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TECHNICAL REPORT 3252

THE EFFECTS OF PROCESSING ON PYROTECHNIC INGREDIENTS

PART I: COMPRESSIBILITY OF POWDERED MAGNESIUM AND SODIUM NITRATE AT CONSOLIDATED PRESSURES TO 10,000 PSI

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SEPTEMBER 1965

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PICATINNY ARSENAL
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THE EFFECTS OF PROCESSING ON PYROTECHNIC INGREDIENTS.

PART I: COMPRESSIBILITY OF POWDERED MAGNESIUM AND SODIUM NITRATE AT CONSOLIDATION PRESSURES TO 10,000 PSI

by

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Dept of the Army Project 1C523801A302

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OBJECT

To investigate the problem of the nonreproducibility of the illuminance and burning rate characteristics of consolidated pyrotechnic systems by studying the effect of consolidation on the ingredients used in typical systems.

SUMMARY

Nonreproducibility of illuminance levels and burning rates has long been a problem with pyrotechnic compositions. This shortcoming has been evident not only in batch-to-batch operations but also within single blends.

One aspect of this problem is the effects of blending and consolidation on the shape and size of the particles. It is obvious that, if the effects of consolidation pressure on particle size, permeability, or porosity vary excessively, such variations may cause nonreproducible end-item performance.

An investigation revealed that, with 44-, 124-, and 347-micron sodium nitrate, increasing the loading pressures to 10,000 psi causes regular decreases in permeability and porosity. The 44- and 124-micron fractions showed little or no particle size change with increasing consolidation pressure, while the 350-micron fraction showed a regular decrease.

When 28.3- and 187-micron atomized magnesium powders were similarly consolidated and evaluated, their particle sizes were found to remain constant while their permeability and porosity decreased with increasing loading pressure.

The data revealed no erratic trends in particle size, permeability, or porosity. The values obtained showed trends consistent with the plasticity and frangibility of the ingredients. It was concluded, therefore, that consolidation per se is not the cause of the nonreproducibility observed in the performance of pressed pyrotechnic end items.

INTRODUCTION

The problem of nonreproducible illuminance and burning rate characteristics has long plagued personnel concerned with the blending and loading of pyrotechnic compositions. The causes and control of this difficulty have been known only to a limited extent. Before this investigation, no significant progress toward the solution of this problem had been reported. Hence, in an attempt to eliminate the expenses of retesting necessitated by the nonreproducibility of the data and to gain insight into the causes of that nonreproducibility, this program was initiated.

From the outset, it was recognized that many variables would have to be considered. Errors associated with the problem of nonreproducibility may be attributed to the following: failure to reproduce processing operations (mixing or blending, and consolidation), lack of precision in weighing operations, variations in particle size and/or shape of ingredients in compositions, variations in case size before and after compaction, variations in chemical properties of ingredients, and finally, lack of precision in measurement and testing methods. The core of the problem lies in isolating and minimizing the factors responsible for all substantial variations in end item performance. Once this was accomplished, specifications could be developed which would adequately control these factors.

It was hypothesized that, of the many possible causes of nonreproducibility, failure to reproduce processing operations may be of greatest significance. If, for example, consolidation leads to irregular particle sizes or percentage voids (porosities) for identically prepared items, or mixing or blending fails to produce adequate homogeneity in identical compositions, then it is obvious that variations in performance will result.

Because of the variety and complexity of the factors involved in the processing operations, it was considered desirable to isolate each operation and study it separately. The effects of consolidation pressure on performance characteristics were considered first. It was decided that the individual ingredients should be studied separately instead of in the compositions that contain them. This procedure would establish which if any of the ingredients were responsible for any marked performance variations. Because of the important role that particle size plays in the performance of consolidated pyrotechnic items, measurements of both particle size and porosity (ratio of the volume of void space in a material to its mass) were made. One further observation should be made. There still remains the possibility

that all of the ingredients in a composition might have identical particle sizes and total porosities but be packed nonuniformly so as to cause variations in composition performance, Hence, in addition to porosity and particle size, permeability was determined. Permeability is concerned with the relative distance between particles measured in terms of the degree of compactness of the system in which they are consolidated. Dallavalle (Ref 1) defines permeability as the volume of a fluid of unit viscosity passing through a unit cross section of a packing under a unit pressure gradient in unit time. Permeability is expressed in Darcys, i.e., cgs units, in this study.

