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REPORT

MRL-R-929

THE INFLUENCE OF INERT PARTICULATE MATERIAL ON THE PROPERTIES OF RDX/POLYETHYLENE WAX COMPOSITIONS

William S. Wilson

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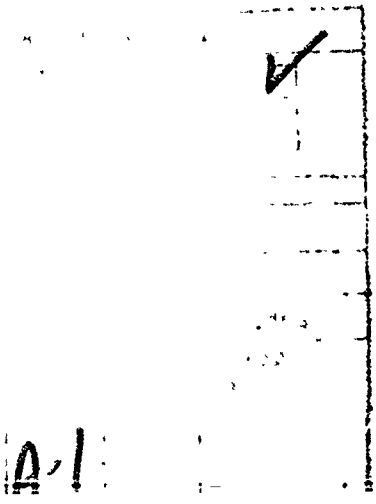

THE INFLUENCE OF INERT PARTICULATE MATERIAL ON THE PROPERTIES OF RDX/POLYETHYLENE WAX COMPOSITIONS

1. INTRODUCTION

In an earlier report (MRL-R-722) the formulation and sensitivity of a series of explosive compositions based on RDX (milled and boiled; Grade B Class 1) and a polyethylene wax were discussed. Also described in that report were compaction of those compositions by pressing and the shock sensitivity and detonation velocity of the resultant explosive charges [1]. In 1977 routine production of milled and boiled RDX ceased and all RDX manufactured in Australia since that time has been recrystallised from cyclohexanone to give a material (Grade A Class 1) with a much larger particle size. A subsequent technical note (MRL-TN-436) described similar explosive formulations and charges prepared from this grade of RDX [2].

In these formulations the polyethylene wax acts first as a phlegmatiser or desensitiser, reducing the sensitivity of the RDX to such stimuli as electrostatic discharge, friction and mechanical impact, and second as a binder for the RDX when the molding powder is consolidated into a charge by pressing. It was also shown that shock sensitivity of the compacted explosive (ease of initiation by an incident shock wave) increases with increasing density (i.e. decreasing voidage) and decreases with wax content (i.e. decreasing RDX). Further, velocity of detonation also increases with density and decreases with wax content.

These relationships allow the "tailoring" of RDX/polyethylene wax charges with specific properties to meet a given requirement. However a greater range of properties might be obtainable by the inclusion of other inert solid materials, and this paper describes the formulation of such charges and the effects on sensitivity and performance of such properties as the density, hardness and particle size distribution of these added materials.

2. EXPERIMENTAL

2.1 Materials Used

Materials used in this study include the emulsifiable polyethylene wax AC 629 (mp. 101-105°; specific gravity 0.93) manufactured by Allied Chemicals Ltd, RDX milled and boiled (Grade B Class 1) and RDX recrystallised from cylcohexanone (Grade A Class 1) (Hardness 2.5; specific gravity 1.82) manufactured by Albion Explosives Factory, natural graphite powder (hardness 1; specific gravity 2.25), fine ground haematite (Fe_2O_3, specification TS 652) (hardness 7; specific gravity 5.64) and four grades of silicon carbide (carborundum) (hardness 13; specific gravity 3.22). Particle size distributions for the RDX and inert solids were determined by sieve analysis and/or sedimentography (Shimadzu Sedimentograph SA-2), and the results were processed to give values for median and number or weight average particle sizes. These values are present in Table 1.

TABLE 1: PARTICLE SIZE OF EXPLOSIVE AND NON-EXPLOSIVE SOLIDS

	MEDIAN (μm)	NUMBER AVERAGE (μm)	WEIGHT AVERAGE (μm)
Explosives			
RDX Milled & Boiled (Grade B Class 1).	75	45	95
RDX Recrystallised (Grade A Class 1).	240	89	230
Non-explosives			
Graphite	38	34	37
Haematite	7	2	8
Silicon Carbide (Carborundum)			
Grade 1	29	24	31
Grade 2	37	25	39
Grade 3	64	53	64
Grade 4	190	150	190

2.2 Preparation of RDX/Inert/Polyethylene Wax Compositions

Explosive formulations with nominal wax content 8% by weight were prepared following the AWRE wax emulsion process described previously [1]. Briefly, an emulsion of the polyethylene wax in water, oleic acid and morpholine was added to a slurry of RDX and the inert solid in water, and the emulsion was broken by the addition of dilute sulphuric acid to the hot mixture (95° C). After repeated washing with distilled water to removal all traces of acid and with 0.05% aqueous methyl p-hydroxybenzoate to inhibit fungal attack on the wax, the explosive formulation was dried to constant weight and submitted for analysis of wax and RDX.

2.3 Evaluation of Explosive Properties

Compositions were prepared using milled and boiled RDX (92-72% by weight) and graphite (0-20%), and using milled and boiled RDX (92-72%) and haematite (0-20%). These compositions were analysed, and subjected to the Rotter Impact Test to determine impact sensitivity. They were then pressed into 2.5 g pellets at about 94.5% theoretical maximum density, 12.7 mm in diameter and about the same length. The pellets were pressed individually in a nest of five moulds, using as a press an INSTRON Universal Testing Machine TT-CM operating in the compression mode with an FRM-Type load cell. For all pressings a two minute dwell time was adopted, and the lowest possible cross head speed (viz. 0.5 mm min^{-1}) was used for application of the pressing load. The explosive pellets so formed were subjected to the Gap Test to determine shock sensitivity, and finally their velocity of detonation was measured using the ionization probe technique.

At this stage the supply of milled and boiled RDX was suddenly and unexpectedly exhausted, and subsequent compositions had to be formulated from recrystallised RDX. Compositions were prepared as previously from 8% by weight of polyethylene wax with recrystallised RDX (92-72%) and each grade of silicon carbide (0-20%) as the inert solid. These compositions were analysed and subjected to Rotter Impact Testing, and those prepared from the finest grade of silicon carbide, Grade 1, were pressed into pellets at 93.5% theoretical maximum density for measurement of shock sensitivity and detonation velocity. Finally the remaining compositions were pressed into pellets for measurement of shock sensitivity.

