

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

NAVORD REPORT NO. 1337
REPORT NO. 1258

EXPLOSIVES DEVELOPMENT

18th Partial Report

INERT LOADING OF MUNITIONS

FINAL Report

Copy No. 50

Task

Assignment MPG-Re2c-18-1-53

Classification CONFIDENTIAL

54AA-26142

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Inert Loading of Munitions
-----PART ASYNOPSIS

1. Various military activities have undertaken and reported investigations of mixtures recommended for use in the inert loading of munitions. However, the densities of available mixtures have not included those required from time to time by projects assigned to the Naval Proving Ground. Therefore, it was necessary to develop inert mixtures, covering a wide density range, which would be inexpensive and easy for non-technical field personnel to mix and pour, and which would develop compressive strengths approximately the same as those of the specific explosive loads to be used ultimately.

2. Data presented in this report include density curves, relative compressive strengths, and field results for both wet and dry-mix inert fillers made by mixing Portland cement with varying proportions of light aggregates (such as vermiculite, granulated cork, and perlite) or heavy aggregates (such as iron filings and granular lead). The wet-mix inert fillers recommended cover the density range from 1.35 to 6.50 grams per milliliter, whereas data for dry-mixes are for the density ranges from 0.65 to 0.975 and from 1.50 to 2.70 grams per milliliter, respectively. In order to obtain reproducible results, all munitions were sealed from the atmosphere immediately after filling.

3. It is pointed out that because of probable variations in particle size (and therefore density) of light or heavy aggregates obtained from different sources throughout the country, the density curves presented should be considered as approximations only. It is likely that each activity utilizing these data will find it necessary to make minor variations in the amount of aggregate added in order to obtain the desired densities. This is particularly true of dry mixtures, in which the degree and duration of tamping or settling are major factors.

4. Because of lower material cost and greater relative compressive strength after setting, it is recommended that wherever possible, perlite be used as the light weight aggregate in wet-loading munitions in which the inert material should have a final density of from 1.35 to 2.05 grams per milliliter.

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PART B

INTRODUCTION

1. AUTHORITY:

These tests were authorized and conducted in accordance with reference (a).

2. REFERENCES:

- a. BJORD Conf ltr Re2c-WEL:rbm Ser S18-1 of 25 Mar 1953
- b. NPG Report No. 663 of 20 Oct 1950

3. BACKGROUND:

Considerable experimental work has been undertaken by various military activities in an effort to develop a suitable material for the inert loading of munitions.

Reference (b) presented density curves, ranging approximately from 1.2 to 1.85 grams per milliliter, obtained by using vermiculite - Portland cement - water mixtures in which the munition remained open from zero to 28 days after pouring, together with one curve for an identical inert mixture in which the system was closed from the atmosphere immediately after filling. Tests indicated that the compressive strength of the set material (closed system) is lower than that of material of comparable density which remained open after pouring, although both methods of filling have proved satisfactory for inert loading.

Because the closed system procedure is known to be more reproducible (for example, the material density shows negligible change after the munition is filled and closed), it is recommended for use whenever conditions permit.

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4. OBJECT OF TEST:

Using the closed system only, the object of this test was:

a. To vary the proportions by weight of Portland cement - vermiculite - water in order to obtain the maximum compressive strength of set material, together with satisfactory fluidity on initial mixing, throughout the density range from 1.35 to 2.05 grams per milliliter.

b. To attain the same objective, but using 20-30 mesh granulated cork instead of vermiculite.

c. To obtain similar data as in a. and b. by the use of perlite, instead of vermiculite or cork.

d. To vary the weight ratios of Portland cement - iron filings - water to cover the density range from 2.05 to 2.95 grams per milliliter.

e. To vary the weights of Portland cement - granular lead - water to obtain densities from 2.85 to 6.50 grams per milliliter.

f. To vary the weight proportions (dry mix) of Portland cement - vermiculite to obtain densities from 0.65 to 0.975 grams per milliliter.

g. To repeat f. above using 20-30 mesh granulated cork instead of vermiculite.

h. To repeat f. above but using perlite instead of vermiculite or cork.

i. To vary the weight proportions (dry mix) of Portland cement - iron filings to obtain densities from 1.50 to 2.70 grams per milliliter.

