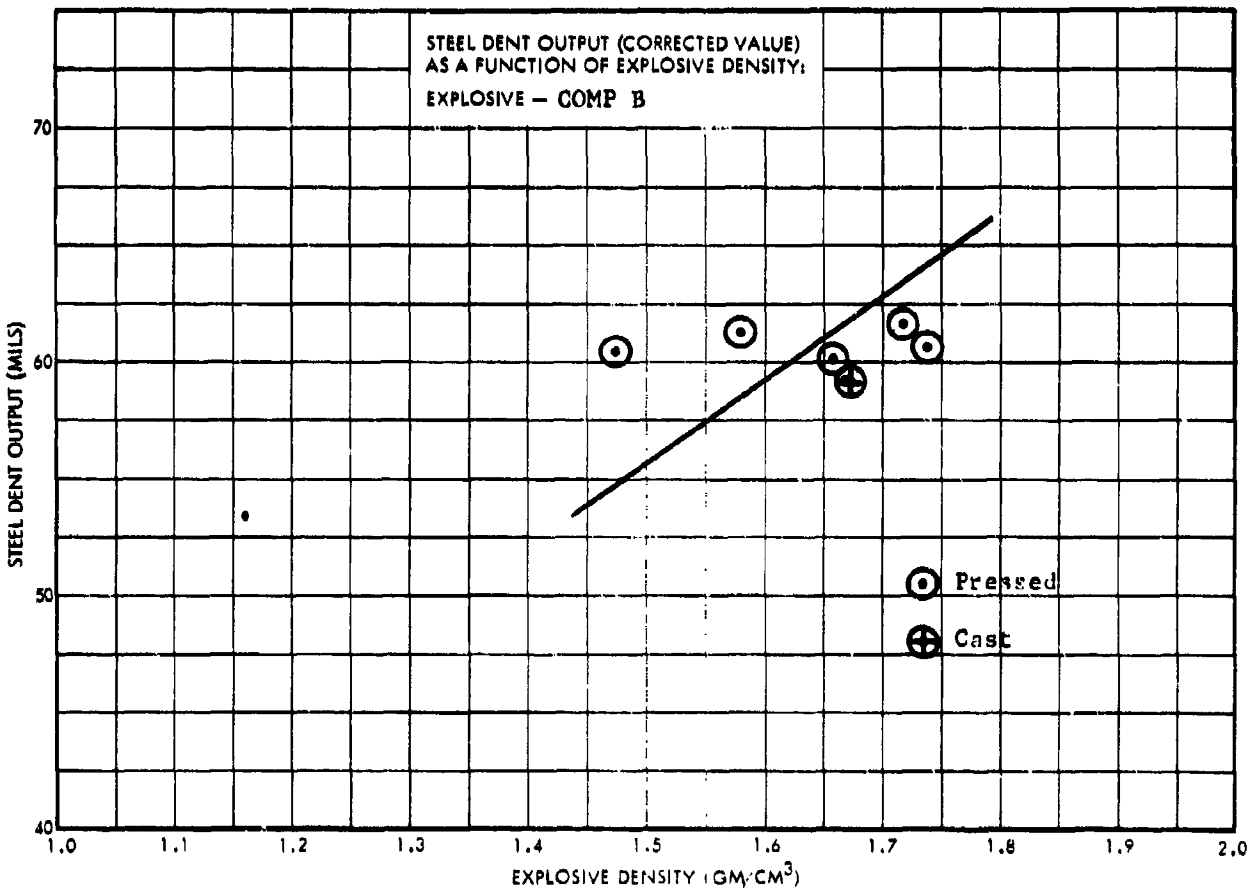


TABLE 26 STEEL DENT OUTPUT DATA FOR COMP B

EXPLOSIVE	TNB	X NO.	None Assigned
TMD	1.69 gm/cm^3	I. D. NO.	179

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.281	0.0076	48.9	1.41	48.8	1.22	48.5	2.70	48.1	2.67	82.9	0.67
8,000	1.440	0.0030	47.9	2.15	47.5	2.08	49.9	1.35	49.7	1.21	82.5	1.58
16,000	1.573	0.0032	55.2	1.35	55.8	1.32	54.5	1.26	54.3	1.22	84.0	2.50
32,000	1.667	0.0016	57.1	3.26	56.8	3.88	56.7	2.02	56.3	2.33	82.6	1.38
64,000	1.693	0.0013	59.9	1.91	59.6	2.22	58.2	1.37	58.0	2.90	82.6	1.08

NOTES:

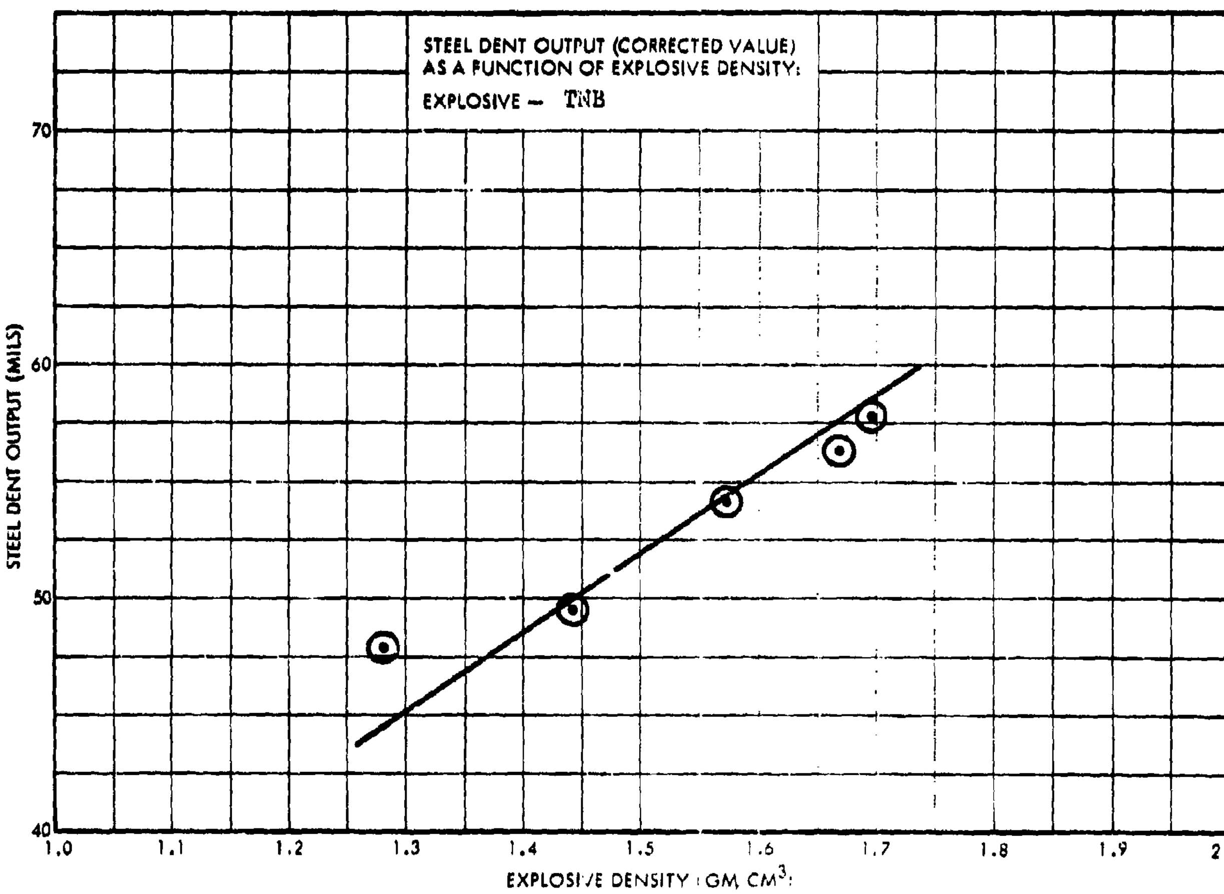


TABLE 27 STEEL DENT OUTPUT DATA FOR TNB

EXPLOSIVE	TNETB	X NO.	563
TMD	1.79	I. D. NOS	208 & 412

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				GROUP I BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.479	0.0029	62.1	1.19	61.9	2.32	60.4	1.21	60.3	1.92	82.7	1.81
8,000	1.615	0.0017	62.9	2.98	62.7	2.89	64.7	1.94	64.3	2.06	82.6	0.69
16,000	1.718	0.0015	64.0	0.97	63.4	1.71	67.4	1.27	66.4	2.13	82.2	1.24
32,000	1.779	0.0019	72.5	2.54	72.5	2.77	72.3	1.72	71.7	1.95	83.0	0.89
64,000	1.799	0.0028	69.7	2.93	70.2	2.50	70.0	2.09	69.4	1.97	83.7	0.70

NOTES:

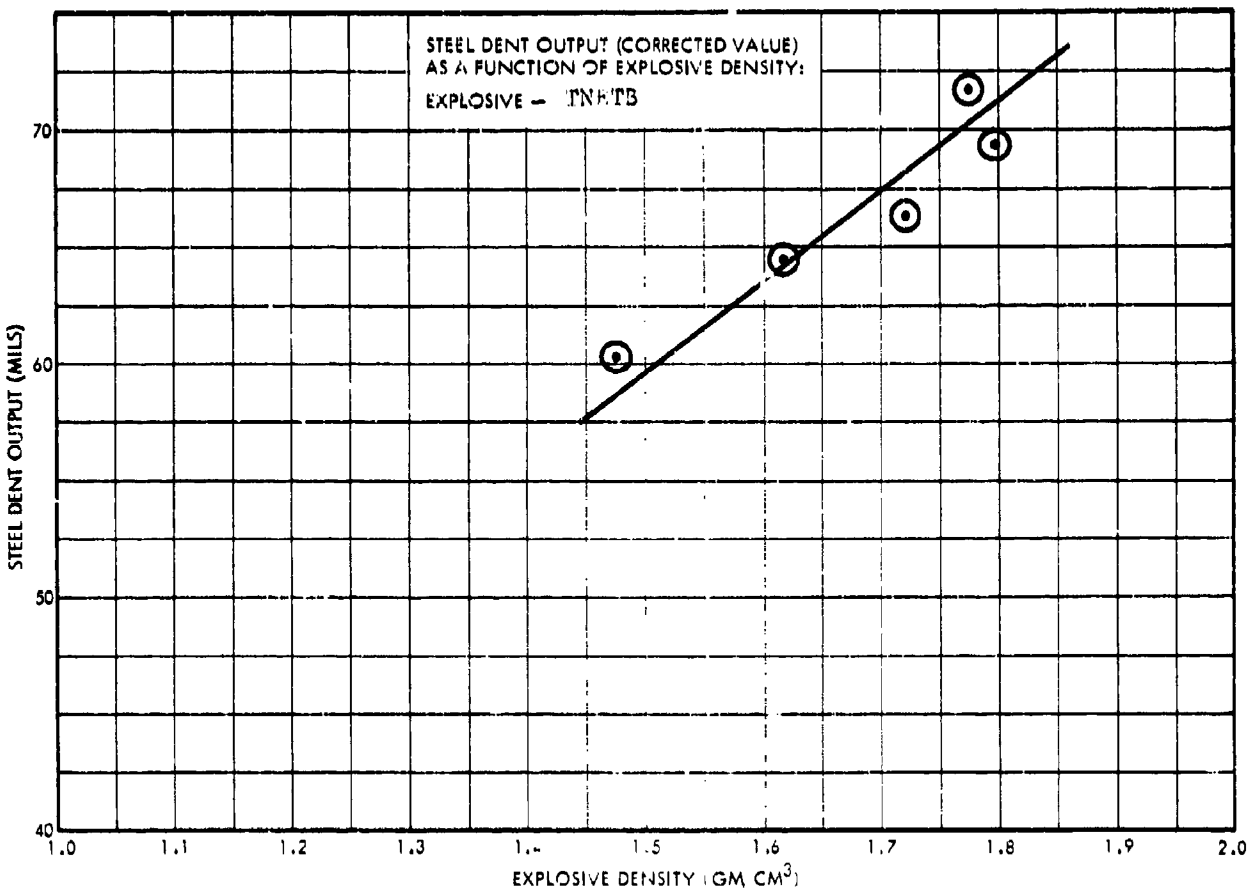


TABLE 28 STEEL DENT OUTPUT DATA FOR TNETB

EXPLOSIVE	Nitroguanidine (Low Bulk Density)	X NO.	None Assigned
TMD	1.7[illegible] gm/cm³	I. D. NO.	967