3. RESULTS AND DISCUSSION

3.1 Impact Sensitivity

The impact sensitivity of an explosive powder is measured at MRL using the Rotter Impact Test described by Mortlock and Wilby [3]. Briefly, a sample of a few milligrams of composition in a metal cap is placed between a striker and an anvil, and a [illegible] weight is dropped from a known height onto the striker. The test is repeated with the drop height being decreased or

increased depending on whether the result of the preceding test was an "explosion" or not, the criterion for an "explosion" being the evolution of not less than 1 ml of gas recorded by a special gas measuring burette. The 50% "explosion" height is calculated using the Bruceton method [4], and a Figure of Insensitiveness (F of I) is obtained by comparison with the 50% "explosion" height for a special grade of RDX used as a standard and to which an F of I of 80 is assigned. The value of F of I gives a measure of the ease of initiation on impact while the volume of gas evolved on "explosion" gives a guide to the ease of propagation.

Dempster showed that particles larger than 10 μm sensitised liquid explosives such as blasting gelatin (92% nitroglycerine thickened with 8% nitrocellulose) to initiation by impact, while particles smaller than 3 μm desensitised them [5]. Hall and Coley examined the effect of small quantities of grit (Kieselguhr) on pure explosives, and demonstrated that the relationship between grit concentration and F of I could be approximated by a hyperbola. These observations were explained in terms of a "saturation" process, taking place as potential hot spot sites are progressively occupied [6]. Scullion examined the influence of several grits, at loadings of up to 5%, on several explosives and compositions. He observed a similar relationship between impact sensitivity and added grit, which he called the "law of diminishing effect", but preferred to characterise this relationship as an exponential equation[7]. Neither relationship was intended to be extrapolated to high grit concentrations, while at low concentrations (say less than 1%) the two treatments are equivalent.

The influence of inert solid on the impact sensitivity of compositions prepared from milled and boiled RDX (92-72%), polyethylene wax (8%) and graphite or haematite (0-20%) is shown in Figure 1. Both graphite and haematite sensitise this RDX/wax formulation to initiation by impact, despite the small particle size of the latter inert. In each case impact sensitivity increases with increasing additive in qualitative agreement with Scullion's law of diminishing effect. However in neither case could the behaviour over the whole range of concentrations be described adequately by either exponential or hyperbolic functions. In the case of the compositions containing graphite, impact sensitivity appears to decrease above about 12% graphite, a trend which might be attributed to dilution of the explosive. This effect is not observed in the case of the compositions containing haematite. It should also be noted that the impact sensitivities of the two series of compositions do not differ by more than 10 F of I units, the accuracy to which results are normally reported. It appears that the effects of the different material properties of the two additives, such as density, hardness and particle size, have essentially cancelled each other out.

The influence of silicon carbide on the impact sensitivity of compositions prepared from recrystallised RDX (92-72%), polyethylene wax (8%) and the four grades of silicon carbide is illustrated in Figure 2. These results are not directly comparable with those of Figure 1 because of the difference in RDX particle size, but the trends may be compared. Again impact sensitivity increases with increasing silicon carbide, reaches a maximum sensitivity in the range 6-12% additive, and then decreases again. As previously this behaviour may be interpreted as a sensitisation following the law of diminishing effect, overlaid by a simple dilution effect as the

explosive is replaced by inert material. It was also observed that sensitisation by a given concentration of silicon carbide increased with particle size - i.e. decreased with surface area of added inert - but that the magnitude of this effect decreased as particle size increased. The explanation of this result is unclear.

3.2 Shock Sensitivity

Dempster showed that blasting g latin could be sensitised to shock initiation by the presence of inert particles of specific gravity greater than 2.8, and snowed moreover that the optimum particle size lay in the range 0.5-10 μm [5]. Avogadro confirmed that these were necessary but not sufficient conditions for shock sensitisation of blasting gelatin by inert materials. In general, those materials which satisfied these conditions and yet proved not to act as sensitisers had a hardness of less than 3, and it is suggested that these particles were pulverised by the incident shockwave to an ineffective particle size range [8,9].

The sensitivity of an explosive to shock initiation is measured at MRL using an adaption of the Gap Test of Cachia and Whitbread [10] described recently by Wolfson [11]. Briefly, a standard detonator (normally the Scale 1 Gap Test Donor, comprising an exploding bridgewire to initiate a low density PETN pellet and hence a high density PETN pellet) generates a standard shock wave which is attenuated by a stack of laminated 0.05 mm brass shims 25 mm square. The attenuated shock wave strikes the receptor or test explosive, usually a cylindrical pellet 24.5 mm long and 12.7 mm in diameter, which rests on a mild steel witness block. The test is repeated with the gap thickness being increased or decreased depending on whether the result of the previous result was a detonation or not, the criterion for a detonation being a deep, sharply defined dent in the witness block. Normally 25 "shots" are fired after the approximate median point has been established, and the results are analysed by the Bruceton method [4] to give a critical height at which 50% detonations in the test explosive are prevented.

The influence of inert solid on the shock sensivitiy of compositions prepared from milled and boiled RDX (92-72%) polyethylene wax (8%) and graphite or haematite (0-20%) is shown in Figure 3. In neither case did the presence of the inert additive sensitise the explosive formulation to shock initiation, and the influences of these materials may be characterised by a gradual but steady decrease in sensitivity. Clearly the effectiveness of these additives in sensitising homogeneous liquid explosives cannot be transposed to heterogeneous solid compositions which already contain the discontinuities required for hot spot initiation.

The influence of the finest grade of silicon carbide on the shock sensitivity of compositions prepared from recystallised RDX (92-72%), polyethylene wax (8%) and silicon carbide (0-20%) is illustrated in Figure 4. Once again these results are not directly comparable with those shown in Figure 3 because of the difference in RDX particle size. However the trend is the same, showing a steady decrease in shock sensitivity with increasing inert additive. Again there is no indication of sensitisation of the formulation.