This report deals with variations of particle size, porosity, and permeability due to consolidation pressures. Previous studies relating consolidation pressure to porosity and particle size are described in the following paragraphs.

J. D. Latva and L. B. Robinson (Ref 2) of Wright-Patterson Air Force Base issued "Fundamental Studies of Compressibility of Powders," which treats the following materials: magnesium, tungsten, thoria, silica, molybdenum disulfide, and tantalum carbide. The authors conclude that compressibility takes place via plastic deformation or fragmentation. They disagree with earlier findings by such authors as Heckel (Ref 10), and Cooper and Eaton (Ref 3), who believe that particles fragment and/or rearrange to fill voids. Latva and Robinson's report contains photographs indicating that particles do not slide past one another during compaction. In their report, porosity, density, and particle size are shown to vary as functions of consolidating pressure. These writers also show photographs that indicate particle breakage of oxidants subjected to consolidation. However, no attempt was made to demonstrate any relationship between pressure and the extent of particle breakage after compaction.

A paper by R. P. Seelig (Ref 4) refers to work by M. Balshin, who claims that the initial pressure required for shifting metal particles and breaking existing bonds between them is higher for fine powders, finer particles permitting better flow and causing better filling of voids. This relationship will be considered later in this report.

W. D. Jones (Ref 5) discusses the mechanism of metal powder consolidation and concludes that in order to weld two surfaces together it is necessary that both surfaces be clean and that they be brought together in perfect contact. Perfect contact, he states, is generally prevented by contaminating

films (dust, oxides, etc.) and by the resistance of the metal to deformation. He points out that, as the pressure applied increases and the pore space between the particles gets smaller, the volume within each particle which has reached the fully plastic condition has to increase until the last remaining trace of porosity is closed up by extrusion of the material of the particles into the residual porosity. He further reasons that each sphere will squash downwards and the top and base of each flattened sphere will increase in area to sustain the load. The width of each flattened sphere, he discloses, remains the same if the number of spheres in a cross section of the die remains constant. Complete closing up of porosity, Jones indicates, is expected at pressures of the order of the "pressure of fluidity" reported by O'Neill and Greenwood (Ref 6).

RESULTS

Oxidant Study

The oxidant used in this investigation was powdered sodium nitrate in fractions of three different sizes: fine (44 microns), medium (124 microns), and coarse (347 microns). Each granulation was consolidated into ½-inch-ID kraft paper cases at pressure levels ranging from 2,000 to 10,000 psi. These cased ingredients were then tested for particle size, permeability, and porosity. Five trials were run at each pressure level. Data for the averages of the five trials is found in Tables 1, 2, and 3 (pp 13, and 14) for the fine, medium, and coarse fractions, respectively.

The relationship between permeability and the extent of particle breakage due to pressure was established for the oxidant. Figure 1 (p 20) shows for each fraction a curve relating the two parameters. Equations for the log function of each line are also given.

Observation of pressed sodium nitrate revealed that particles nearest the point of contact with the ram appear to be smaller and more closely packed than particles further down the column. In order to examine variations in this effect, an experiment was designed using the coarse sodium nitrate items previously consolidated. At each pressure level, an item was selected and sectioned into three equal portions. All of these portions were tested for permeability. The data obtained appears in Table 4 (p 14). A composite permeability value for the three sections of each column was calculated using Darcy's equation for nonuniform beds. The composite values are compared in Table 5 (p 15) with those obtained for the total unsectioned column.

The three fractions of sodium nitrate are compared by showing in a single table the three parameters studied (particle size, permeability, and porosity). This data maybe found in Table 6 (p 16).

Fuel Study

The fuel used in this investigation, atomized magnesium powder, was studied in the same manner as was the sodium nitrate with the following exceptions. The number of fractions used was reduced to two, fine (28 microns) and coarse (187 microns), in an attempt to expedite the program. None of the items were sectioned and tested for variations as they were for the oxidant. At the lower loadingpressures, the material did not pelletize; this prevented the study of pellets formed at such pressures. Finally, the particle size measurements made at each pressure level during testing of the oxidant were omitted for the fuel. It was decided that magnesium particles were sufficiently hard to allow the careful separation of particles in the pressed column so that the unconsolidated particle bed could be tested for average particle size by air permeability in a normal fashion. It was further decided to test for particle size at the unconsolidated and the 10,000-psi pressure levels initially, since further testing would be unnecessary if particle size remained constant.