LOADING PRESSURE (PSI)	DENSITY (GM/CM^3)		GROUP I DATA: OBSERVED DENT DATA (MILS)		GROUP I DATA: CORRECTED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: OBSERVED DENT DATA (MILS)		AVERAGE GROUP I, II & III DATA: CORRECTED DENT DATA (MILS)		BLOCK HARDNESS DATA (ROCKWELL B)	
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.156	0.0037	37.5	1.31	37.1	2.58					82.4	2.71
8,000	1.294	0.0027	41.5	0.84	41.5	0.76					83.0	1.27
16,000	1.393	0.0029	43.8	1.01	44.1	1.40					83.3	0.70
32,000	1.529	0.0035	46.6	1.67	46.7	2.27					83.1	1.08
64,000	1.673	0.0023	9.7	5.16	10.25	5.33					83.8	0.70

NOTES:

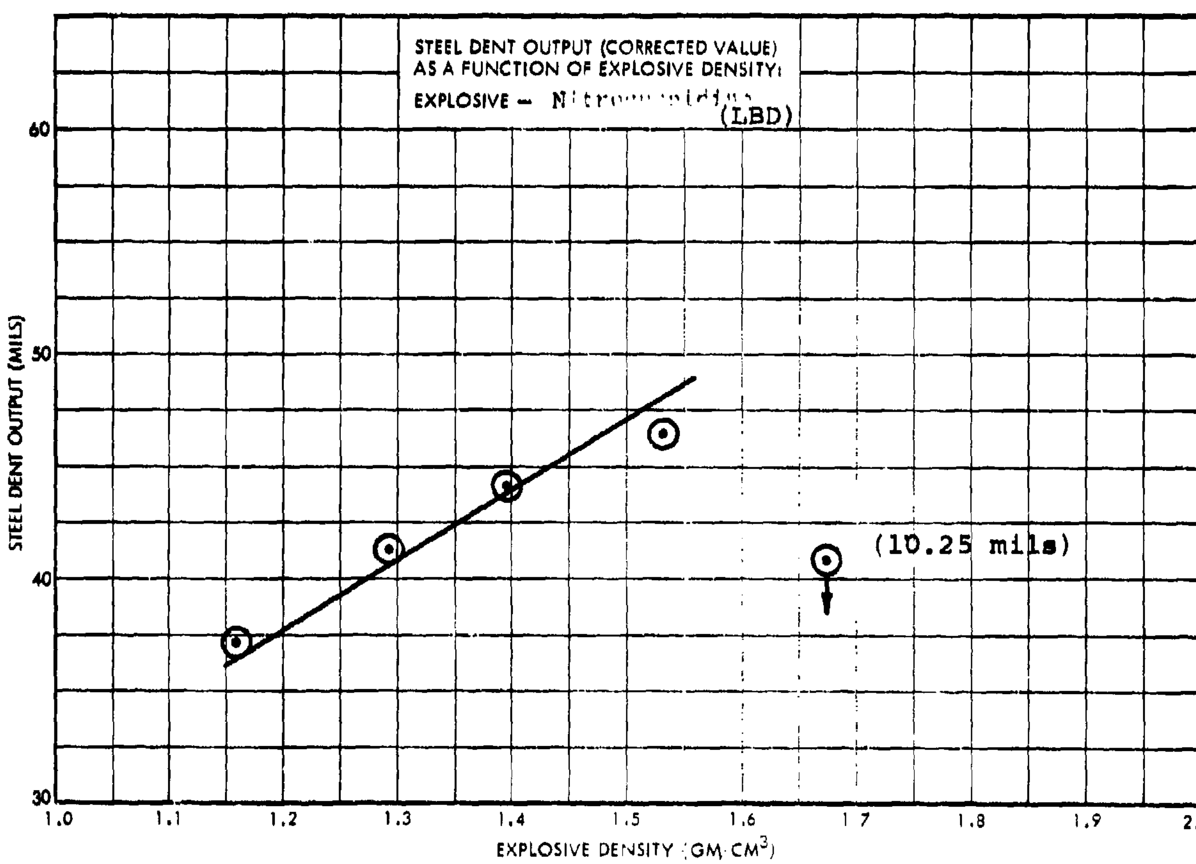


TABLE 29 STEEL DENT OUTPUT DATA FOR Nitroguanidine (LBD)

EXPLOSIVE	Nitroguanidine (High Bulk Density)	X NO.	x510
TMD	1.73 gm/cm³	I. D. NO.	194

LOADING PRESSURE (. PSI)	DENSITY (GM/CM³)		GROUP I DATA				AVERAGE GROUP I, II & III DATA				BLOCK HARDNESS DATA (ROCKWELL B)	
			OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)		OBSERVED DENT DATA (MILS)		CORRECTED DENT DATA (MILS)			
	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S	AVG.	S
4,000	1.329	.0023	13.5	2.30	13.04	2.44					82.2	0.77
8,000	1.452	.0019	2.9	0.50	2.76	0.37					82.8	0.35
16,000	1.532	.0019									-	-
32,000	1.627	.0032	See note (1)								-	-
64,000	1.713	.0018									-	-