The shock sensitivity of various compositions prepared from recrystallised RDX, polyethylene wax and other grades of silicon carbide are presented in Table 2. Unfortunately there are no discernible trends in these data, but as with previous formulations there is no indication of sensitisation by the inert additive.

TABLE 2: SHOCK SENSITIVITY OF COMPOSITIONS PREPARED FROM RECRYSTALLISED RDX (92-72%), POLYETHYLENE WAX (8%) AND SILICON CARBIDE (0-20%) (MM BRASS)

Composition	Grade 1 (29 μm)	Grade 2 (37 μm)	Grade 3 (64 μm)	Grade 4 (186 μm)
92:8:0	1.35			
91:8:1	1.35	1.22	1.37	1.40
90:8:2	1.25	1.35	1.22	1.37
88:8:4	1.08			
84:8:8	1.05	1.22	1.36	1.30
80:8:12	0.77			
76:8:16	0.63	1.42	1.14	0.88
72:8:20	0.56			

3.3 Velocity of Detonation

The velocity of detonation of an explosive charge is usually measured at MRL by high speed streak photography or by ionisation probe techniques. The latter technique was employed for the current study. Ten pellets of explosive 12.7 mm in diameter and about the same length were measured accurately and stacked end-on-end, with two brass strips 2 mm wide and 0.05 mm thick placed about 2 mm apart between each pair of pellets to act as ionisation probes. A voltage source was applied between the brass probes, the assembly was initiated by an exploding bridgewire detonator, and the electrical impulses produced by capacitor discharge as the detonation front passed each ionisation probe were recorded using a time calibrated oscilloscope. The velocity of detonation was calculated from the inter-probe distances and the time between pulses.

The influence of added inert materials on the velocity of detonation of RLX/polyethylene wax formulations cortaining graphite, haematite and silicon carbide is illustrated in Figures 5, 6 and 7 respectively. As expected, in each case the velocity of detonation showed a linear decrease with increasing inert. The initial velocity of detonation (i.e. that for the composition without additive) is somewhat lower in Figure 7, as a consequence of a slightly lower density (93.5% as opposed to 94.1 and 94.3%) and a slightly higher wax content (8.6% rather than 8.2 and 8.1%). The lower density probably arises from the larger RDX particle size, while the increased

wax content was an experimental error.

These inconsistencies not withstanding, it is nevertheless possible to compare the rates at which the three materials reduce the velocity of detonation of the RDX/polyethylene wax compositions. The gradients of the velocity of detonation/impurity level plots in Figures 5,6 and 7 are presented in Table 3, together with the comparable data for the polyethylene wax and voidage from the previous work [1]. The relationship between this parameter and the density of the material is illustrated in Figure 8. These results may be compared with those of Humphris and Thompson, who measured the velocity of detonation of a series of PETN, silicone rubber and inert diluent at the same concentrations by volume, and determined a linearly decreasing relationship of velocity of detonation with the density of the diluent [12]. Two theories have been proposed to account for the reduction of velocity of detonation by inclusion of inerts. In the first Cook suggested that the decrease is due largely to compression of the inert in the reaction zone [13]. In the second Taylor discounted this mechanism and proposed that the major contribution arises from loss of translational energy of the gases produced incurred in accelerating the diluent particles [14]. The data in Figure 8 suggest that indeed both mechanisms contribute to this phenomenon, with compression becoming more important at lower densities [i.e. for wax, and of course voidage].

TABLE 3: RATE OF REDUCTION OF VELOCITY OF DETONATION BY INERT DILUENTS

Inert Diluent	Specific Gravity	Reduction of V of D $(-\frac{dy}{dx})$
Voidage	0	93.2
Polyethylene Wax	0.93	55.4
Graphite	2.25	39.1
Silicon Carbide	3.22	28.5
Haematite	5.24	22.6

4. CONCLUSION

The impact sensitivity of RDX/polyethylene wax compositions is increased by the presence of inert materials such as graphite, haematite and silicon carbide, according to the "law of diminishing effect". Above concentrations of 6-12% of graphite or silicon carbide the impact sensitivity of the formulations appeared to decrease, this effect being attributed simply to dilution of the explosive. Differences due to density and hardness of the

additive were not discernible, but the sensitisation by silicon carbide increased with increasing particle size.

Unlike the liquid and gelatinous explosives studied by Dempster and Avogadro, the shock sensitivity of pressed RDX/polyethylene wax charges was not increased by the presence of inert particulate matter. Instead the shock sensitivity of such charges decreased with increasing concentrations of inerts in a manner which suggested simple dilution of the explosive.

The velocity of detonation of pressed RDX/polyethylene wax charges decreases with the presence of inert particulate material. The extent of this reduction decreases with increasing density, and appears to result from absorption of the detonation energy by the inert material as kinetic energy and by compression of that material.

5. ACKNOWLEDGEMENTS

The author is pleased to acknowledge the contribution of others to this project. In particular, impact sensitivies were measured by Explosives Testing Group, while shock sensitivities and velocities of detonation were measured by Explosives Instrumentation Group.