Data for the average of five runs on the permeability and porosity parameters may be found in Tables 7 and 8 (pp 17 and 18), for a coarse fraction and a fine fraction, respectively.

Data for the particle sizes of each fraction tested at the unconsolidated and the 10,000-psi pressure levels is shown in Table 9 (p 18). Photomicrographs of these fractions at unconsolidated and 10,000-psi pressure levels may be found in Figure 2 (p 21).

Data comparing the two fractions by using the three parameters employed for test measurements appears in Table 10 (p 19).

DISCUSSION OF RESULTS

Oxidant Study

The three fractions of sodium nitrate (fine, medium, and coarse) consolidated at seven increasing pressure levels show decreases in permeability and porosity with increasing pressures to 10,000 psi. The permeability

values at identical pressure levels decrease from fraction to fraction in the direction of coarse to fine (Table 6, p 16). These trends are expected, since with increasing pressure the data also shows increasing pressed density, apparently due to particle breakage, excess void elimination, or plastic deformation (Tables 1, 2, and 3, pp 13 and 14).

The porosities for all three fractions show nearly equal values at identical pressure levels for all three fractions, with the medium fraction very slightly below the coarse and the fine (Table 6). The results are somewhat anomalous, but when accepted point out an important relationship. For consolidation of sodium nitrate to 10,000 psi, the factor causing any significant change in the volume of void to the volume of mass of this material is not the size of the sodium nitrate particles in the packing but the pressures at which they are packed.

The particle sizes of the fine and medium fractions show a fair degree of constancy as the pressure is increased, with a slight trend toward decrease in size (Tables 1 and 2). From approximately 5,000 psi up, however, the fine fraction did show a slight increase in size. This increase was attributed to errors associated with the equations for the flow of fluids through packed beds when these equations are used to measure the average particle size of beds having very low porosities. From 2,000 psi up, the particle sizes of the medium fraction remain somewhat constant, at a level differing from the original by about 9%.

The coarse sodium nitrate fraction shows a decided decrease in particle size with increasing consolidation pressure (Table 3).

The data on permeability for the three equal lengths of sectioned items shows that the particles, voids, and densities did not retain their original uniformity on pressing but developed gradients (Table 4, p 14). The particles involved were more loosely packed at the unpressed end of the column than they were at the pressed end of the column. The reason for this gradual change in permeability is probably particle breakage and the elimination of excess voids as pressure is applied and transferred throughout the column. The composite permeability value for the three equal sections of the column was found to be nearly identical to the permeability value for the total unsectioned system, as Darcy (Ref 1) predicts (Table 5, p 15). It is thought that these gradients resulting from the consolidation of sodium nitrate would have little or no effect on the reproducibility of performance characteristics. The gradients produced would cause variation in the performance of a single

item (due to nonuniformity), but the change should be regular and, other things being equal, reproducible.

Earlier in this report a reference was made to Balshin's work (Ref 4) on shifting metal particles in which he found that the initial pressure required for shifting metal particles and breaking the existing bonds between them is higher for fine powder. If the particle size trend that has been apparent in this program is at all real, then Balshin's statement on the shifting of metal particles also holds true for the breaking of sodium nitrate particles.

A linear relationship was found when permeability values were plotted against particle size values on log-log graph paper for the coarse and the medium fractions. A near linear relationship was found for the fine fraction. This slight departure from linearity is probably due to errors associated with the flow equations when they are used for beds having low porosities (Fig 1, p 20).

Fuel Study

The fine and coarse fractions of atomized magnesium powder, when consolidated at seven progressively higher pressure levels, showed decreases in permeability and porosity with increasing pressures to 10,000 psi (Table 10, p 19). The permeability values at identical pressure levels decrease from fraction to fraction in the direction of coarse to fine. These trends also were shown by the oxidant and may be explained by the same reasoning as was used above for the sodium nitrate.

The porosity values for the fine fraction were, for the several samples tested, from 11% to 42% below similar values for the coarse fraction. This trend is in contrast with that shown by the sodium nitrate fractions. The oxidant porosities showed nearly equal values from fraction to fraction with increasing pressure. The trend in the ratio of volume of void to volume of mass shown by the oxidant is then somewhat different from that shown by the metal, for in the latter case both the original size of the particles and the pressure at which they are packed are of some significance.