NOTES: (1) Explosive could not be detonated in this test configuration

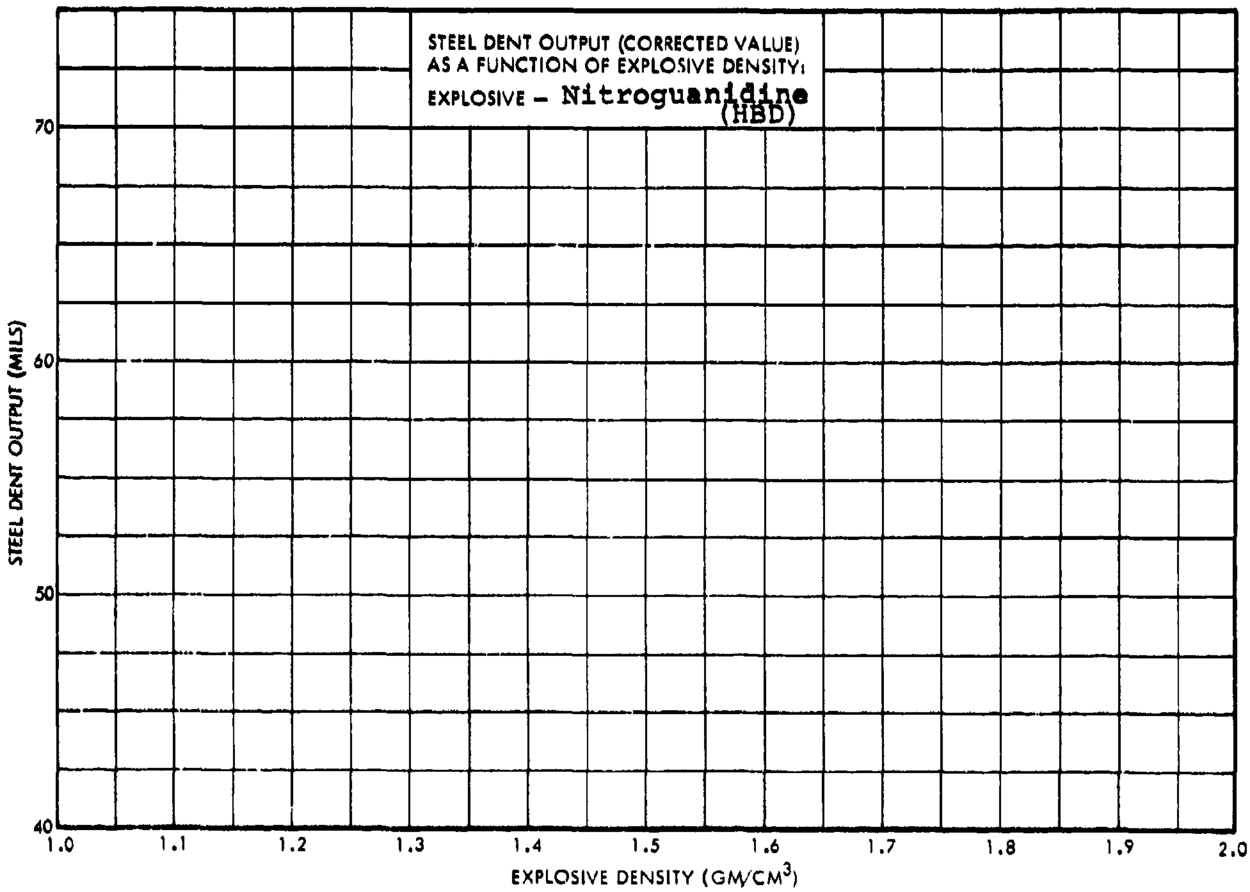


TABLE 30 STEEL DENT OUTPUT DATA FOR Nitroguanidine (HBD)

Table 31

Results of Operator on Block Hardness Measurements

OPERATOR

Block No	A	B	C	D
5738	82.4	81.9	82.6	83
5739	83	78.7	83	83
5748	82.6	80.9	82	83
5758	82.6	80.3	83.6	83
5763	83	79.2	81.4	83
5770	82.3	81.2	82.3	83
5780	81.8	80.1	82	83
5784	81.9	81.2	83.1	82
5787	82.4	82	82	82
5788	81.2	78	81	82
5797	82	82.2	82.9	83
5810	81.1	81.8	82.6	83
5812	83.1	79.8	81.9	82
5741	81.1	80.6	81.2	81
5749	82.5	79.9	82	82
5798	81.8	80.2	81.8	83
5802	81.8	80.7	82	83
5813	83	81.9	82	83
5823	82	79.4	82.8	83
5833	81.8	76.8	81.6	83
5837	81.1	75.2	81.6	84

Table 32

List of Explosives Whose Output Test Values of Block Hardness and Depth of Dent Were Remeasured

Explosive	Table Number
Lead Azide (Dex)	4
Nitromannite	5
HMX	11
PBXN-5	12
HNS-II/Tef (95/5)	15
HNS-II/Tef (90/10)	16
OCTOL (75/25)	22
Pentolite (50/50)	24
TNT	25
COMP B	26
TNB	27
TNETB	28

Table 33

Analysis of Variation (Anova) Table for the Steel Dent Output (Observed Data) for HNS/Tef., (90/10), 16k

Block Number (j)	Observation Number (i)			
	1	2	3	
1	52.79	49.95	49.05	151.79
2	54.38	50.27	49.50	154.15
3	49.67	46.85	46.20	142.72
4	48.37	46.00	46.50	140.87
5	49.50	49.87	49.62	148.99
Sums =	254.71	242.94	240.87	738.52
Sums of Squares	13,000.98	11,820.01	11,614.99	36,435.97

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F (Calculated)	$F_{.05}$
Total	75.18	14			
Operator	22.30	2	11.15	9.87	4.46
Block	43.82	4	10.96	9.70	3.84
Error	9.06	8	1.13		

Table 34

Analysis of Variance (Anova) Table for the Steel Dent Output (Observed Data) for PBXN-5, (4k).

Block Number (j)	Observation Number (i)			
	1	2	3	
1	58.00	54.97	55.35	168.32
2	55.87	60.10	56.27	172.24
3	55.37	55.32	55.20	165.89
4	56.62	56.12	56.52	169.26
5	56.00	56.50	56.40	168.90
Sums =	281.86	283.01	279.74	844.61
Sums of Squares	15,893.12	16,035.72	15,652.45	47,581.29

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F (calculated)	$F_{.05}$
Total	23.55	14			
Operator	1.09	2	.55	0.28	4.46
Block	6.89	4	1.72	0.88	3.84
Error	15.57	8	1.95		

Table 35

Analysis of Variance (Anova) Table for the Steel Dent Output (Observed Data) for Pentolite (50/50), 8k.