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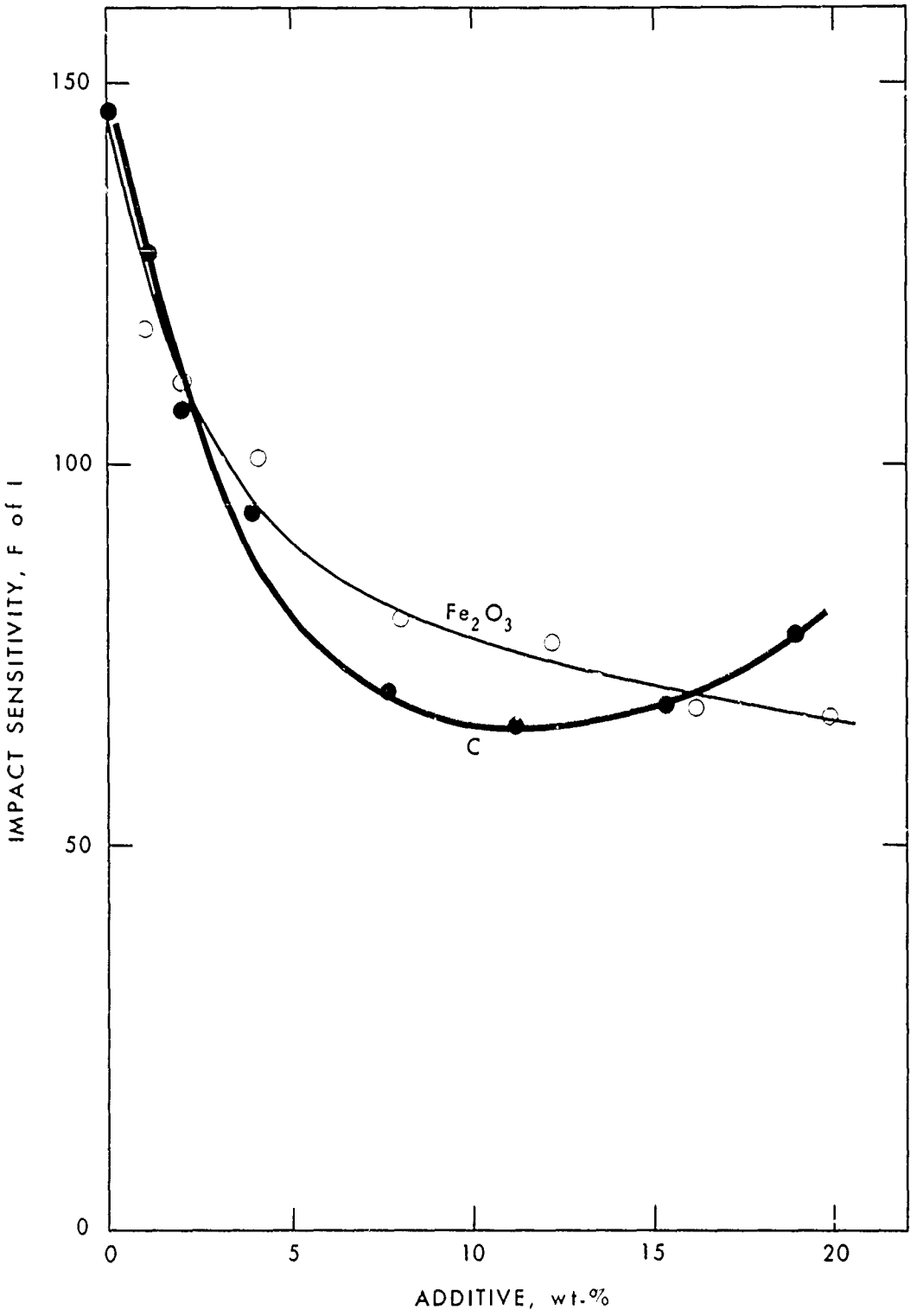

Figure 1. Impact Sensitivity of RDX (Milled and Boiled)/Wax Compositions Containing Graphite and Haematite.