The particle sizes of the coarse and fine magnesium fractions did not change after subjection to 10,000 psi of pressure (Table 9, p 18). It is thought that up to this pressure level no significant plastic deformation occurs, but rather that density is raised through the elimination of excess voids or (though this hypothesis is questionable) through particle shift. These changes would result in decreases in porosity and permeability.

Microscopic examination revealed no discernible change in the shape or size of the fine or coarse magnesium particles at 10,000 psi (Fig 2, p 21).

CONCLUSIONS AND RECOMMENDATIONS

1. No irregularities that could be attributed to consolidation at pressures to 10,000 psi were evident in the behavior of either sodium nitrate or atomized magnesium powder. Regular decreases in permeability, porosity, and, in some cases, particle size occurred as expected when the ingredients were subjected to increasing pressures. In cases where the particle size values did not decrease, it appeared that no particle breakage had occurred. None of the above trends are thought to be responsible for irregularities in pressed compositions which might cause nonreproducible performance. Therefore, it is concluded that consolidation per se is reproducible, and that any errors resulting from pressing operations may be attributable to mistakes in reading the pressure gage, variations in precision of equipment performance, inaccuracies in weighing or height measurement, etc. The installation of automated pressing equipment should substantially reduce these types of errors.

2. It is recommended that, in future reproducibility studies, attention be centered on the particle size distribution of pyrotechnic ingredients prior to their incorporation into compositions. Current specifications may allow for differences in size distribution sufficient to result in nonreproducible performance.

EXPERIMENTAL PROCEDURES

Loading

Twenty-eight ⅝-inch-ID kraft paper cases were used to load 22.57 grams of sodium nitrate in one increment. Four of these items were pressed at each of seven pressure levels up to 10,000 psi. This pressing procedure was used for both the coarse (347 microns) and the medium (124 microns) oxidant fractions. For the fine fraction, a charge weight of 6.77 grams was used. These weights, 22.57 grams (ten times the density of sodium nitrate) and 6.77 grams (three times the density of sodium nitrate), were used so that the particle size analysis of the pressed ingredient could be made by air permeability.

The same procedure was used for the fuel. Charge weights used were 17.40 grams (ten times the density of magnesium) for the coarse (187 micron) fraction and 5.22 grams (three times the density of magnesium) for the fine (28.3 microns) fraction.

Materials

The following materials were used for this program:

Magnesium Fractions. Type I, nominal mesh sizes 200/325 and 50/100. Supplied by Valley Metallurgical Processing Co. in accordance with Specification MIL-P-14067A. Average particle size by air permeability

Coarse fraction, 187 microns

Fine fraction, 28.3 microns

Sodium Nitrate Fractions. Supplied by Davies Nitrate Company in accordance with Specification MIL-S-322B. Average particle size by air permeability

Coarse fraction, 347 microns

Medium fraction, 124 microns

Fine fraction, 44 microns.

Testing

Average Particle Size Measurements

To determine the average particle size by air permeability of pressed ingredients, paper cases $\frac{5}{8}$ inch in inside diameter were used. This diameter is the same as that of the sample tube used with the PA Particle Size Apparatus. A weight ten times the density was used for materials having an original average particle size greater than 100 microns. A weight three times the density was used for materials between 30 and 100 microns. This is the procedure usually followed. The porosities due to pressing were lower than those usually permitted for such analyses.

It is understood that questions will be raised as to the validity of air permeability size measurements made by the Gooden-Smith equation on pressed ingredients, since this technique was designed for use on uniform

beds with porosities in the range of 40 to 70%. The authors realize that other investigators, such as Herdan (Ref 8), have pointed out that, since the permeability constant varies with porosity, the equation cannot strictly be used to give absolute values. Consideration has also been given to Ergun's findings (Ref 9) in which he reports that as a porous material is broken into smaller pieces the particle density is increased by the elimination of pores in the course of breakage. This is another way in which porosity is dependent on particle size. Recognizing the above limitations it was decided that the particle size measurements as presented would give some idea of the breakage that takes place when particles are consolidated to 10,000 psi. The values are not to be considered absolute.

The scope of this report does not allow for a complete description and explanation of the methods employed in determining average particle size by means of the Fisher Sub-Sieve Sizer and the Picatinny Arsenal Air Permeability Apparatus. Such information may be found in the Handbook of Particle Size Procedures (Ref 7) used in the Pyrotechnics Laboratory.