Block Number (j)	Observation Number (i)			
	1	2	3	
1	52.42	53.72	53.60	159.74
2	52.82	55.05	54.50	162.37
3	51.17	52.95	51.67	155.76
4	52.95	54.00	53.77	160.72
5	52.05	51.57	51.30	154.92
Sums =	261.41	267.26	264.84	793.51
Sums of Squares	13,669.08	14,292.33	14,035.90	41,997.31

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F (Calculated)	$F_{.05}$
Total	26.10	14			
Operator	3.46	2	1.73	4.80	4.46
Block	13.75	4	3.44	9.55	3.84
Error	2.89	8	.36		

Table 36

Results of Least Square Fit to the Correct Dent Data for the Explosive

Explosive	X Number	I.D. Number	Least Square Fit Equation of Corrected Dent Data	
			Average Group I Data	Average Group I, II, and III Data
Lead Azide (Dex.)	-	1072	-	-
Nitromannite	601	311	$\delta = 0.002 + 37.63\rho$	$\delta = -0.384 + 38.25\rho$
PETN	321	85	$\delta = -0.322 + 41.18\rho$	-
RDX	334	998	$\delta = 0.366 + 40.82\rho$	-
CH-6	267	115	$\delta = 0.066 + 39.93\rho$	-
Tetryl	436	1054	$\delta = -0.308 + 36.60\rho$	-
Tetryl/ Graphite	460	374	$\delta = 0.195 + 36.91\rho$	-
HMX	433	439	$\delta = 0.408 + 40.79\rho$	-
PBXN-5	618	579	$\delta = 1.412 + 29.94\rho$	-
HNS-I	537	714	$\delta = 0.659 + 33.66\rho$	-
HNS-II	567	165,30	$\delta = 0.275 + 33.04\rho$	-
HNS-II/Tef (95/5)	526	212	$\delta = 0.225 + 31.58\rho$	$\delta = 0.193 + 31.68\rho$
HNS-II/Tef (90/10)	581	162	$\delta = 0.190 + 29.09\rho$	$\delta = 0.315 + 28.98\rho$
DIPAM	549	223	$\delta = 0.210 + 33.87\rho$	-
DATB	315	185	$\delta = 0.670 + 31.08\rho$	-
TATB	398	968	$\delta = 1.412 + 29.94\rho$	-
TACOT-T	431	436	$\delta = -2.647 + 32.91\rho$	-
KHND	616	43,1001	$\delta = -0.091 + 29.26\rho$	-
Octol (75/25)	577	352	$\delta = 0.668 + 41.24\rho$	$\delta = 0.616 + 40.39\rho$
Octol (65/35)	-	433	$\delta = 1.295 + 37.65\rho$	-
Pentolite (50/50)	551	185	$\delta = -0.245 + 37.23\rho$	$\delta = 0.290 + 37.20\rho$
TNT	412	369	$\delta = 0.159 + 32.68\rho$	$\delta = 0.413 + 32.45\rho$
Comp-B	576	173	$\delta = 1.306 + 35.52\rho$	$\delta = 0.988 + 36.59\rho$
TNB	-	179	$\delta = 0.531 + 34.67\rho$	$\delta = 0.768 + 34.19\rho$
TNETB	563	208,412	$\delta = 0.232 + 39.62\rho$	$\delta = 0.311 + 39.36\rho$
Nitroguanidine (LBD)	-	967	$\delta = 0.316 + 31.21\rho$	-

Table 37

Steel Dent Output Test Results of Six Cast Explosives

Explosive	Number Tested	Explosive Density (gm/cm^3) Ave	Explosive Density (gm/cm^3) Std. Dev.	Steel Dent Output (Mils) Ave	Steel Dent Output (Mils) Std. Dev.	Remarks
Octol (75/25)	5	1.792	0.0087	66.0	1.55	(1)
Octol (65/35)	7	1.768	0.0097	65.2	1.10	(2)
Pentolite (50/50)	10	1.670	0.0047	60.5	1.43	
TNT	9	1.616	0.0046	33.0	15.02	(3) The minimum and maximum dent observed were 15 mils and 57 mils.
Comp-B	4	1.667	0.0263	59.3	1.28	(4)

(1) The density of five other pieces ranged from 1.47 - 1.72 gm/cm^3. Of these, four gave steel dents greater than 61.0 mils, one (ρ = 1.68 gm/cm^3) failed.

(2) The density of two other pieces were 1.41 and 1.54 gm/cm^3. Both pieces failed to give any dent in a steel block.

(3) The density of one piece was 0.86 gm/cm^3, however, the unit was tested, and the resulting steel dent was approximately 57 mils.

(4) The density of five other pieces was less than 1.6 gm/cm^3. These units were fired, and the steel dent varied from 7 to 30 mils.