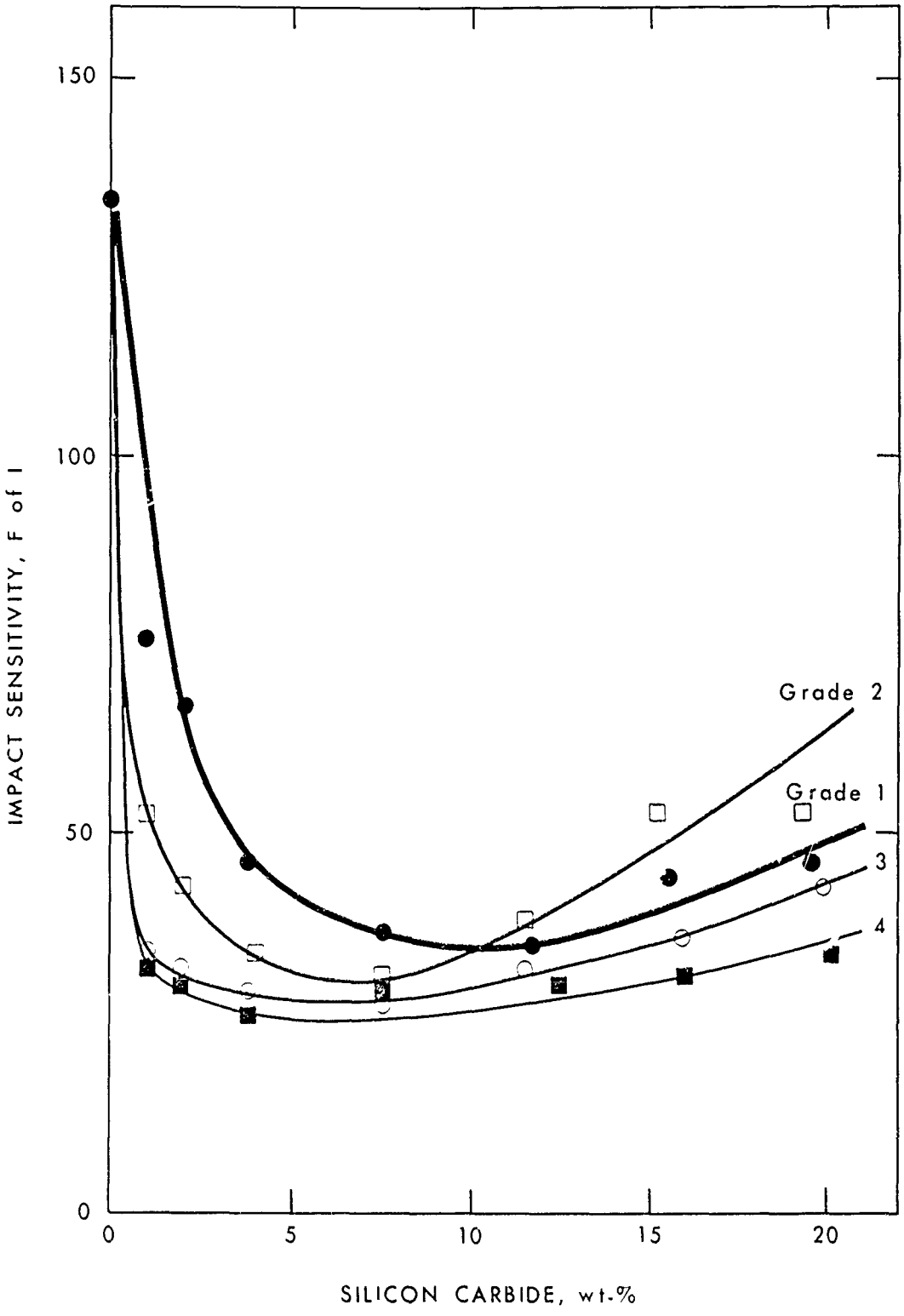

Figure 2. Impact Sensitivity RDX (Recrystallised)/Wax Compositions Containing Silicon Carbide.

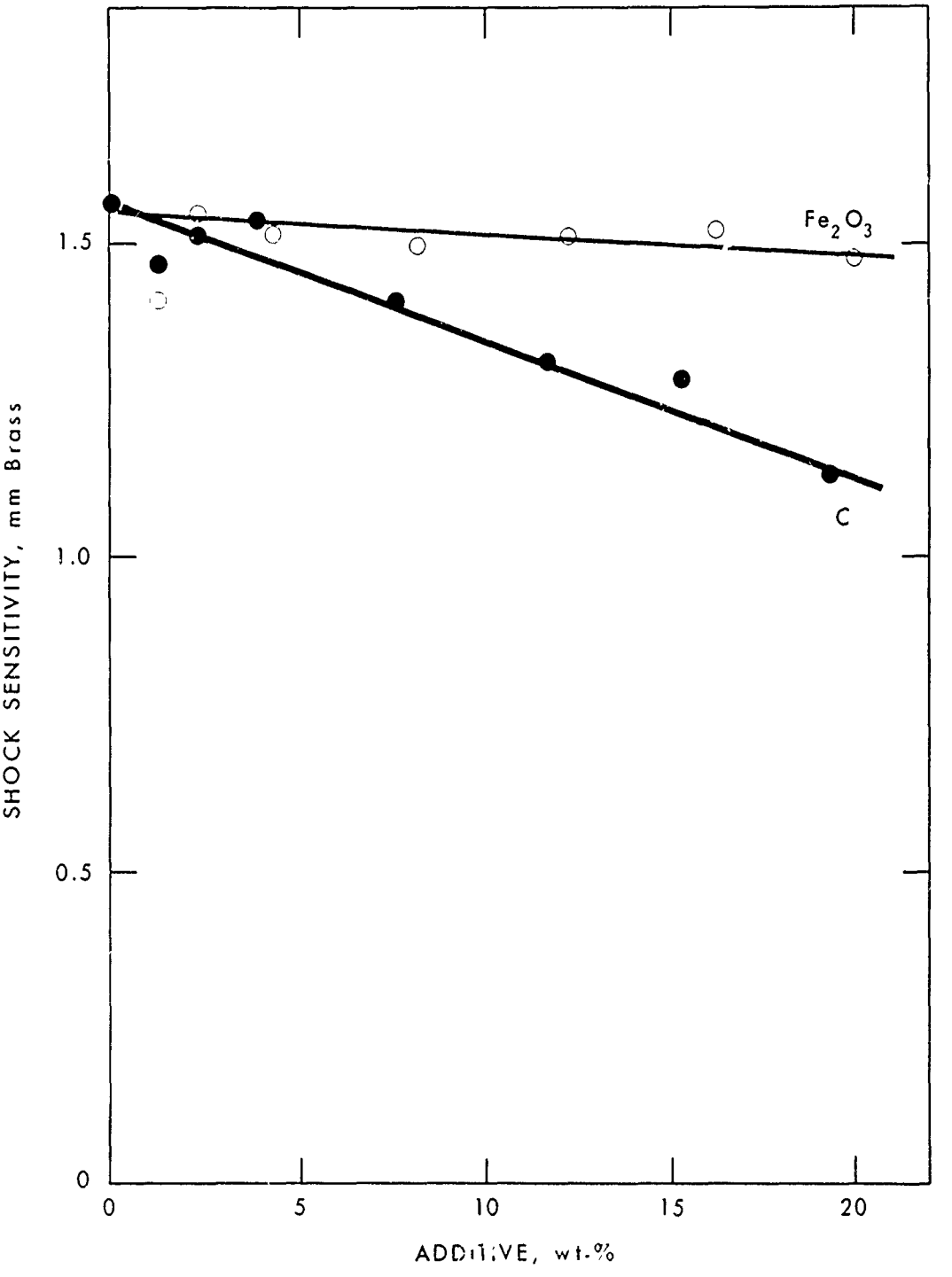

Figure 3. Shock Sensitivity of RDX (Milled and Boiled)/Wax Charges Containing Graphite and Haematite.