The Fisher apparatus in normally used to make determinations on materials under 100 microns in average particle size, and the Picatinny Arsenal Particle Size Apparatus is used for material from 44 to 1000 microns in average particle size.

Permeability Measurements

The permeability measurements made on the items as described were computed using Darcy's Law (Ref 1) for the flow of fluids through packed beds. This law defines permeability as follows:

$$P = \frac{uqL}{A\,(P_1 - P_2)}$$

where:

q = volume of fluid flowing per unit time through a cross sectional area A of a packing L units in length

P = permeability

u = viscosity of the fluid

A = cross sectional area of bed

L = dept of bed

$(P_1 - P_2)$ = pressure difference between extremes of section L

The particle size apparatus was used as a flowmeter in order to maintain a constant pressure head and to keep this pressure head consistent with the one used for particle size analysis. The wet test meter was calibrated and used to measure the volume of air passing through the packing in a given time interval.

Porosity

The porosity of the items was computed by using the following relationship (Ref 8):

$$P = \frac{V_a - V}{V_a} \times 100$$

where:

P = porosity (expressed as a percentage)

V_a = apparent volume of the compressed powder (cubic centimeters)

V = actual volume (i. e. weight of powder taken divided by its specific gravity in cubic centimeters)

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TABLE 1

Effects of compression on a fine fraction of sodium nitrate consolidated at pressures to 10,000 psi*

Consolidation Pressure, psi	Average Permeability Value, Darcys	Average Particle Size P.A. Sizer, microns	Average Porosity, % void	Pressed Density, g/cc
0	0.0628	44	43	1.276
2,000	0.0085	39	30	1.583
3,000	0.0064	36	28	1.615
4,000	0.0030	34	25	1.689
5,000	0.0021	36	21	1.784
6,500	0.0011	47	14	1.930
8,000	0.0007	38	14	1.935
10,000	0.0004	46	11	2.035

*Original average particle size: 44 microns. Sample weight: 6.771 grams.

TABLE 2

Effects of compression on a medium size fraction of sodium nitrate consolidated at pressures to 10,000 psi*

Consolidation Pressure, psi	Average Permeability Value, Darcys	Average Particle Size P.A. Sizer, microns	Average Porosity, % void	Pressed Density, g/cc
0	0.201	124	37	1.411
2,000	0.075	113	29	1.597
3,000	0.040	119	25	1.692
4,000	0.023	112	21	1.784
5,000	0.015	117	18	1.855
6,500	0.008	116	14	1.948
8,000	0.003	109	9	2.032
10,000	0.002	118	7	2.108

*Original average particle size: 124 microns. Sample weight: 22.57 grams.

TABLE 3

Effects of compression on a coarse fraction of sodium nitrate consolidated at pressures to 10,000 psi*

Consolidation Pressure, psi	Average Permeability Value, Darcys	Average Particle Size P.A. Sizer, microns	Average Porosity, % void	Pressed Density, g/cc
0	0.833	347	35	1.466
2,000	0.343	341	30	1.578
3,000	0.101	300	23	1.748
4,000	0.057	261	21	1.792
5,000	0.035	250	18	1.847
6,500	0.013	244	15	1.930
8,000	0.007	232	11	2.013
10,000	0.002	195	10	2.095

*Original average particle size: 347 microns. Sample weight: 22.57 grams.

TABLE 4

Permeability values for three equal sections of selected coarse sodium nitrate columns that had undergone consolidation at pressure levels to 10,000 psi

Consolidation Pressure, psi	Permeability Darcys		
	Pressed End	Middle Portion	Unpressed End
2,000	0.197	0.307	0.359
3,000	0.070	0.108	0.196
4,000	0.041	0.079	0.136
5,000	0.027	0.048	0.081
6,500	0.011	0.019	0.027
8,000	0.003	0.007	0.016
10,000	0.002	0.003	0.003

TABLE 5

A comparison of Darcy* composite permeability values for three equal sections of a column with like values for the total unsectioned column of selected coarse sodium nitrate

Consolidation Pressure, psi	Permeability Value for Complete Column, Darcys	Composite Permeability for Three Sections, Darcys
2,000	0.343	0.269
3,000	0.101	0.104
4,000	0.057	0.067
5,000	0.035	0.043
6,500	0.013	0.016
8,000	0.007	0.008
10,000	0.002	0.003