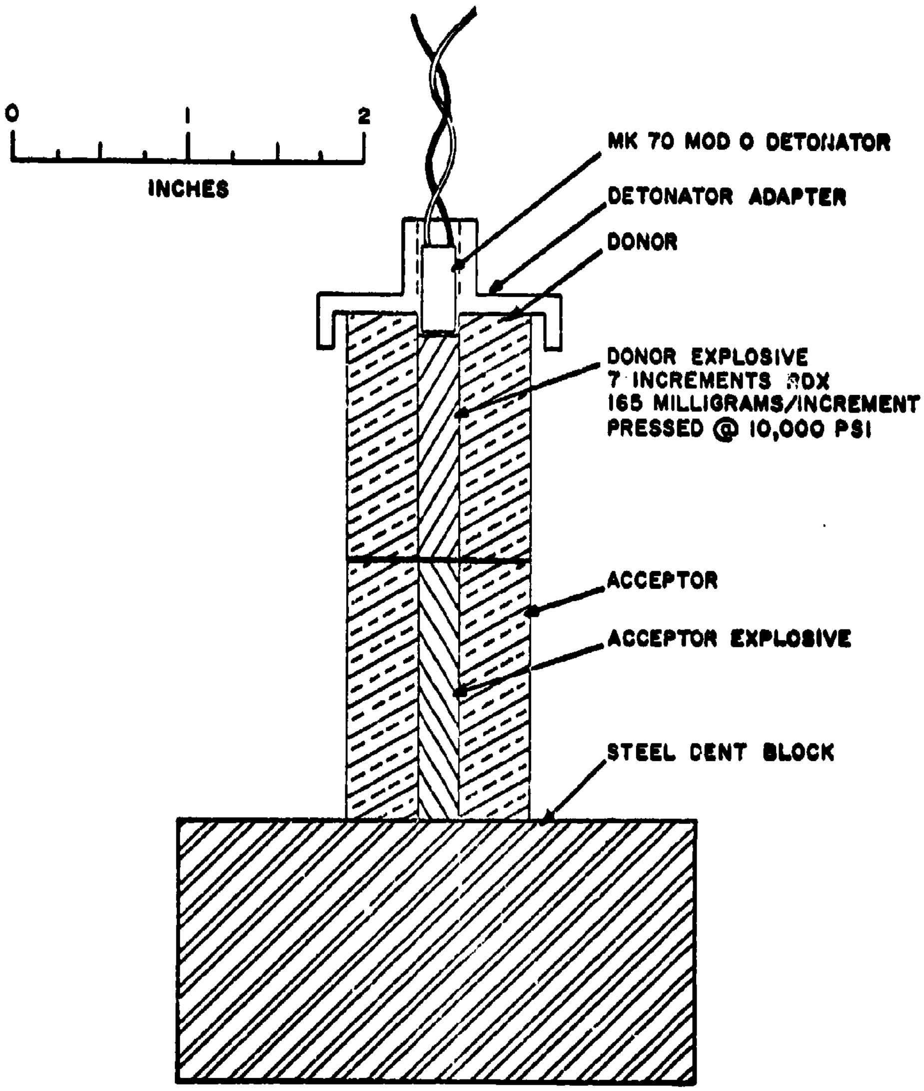
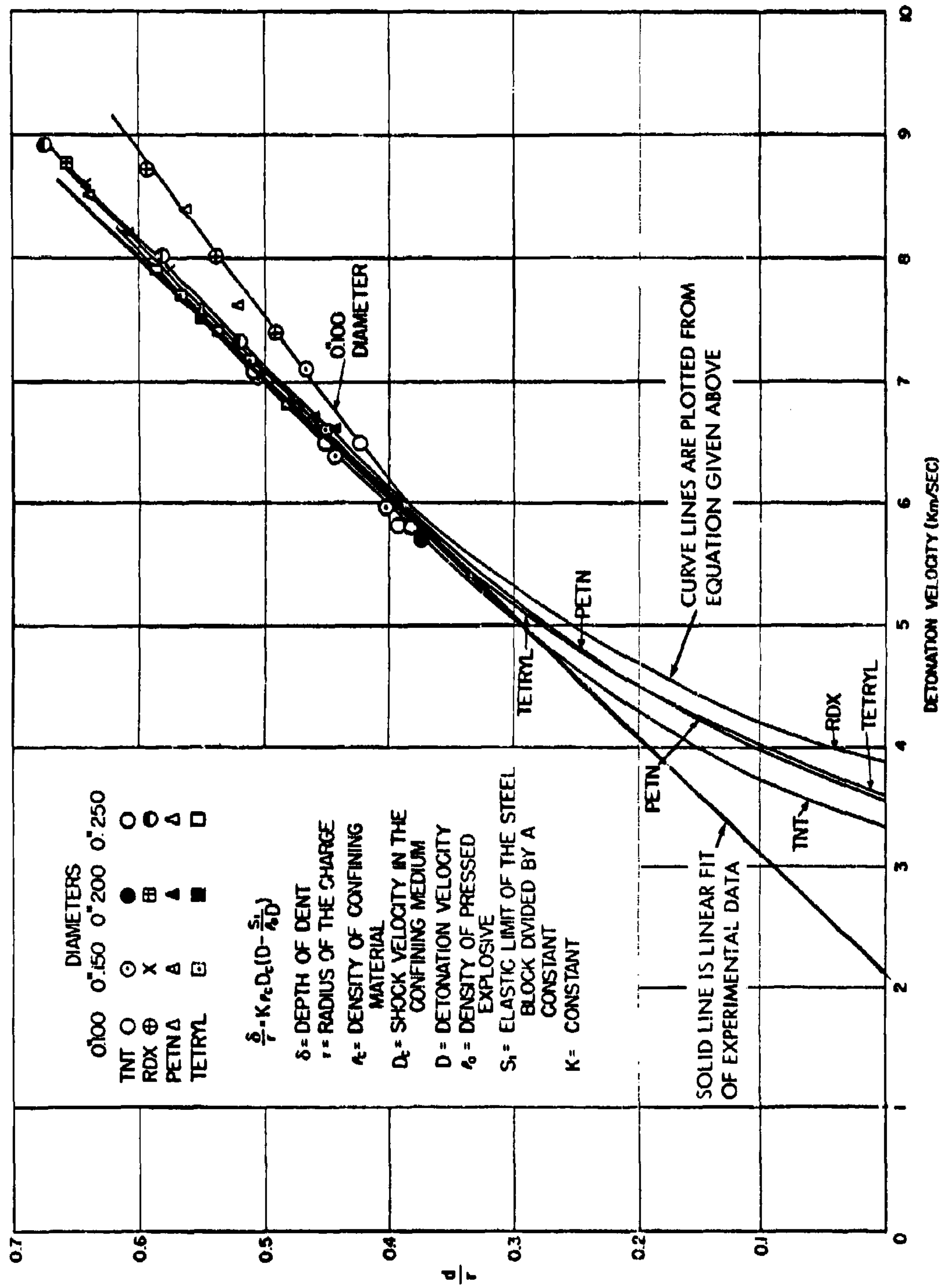