5. PERIOD OF TEST:

a. Date Project Letter	25 March 1953
b. Date All Necessary Material Received	3 April 1953
c. Date Commenced Test	11 July 1952
d. Date Completed Test	7 October 1953

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-----PART CDETAILS OF TEST

6. DESCRIPTION OF TEST EQUIPMENT:

a. Small scale laboratory mixing was done manually in a 12" x 12" x 3" Pyrex glass tray.

b. Mixing in the field for larger munitions was accomplished by means of a 4-bag capacity mortar mixer powered by a 2-horsepower gasoline engine.

c. Compressive strength tests were run on a Baldwin-Southwark Universal Testing Machine, insofar as possible in accordance with A.S.T.M. Method C192-49.

7. PROCEDURE:

The following materials were used:

a. Various brands of Portland cement, at approximately \$0.75-0.90 per 94-lb. sack, were used; the brand used had no significant effect on the density of the inert filler. These brands included "Penn-Dixie", "Capitol", "Incor Type III High Early Strength", and others.

b. "Zonolite" Brand Vermiculite (Stabilized Concrete Aggregate) at \$1.65 per 28-lb. bag (\$1.20 per 28-lb. bag in 500 bag lots) distributed by the Vermiculite Products Company, 3100 K Street, N.W., Washington, D. C. (Main Office, Zonolite Company, 135 South LaSalle Street, Chicago 3, Illinois) and purchased from the Hudson Supply and Equipment Company, 1727 Pennsylvania Avenue, N.W., Washington, D. C. This vermiculite is so graded that at least 95% will pass a No. 3 sieve, and its 100-mesh fines content shall not exceed the A.S.T.M. standard specifications for concrete aggregate (C33-44). It weighs approximately 8 lbs/cu.ft., equivalent to a density of 0.128 grams per milliliter.

c. Granulated cork, 20-30 mesh, about 8 lbs/cu.ft., (equivalent to 0.128 g/ml) at \$1.90 per 25-lb. bag plus \$1.00 refundable bag deposit, purchased from the Maryland Cork Company, Elkton, Maryland.

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d. "Tensulate Perlite" expanded volcanic glass, about 8 lbs/cu.ft. (equivalent to 0.128 g/ml) at \$2.00 per 32-lb. bag in less than carload lots, \$1.15 per 32-lb. bag in carload lots (1000 bags), purchased from the Tennessee Products and Chemical Corporation, First American National Bank Building, Nashville 3, Tennessee. A typical screen analysis is as follows:

<u>U. S. Standard Sieve, Mesh</u>	<u>% Retained</u>	<u>U. S. Standard Sieve, Mesh</u>	<u>% Retained</u>
12	28.6	35	4.4
14	13.2	40	1.4
18	22.0	45	5.2
20	4.4	120	7.8
25	4.4	200	3.2
30	4.8	-200	<u>0.6</u>
			100.0

To summarize the above, approximately 64% is larger than 18 mesh, 24% between 18 and 50 mesh, and 12% smaller than 50 mesh.

e. Iron filings obtained from Naval Ammunition Depot, Crane, Indiana, with a screen analysis as follows:

<u>U. S. Standard Sieve, Mesh</u>	<u>% Retained</u>
40	0.0
50	61.0
120	39.0

f. Granular lead purchased from the Fisher Scientific Company, 7722 Woodbury Drive, Silver Spring, Maryland, with the following screen analysis:

<u>U. S. Standard Sieve, Mesh</u>	<u>% Retained</u>
20	1.2
30	6.4
40	10.0
50	14.7
120	42.2
200	16.2
>200	<u>9.4</u>
	100.0

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g. Tap Water

In all of the closed system tests to obtain density data from 1.35 to 2.05 grams per milliliter, varying proportions of Portland cement, light weight aggregate (vermiculite, granulated cork, or perlite) and water were mixed thoroughly, then transferred to round-bodied wide-mouth quart Mason jars and sealed. After the 14 day setting period, the jars were broken to obtain the cylindrical set material. After the ends were cut square by means of a high speed abrasive cutting disk, compressive strength measurements were made.