*Darcy's equation for permeability of nonuniform beds when flow is perpendicular to sections (Ref 1) is

$$P = \frac{\sum_{n=1}^{n=n} L_n}{\sum_{n=1}^{n=n} \frac{L_n}{P_n}}$$

where

L_n = the sum of length of the sections

P_n = the sum of the permeability of the sections

n = the number of sections

P = composite permeability

TABLE 6

A comparison of effects of compression on three sodium nitrate fractions (coarse, medium and fine) at consolidation pressures to 10,000 psi

Consolidation Pressure, psi	Permeability, Darcys			Porosity, % void			Particle Size, microns		
	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
0	0.833	0.201	0.0628	35	37	43	347	124	44
2,000	0.343	0.075	0.0085	30	29	30	341	113	39
3,000	0.101	0.040	0.0064	23	25	28	300	119	36
4,000	0 057	0.023	0.0030	21	21	25	261	112	34
5,000	0.035	0.015	0.0021	18	18	21	250	117	36
6,500	0.013	0.008	0.0011	15	14	14	244	116	47
8,000	0.007	0.003	0.0007	11	9	14	232	109	38
10,000	0.002	0.002	0.0004	10	7	11	195	118	46

TABLE 7

Effects of compression on a coarse fraction of atomized magnesium powder at consolidation pressures to 10,000 psi*

Consolidation Pressure, psi	Average Permeability, Darcys	Average Porosity, % void	Pressed Density, g/cc
0	0.468	37	1.114
2,000	0.528	36	1.117
3,000	0.462	35	1.136
4,000	0.458	33	1.163
5,000	0.483	34	1.158
6,500	0.340	30	1.208
8,000	0.274	28	1.250
10,000	0.248	26	1.293

*Original average particle size: 187.0 microns (50/100 mesh). Sample weight: 17.4 grams.

TABLE 8

Effects of compression on a fine fraction of atomized magnesium powder at consolidation pressures to 10,000 psi*

Consolidation Pressure, psi	Average Permeability, Darcys	Average Porosity, % void	Pressed Density, g/cc
0	0.008	33	1.169
2,000	0.007	30	1.218
3,000	0.006	29	1.236
4,000	0.004	27	1.276
5,000	0.003	25	1.312
6,500	0.003	21	1.359
8,000	0.002	18	1.399
10,000	0.001	15	1.464

*Original average particle size: 28.3 microns (200/325 mesh). Sample weight: 5.22 grams.

TABLE 9

The average particle size as determined by air permeability for coarse and fine fractions of atomized magnesium powder at unconsolidated and 10,000 psi pressure levels

Magnesium Fraction	Average Particle Size, microns	
	Unconsolidated	Consolidated at 10,000 psi
200/325 mesh	28.3	27.5
50/100 mesh	187.0	189.7

TABLE 10

A comparison of the effects of compression on
fine and coarse (200/325 and 50/100 mesh) fractions of
atomized magnesium powder at consolidation pressures to 10,000 psi

Consolidation Pressure, psi	Permeability, Darcys		Porosity, % void		Particle Size, microns	
	Coarse	Fine	Coarse	Fine	Coarse	Fine
0	0.468	0.008	37	33	187.0	28.3
2,000	0.528	0.007	36	30		
3,000	0.462	0.006	35	29		
4,000	0.458	0.004	33	27		
5,000	0.483	0.003	34	25		
6,500	0.340	0.003	30	21		
8,000	0.274	0.002	28	18		
10,000	0.248	0.001	26	15	189.7	27.5