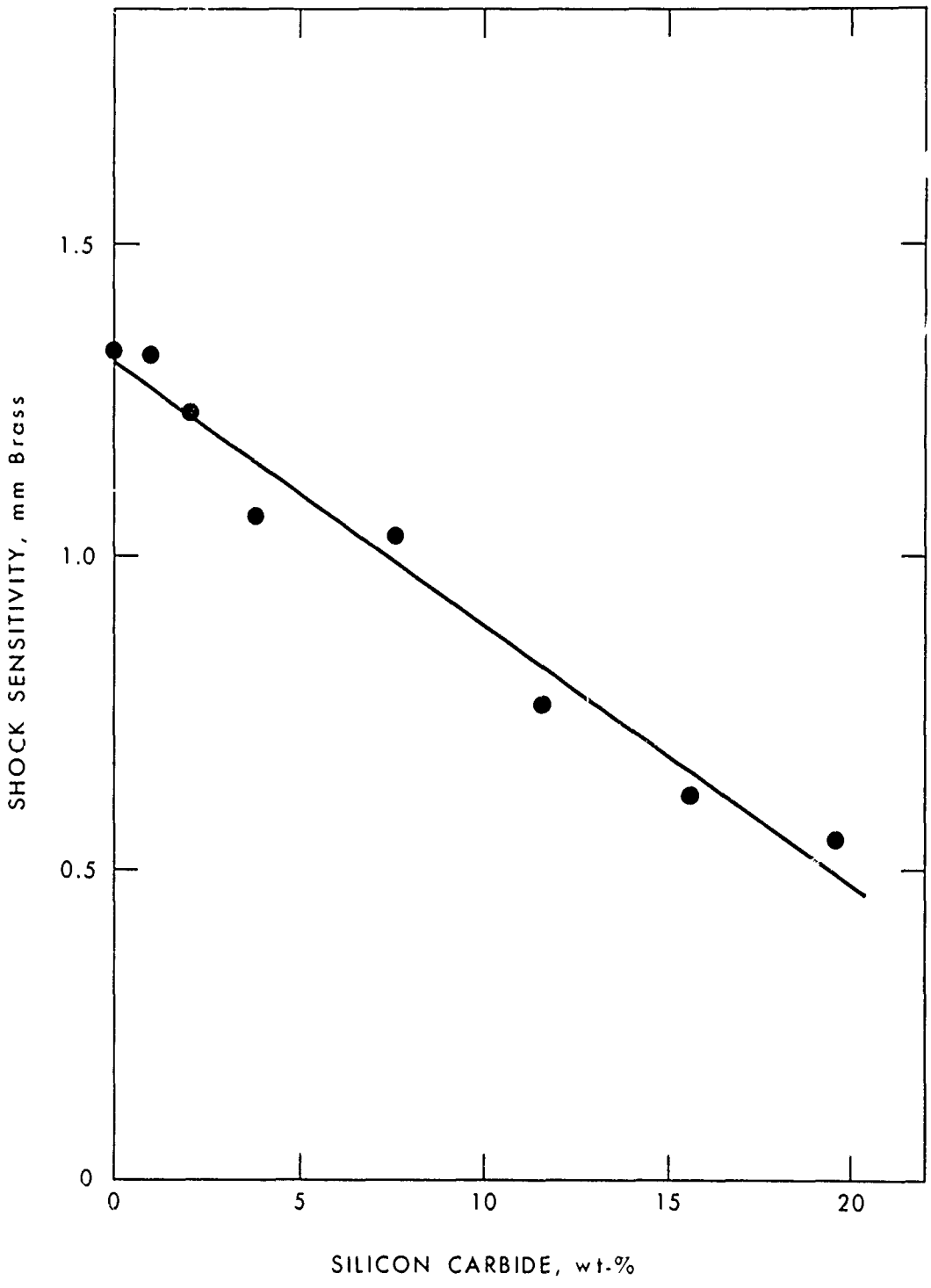

Figure 4. Shock Sensitivity of RDX (Recrystallised)/Wax Charges Containing Silicon Carbide.