FIG. 1 MODIFIED SMALL SCALE GAP TEST USED FOR STEEL DENT OUTPUT TEST FOR EXPLOSIVES



$$\frac{\delta}{r} = K\rho_c D_c \left(D - \frac{S_L}{\rho_0 D}\right)$$

FIG. 2 DEPTH OF DENT DIVIDED BY THE RADIUS VS DETONATION VELOCITY

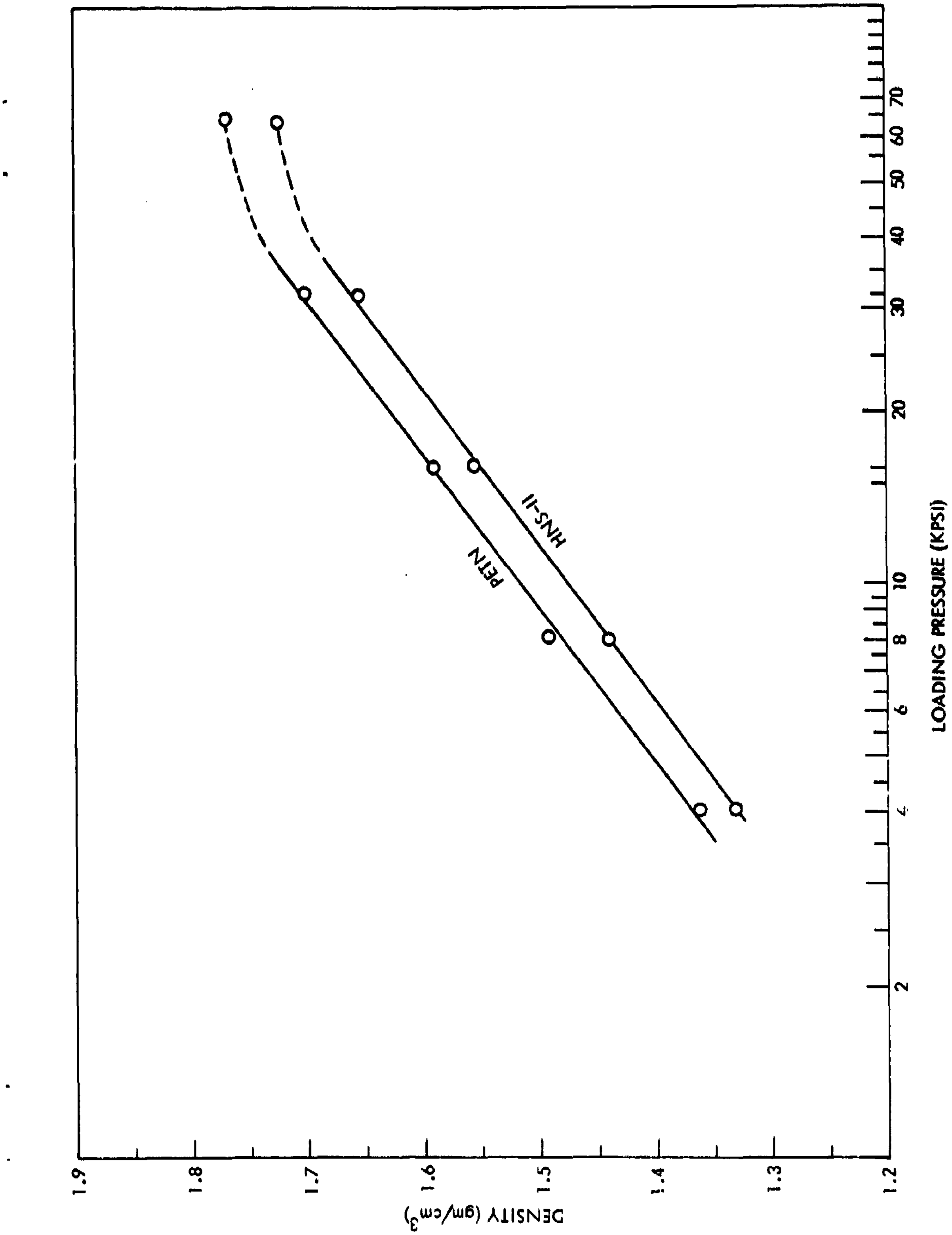


FIG. 3 DENSITY/LOADING PRESSURE RELATIONSHIP FOR PETN AND HNS-II