The following mixtures were investigated:

PORTLAND CEMENT - VERMICULITE - WATER MIXTURES
(APPENDIX (A)) (all ratios by weight)

1. Series A: 3.5/1.0 cement - water;
1.0/2.0 vermiculite - water
2. Series B: 3.0/1.0 cement - water;
1.0/3.0 vermiculite - water
3. Series C: 3.0/1.0 cement - water;
1.0/2.0 vermiculite - water
4. Series D: 3.5/1.0 cement - water;
1.0/3.0 vermiculite - water
5. Series E: 3.5/1.0 cement - water;
1.0/3.0 vermiculite greater than
16 mesh - water
6. Series F: 3.5/1.0 cement - water;
1.0/3.0 vermiculite less than
16 mesh - water

PORTLAND CEMENT - GRANULATED CORK (20-30 MESH) - WATER
MIXTURES. (APPENDIX (B)) (all ratios by weight)

7. Series H: 3.0/1.0 cement - water; 1.0/2.0 cork - water
8. Series I: 3.5/1.0 cement - water; 1.0/2.0 cork - water

PORTLAND CEMENT - PERLITE - WATER MIXTURES,
(APPENDIX (C)) (all ratios by weight)

9. Series J: 3.0/1.0 cement - water;
1.0/3.0 perlite - water

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PORTLAND CEMENT - IRON FILINGS - WATER MIXTURES,
(APPENDIX (D)) (all ratios by weight)

10. Series K: successively increasing amounts of iron filings were added to 2.0/1.0 cement - water mixtures.

PORTLAND CEMENT - GRANULAR LEAD - WATER MIXTURES,
(APPENDIX (E)) (all ratios by weight)

11. Series L: successively increasing amounts of granular lead were added to 1.67/1.0 cement - water mixtures.

PORTLAND CEMENT - VERMICULITE DRY MIXTURES,
(APPENDIX (F))

12. Series M: vermiculite was added in successively larger amounts to 200 grams of cement.

PORTLAND CEMENT - GRANULATED CORK DRY MIXTURES,
(APPENDIX (G))

13. Series N: identical with Series M except that 20-30 mesh granulated cork was used instead of vermiculite.

PORTLAND CEMENT - PERLITE DRY MIXTURES,
(APPENDIX (H))

14. Series O: identical with Series M except that perlite was used instead of vermiculite.

PORTLAND CEMENT - IRON FILINGS DRY MIXTURES,
(APPENDIX (I))

15. Series P: successively increasing amounts of iron filings were added to 200 grams of cement.

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8. RESULTS AND DISCUSSION (specific):

PORTLAND CEMENT - VERMICULITE - WATER MIXTURES,
TABLE I, FIGURE 1 (APPENDIX (A))

Series D and F of Table I gave the best results insofar as initial fluidity, wide density coverage, and final compressive strength were concerned. The optimum cement - water ratio was determined to be 3.5 to 1.0 by weight with an additional 3 milliliters of water necessary per gram of vermiculite added.

Although Series F indicated a somewhat greater compressive strength, believed to be because the vermiculite used consisted of particles less than 16 mesh, Series D data were selected for field use because no screening of the vermiculite was required.

Using the proportions from Figure 1 for a density of 1.55 grams per milliliter, and calculating the cost of Portland Cement and vermiculite at 0.85 cents per pound and 5.9 cents per pound respectively, one finds the material cost of the final material to be 0.80 cents per pound, equivalent to 77.5 cents per cubic foot.

Field results are summarized in Table II.

PORTLAND CEMENT - GRANULATED CORK (20-30 MESH) - WATER
MIXTURES, TABLE III, FIGURE 2 (APPENDIX (B))

Series H was chosen over Series I because of greater relative compressive strength and wider density coverage.

In comparison with vermiculite at the same final density (1.55 grams per milliliter), and with the cost of granulated cork at 7.6 cents per pound, the material cost of the set material per pound would be 0.89 cents or 85.7 cents per cubic foot.

Table IV summarizes actual results obtained in the field.

PORTLAND CEMENT - PERLITE - WATER MIXTURES,
TABLE V, FIGURE 3 (APPENDIX (C))

A preliminary investigation showed that a cement-water ratio of 3.0 to 1.0 was required when using a 1.0 to 3.0 perlite-water ratio, in order to obtain an initially pourable mixture throughout the density range from 1.3 to

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1.9 grams per milliliter. It will be noted from Table V that these mixtures gave higher compressive strengths for the same densities than mixtures incorporating either vermiculite or granulated cork.