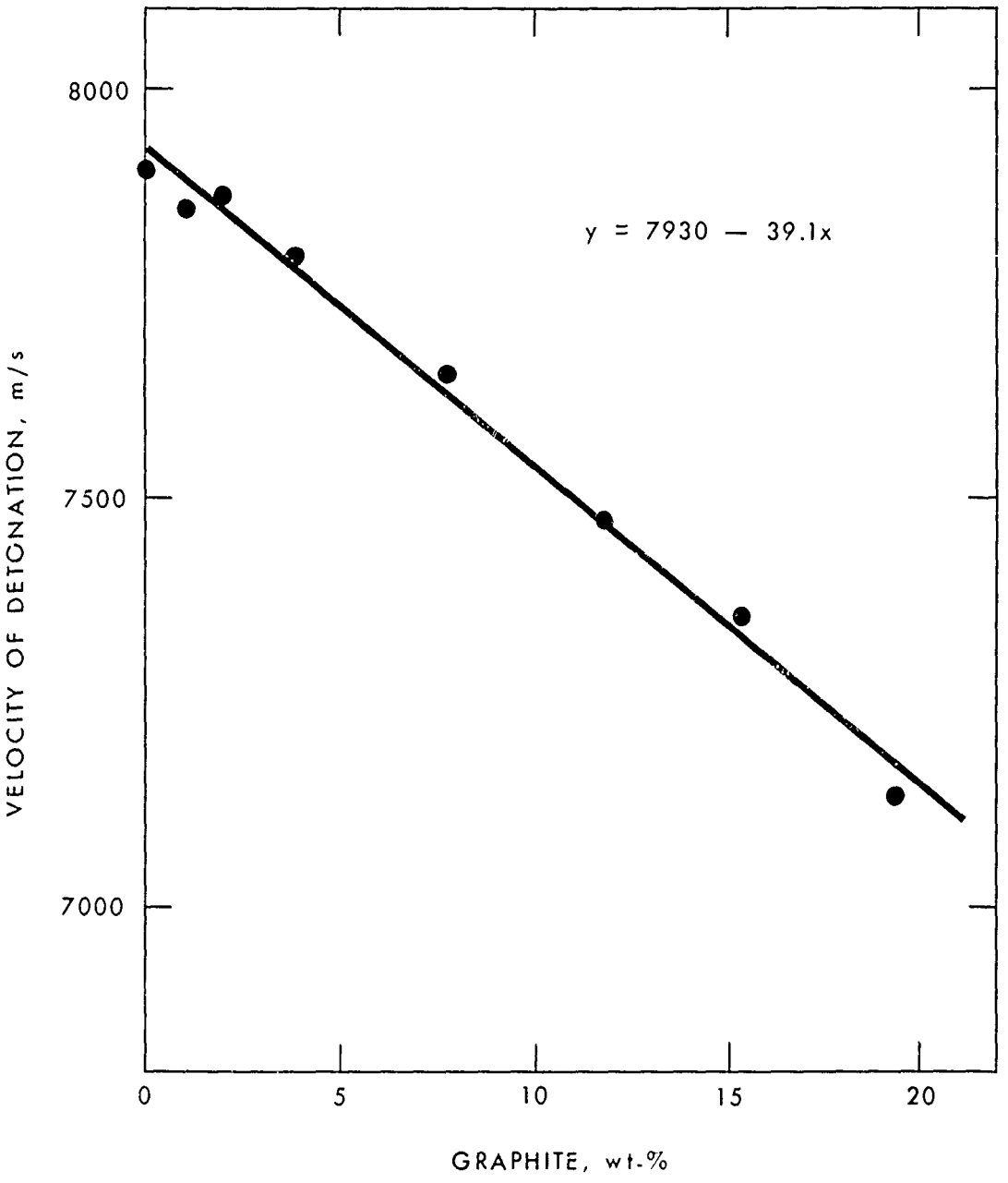

Figure 5. Velocity of Detonation of RDX (Milled and Boiled)/Wax Charges Containing Graphite.

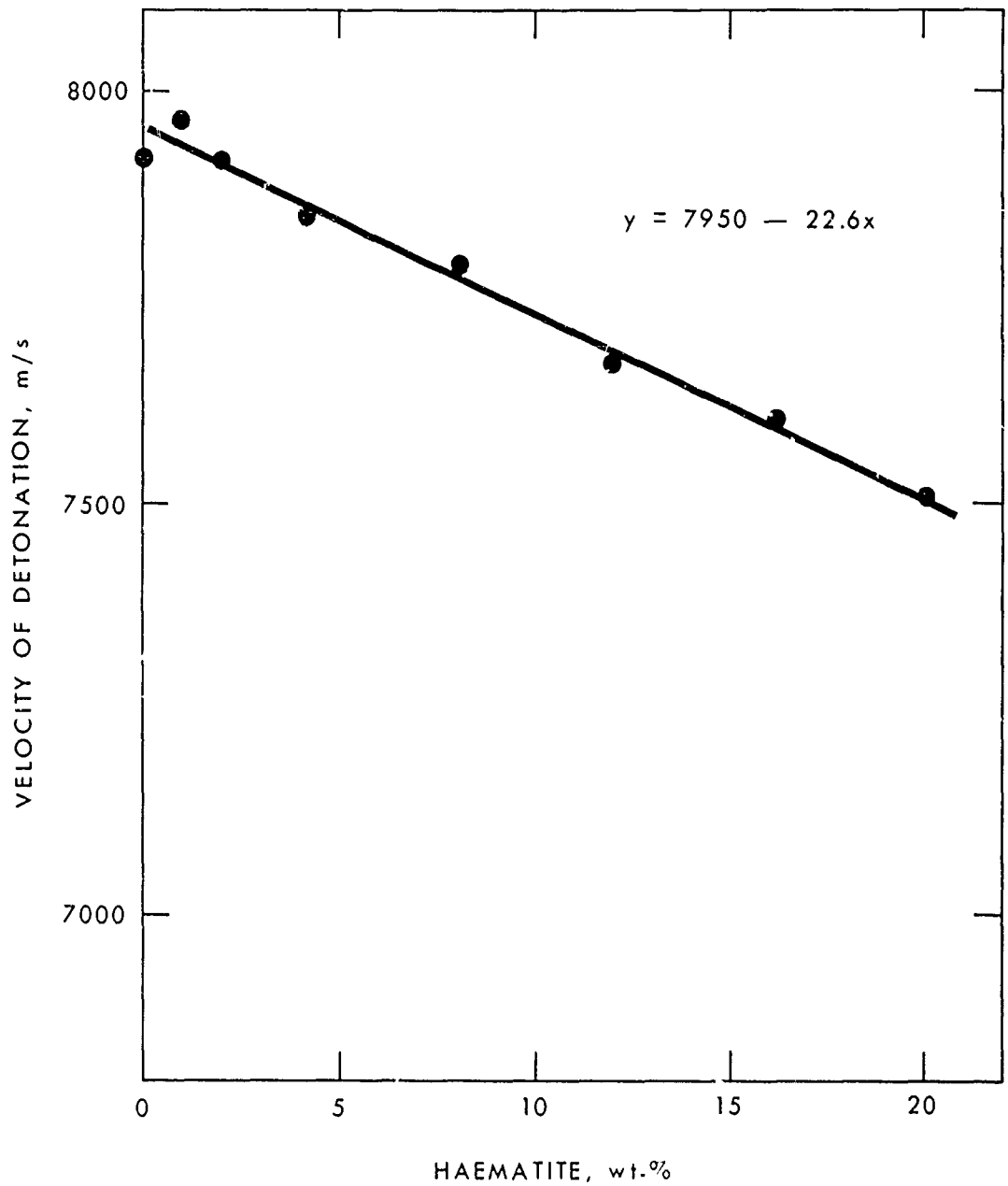

Figure 6. Velocity of Detonation of RDX (Milled and Boiled)/Wax Charges Containing Haematite.