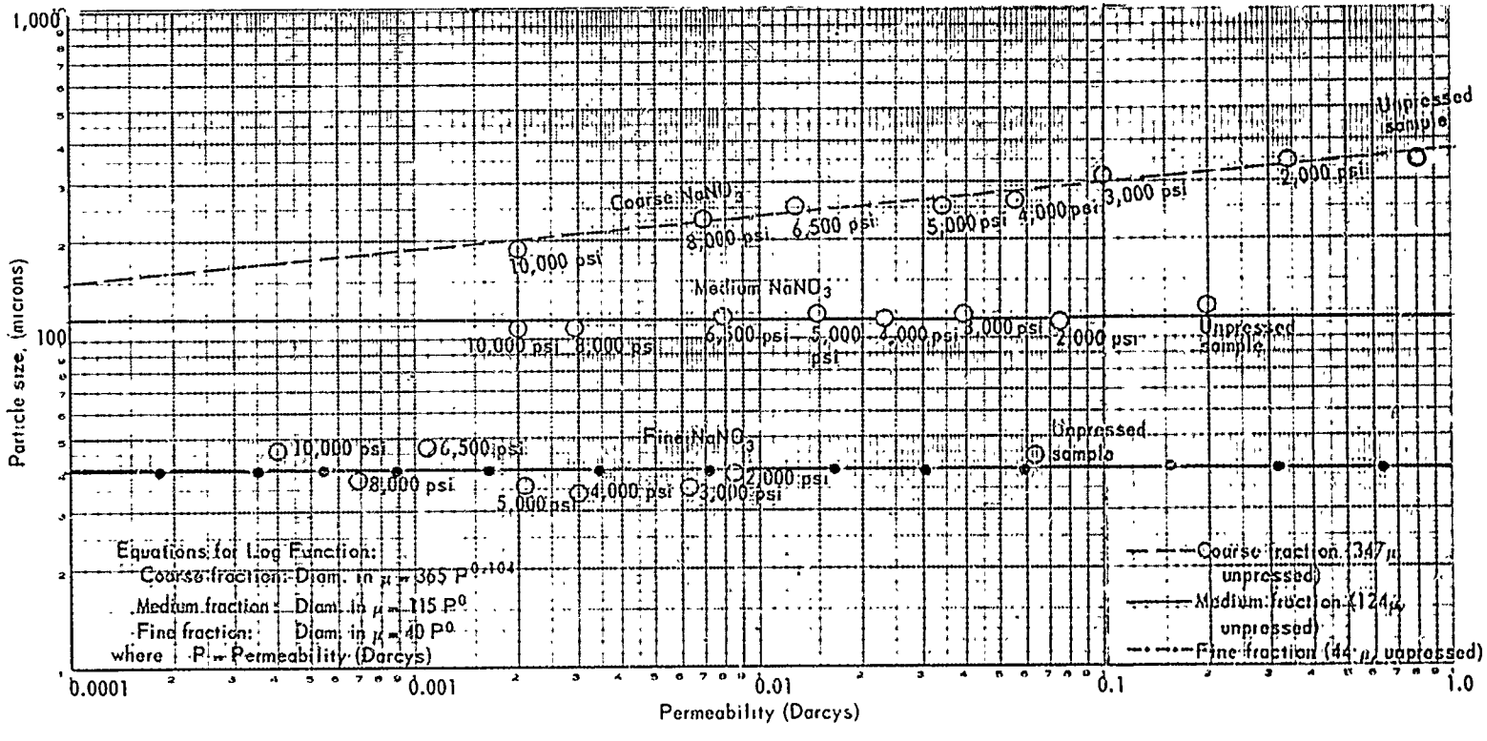
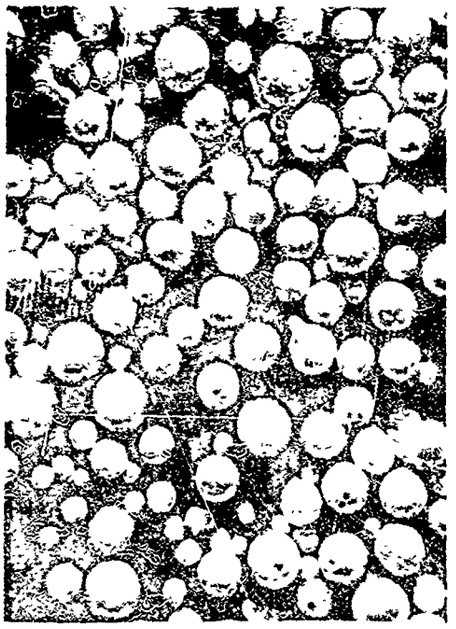
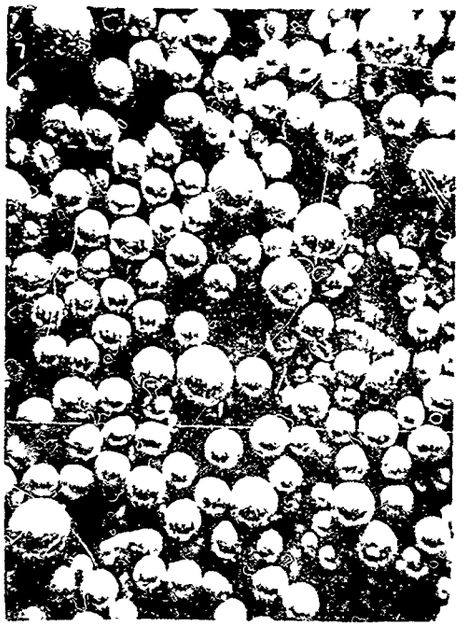