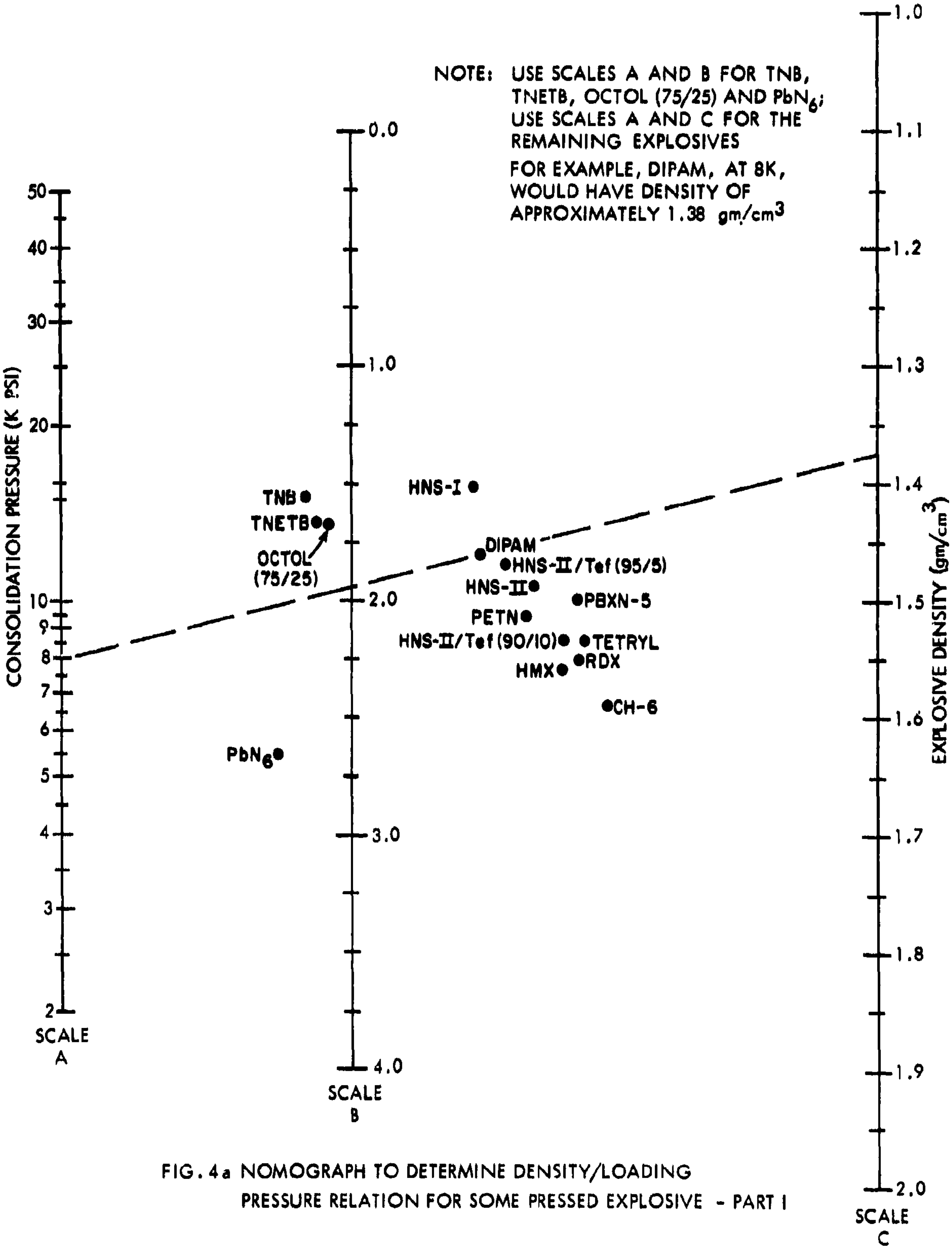


FIG. 4a NOMOGRAPH TO DETERMINE DENSITY/LOADING PRESSURE RELATION FOR SOME PRESSED EXPLOSIVE - PART I

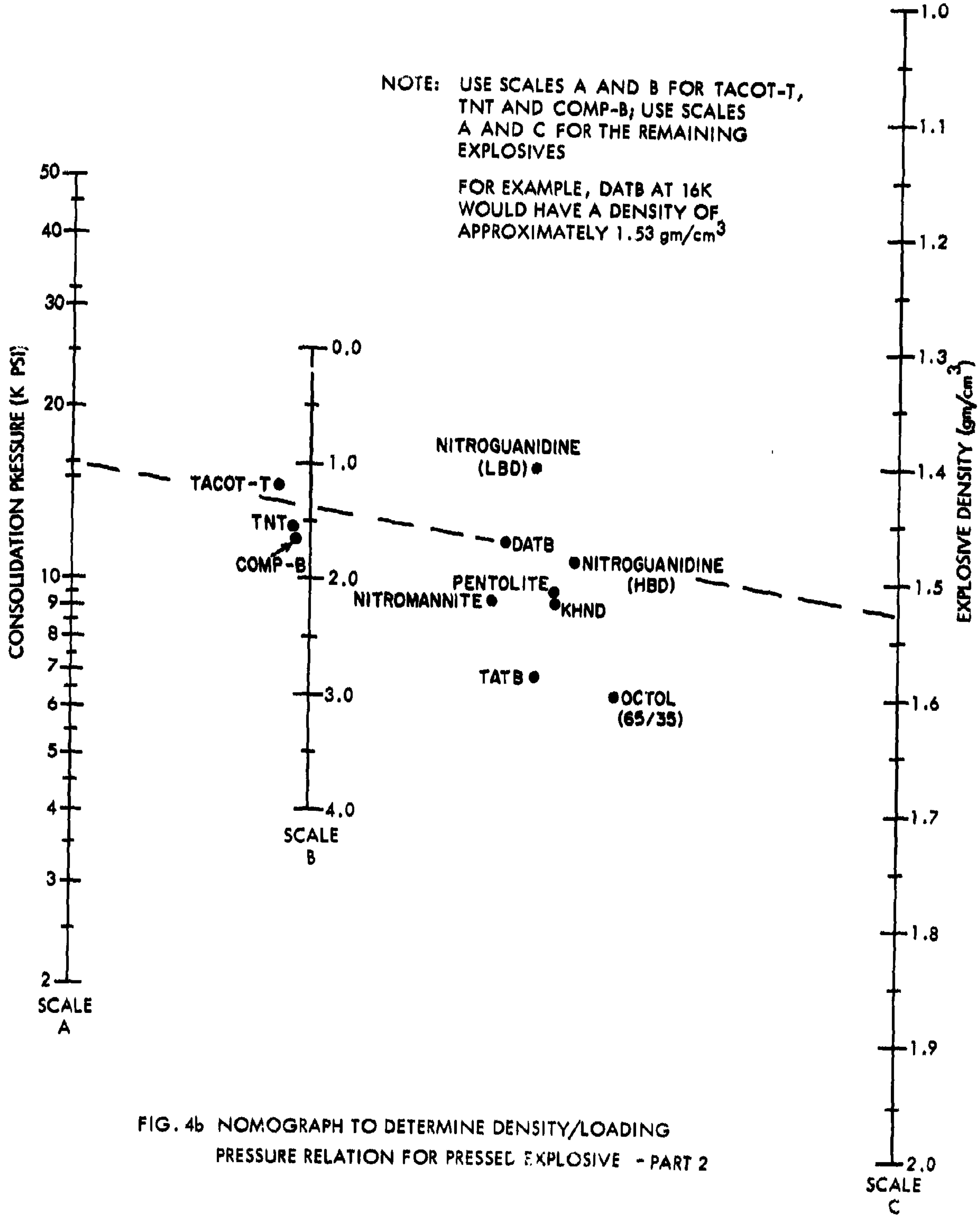


FIG. 4b NOMOGRAPH TO DETERMINE DENSITY/LOADING PRESSURE RELATION FOR PRESSED EXPLOSIVE - PART 2