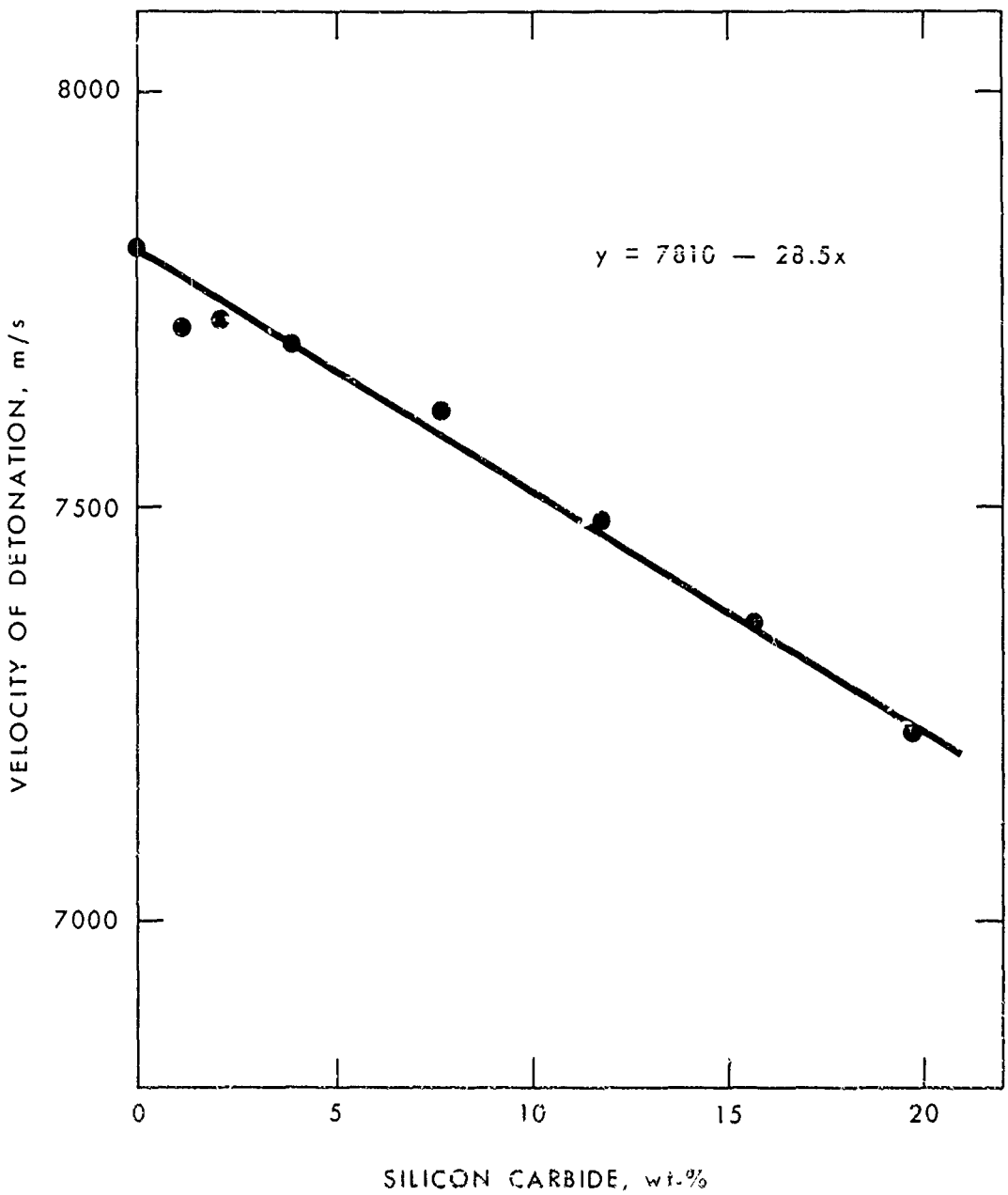

Figure 7. Velocity of Detonation of RDX (Recrystallised)/Wax Charges Containing Silicon Carbide.

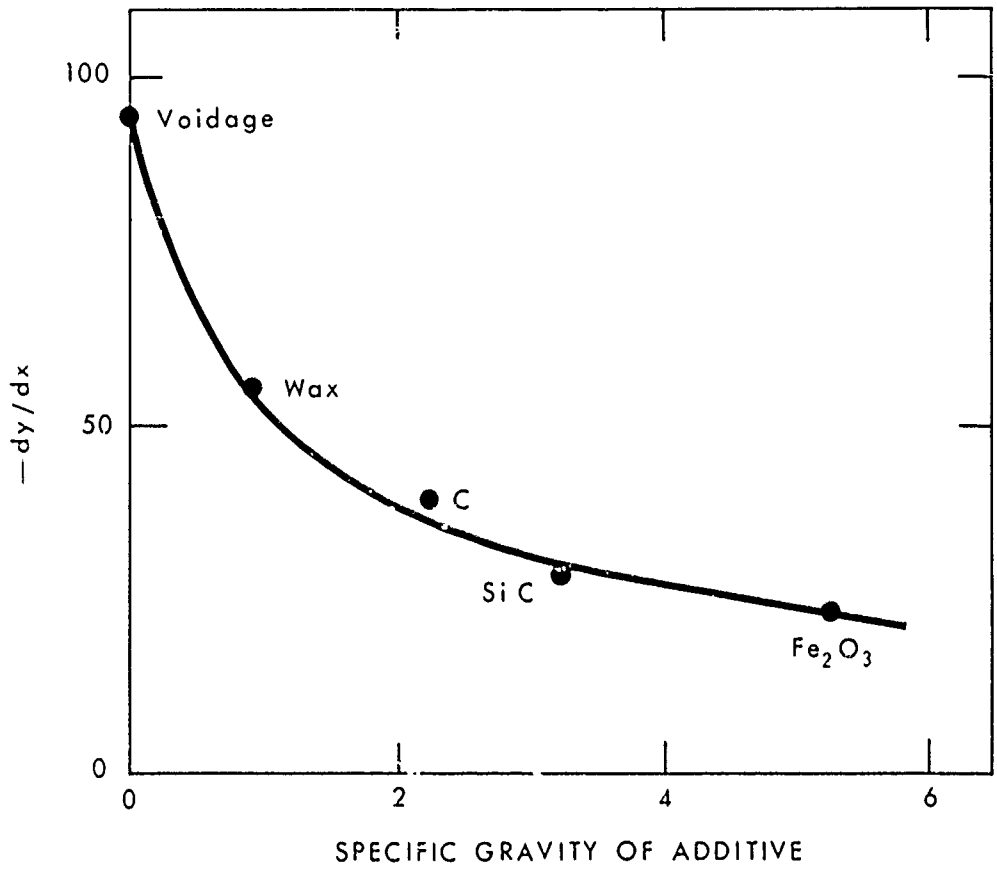

Figure 8. Dependence of Velocity of Detonation on Density of Inert Additive.

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