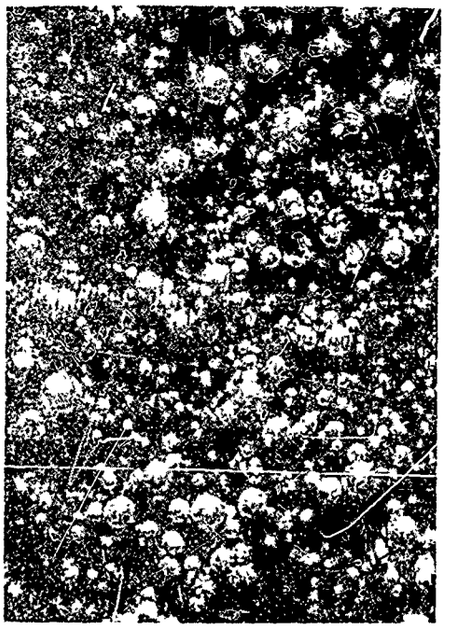
Fig 1 Particle size as measured by the air permeability method vs permeability (Darcys) for pressed sodium nitrate fractions



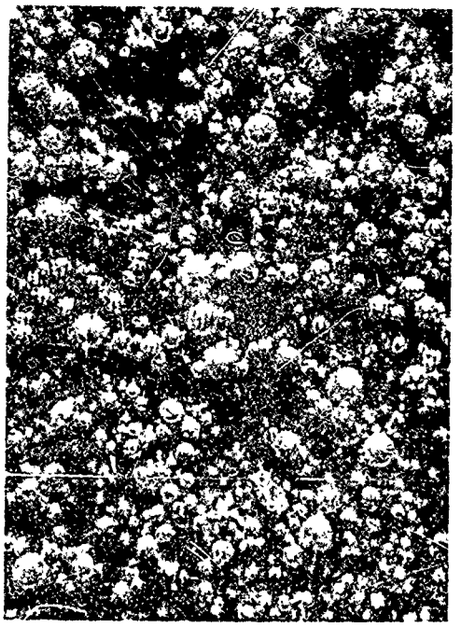
Mg (189.7 microns) pressed at 10,000 psi; magnification, 35 X; scale: 1 inch equals 785 microns



Mg (187.0 microns) unconsolidated; magnification, 35 X; scale: 1 inch equals 785 microns



Mg (28.3 microns) pressed at 10,000 psi; magnification, 100 X, scale: 1 inch equals 265 microns



Mg (27.5 microns) unconsolidated; magnification, 100 X; scale: 1 inch equals 265 microns

Fig 2 Photomicrographs of magnesium powder fractions at unconsolidated and 10,000 psi pressure levels

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13. ABSTRACT

Nonreproducibility of illuminance levels and burning rates has long been a problem with pyrotechnic compositions. This shortcoming has been evident not only in batch-to-batch operations but also within single blends.

One aspect of this problem is the effects of blending and consolidation on the shape and size of the particles. ~~It is obvious that~~, if the effects of consolidation pressure on particle size, permeability, or porosity vary excessively, such variations may cause nonreproducible end-item performance.

An investigation revealed ~~that, with 44-, 124-, and 347-micron sodium nitrate,~~ increasing the loading pressures to 10,000 psi* caused regular decreases in permeability and porosity. The 44- and 124-micron fractions showed little or no particle size change with increasing consolidation pressure, while the 350-micron fraction showed a regular decrease.

When 28.3- and 187-micron atomized magnesium (Mg) powders were similarly consolidated and evaluated, their particle sizes were found to remain constant while their permeability and porosity decreased with increasing loading pressure.

The data revealed no erratic trends in particle size, permeability, or porosity. The values obtained showed trends consistent with the plasticity and frangibility of the ingredients. It was concluded, ~~therefore~~, that consolidation per se is not the cause of the nonreproducibility observed in the performance of pressed pyrotechnic end items.

* on 44, 124 and 347 micron $NaNO_3$

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Powdered magnesium						
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