In addition, the cost of this mixture at a density of 1.55 grams per milliliter, with the cost of perlite at 6.25 cents per pound, would be 0.79 cents per pound or 76.4 cents per cubic foot; this is the least expensive of the three light-weight aggregates.

If perlite were purchased in carload lots, thereby reducing its cost to 3.6 cents per pound, the final cost of the inert filler per pound would be 0.68 cents or 65.75 cents per cubic foot.

A typical calculation of the proportions of Portland cement-perlite-water necessary to produce a final density of 1.55 grams per milliliter is illustrated as follows:

From Figure 3

29 gms perlite/lb Portland cement/151.2 + (3X29) ml H₂O

29 gms perlite/lb Portland cement/238.2 ml H₂O

2726 gms perlite/94 lbs Portland cement/22391 ml H₂O

6.0 lbs perlite/sack Portland cement/5.9 gals H₂O

Conversion Factors: 1 lb = 453.6 gms
1 gal = 3785 ml

Field results are shown in Table VI.

PORTLAND CEMENT - IRON FILINGS - WATER MIXTURES,
TABLES VII AND VIIa, FIGURES 4 AND 4a (APPENDIX (D))

Compressive strengths were not determined. Two density curves, Figures 4 and 4a, constructed from information in Tables VII and VIIa respectively, are given to furnish data for filling large and small munitions. Field results are shown in Table VIII.

PORTLAND CEMENT - GRANULAR LEAD - WATER MIXTURES,
TABLES IX AND IXa, FIGURES 5 AND 5a (APPENDIX (E))

Neither compressive strengths nor field results were obtained. Two curves are presented, as in the case of iron filings, that is, for both large and small munitions.

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-----PORTLAND CEMENT - VERMICULITE - DRY MIXTURES,
TABLE X, FIGURE 6 (APPENDIX (F))

Density data are presented in Table X and Figure 6.
No field results are available.

PORTLAND CEMENT - GRANULATED CORK DRY MIXTURES,
TABLE XI, FIGURE 7 (APPENDIX (G))

Field results are given in Table XII, density determinations in Table XI and Figure 7.

PORTLAND CEMENT - PERLITE DRY MIXTURES,
TABLE XIII, FIGURE 8 (APPENDIX (H))

Tables XIII and XIV, and Figure 8 summarize the results obtained.

PORTLAND CEMENT - IRON FILINGS DRY MIXTURES,
TABLES XV, XVa AND XVI, FIGURES 9 AND 9a (APPENDIX (I))

Two density curves, the first for large and the second for small munitions, are presented in Figures 9 and 9a. These data were developed because an inert filler was required which would give minimum support to the munition wall during firing. Field results are shown in Table XVI.

DISCUSSION (general):

A compressive strength comparison among Series D (cement - vermiculite - water, Table I, Appendix (A)); Series H (cement - granulated cork - water, Table III, Appendix (B)); and Series J (cement - perlite - water, Table V, Appendix (C)) shows that for approximately the same density, the latter mixture (perlite), is the strongest of the three.

It is pointed out that because of probable variations in particle size (and therefore density) of the light or heavy aggregates obtained from different sources throughout the country, the density curves presented in this report should be considered as approximations only. It is likely that each activity utilizing these curves will find it necessary to make minor variations in the amount of aggregate added in order to obtain the desired densities. This is particularly true of dry mixtures in which the degree and duration of tamping or settling are major factors.

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PART D

CONCLUSIONS

9. Data, density curves, and field results (in most instances) are submitted which show that a munition can be wet-loaded with an inexpensive inert material possessing a satisfactory compressive strength after setting, and ranging in density from 1.35 to 6.50 grams per milliliter.

Additional data are presented for the inert loading of munitions with dry mixtures throughout the density ranges from 0.65 to 0.975 and from 1.50 to 2.70 grams per milliliter, respectively.

By closing the system immediately after filling, reproducible results can be obtained.

PART E

RECOMMENDATIONS

10. Because of lower material cost and greater compressive strength after setting, it is recommended that, wherever possible, perlite be used as the light weight aggregate in wet-loading munitions in which the inert material should have a final density of from 1.35 to 1.95 grams per milliliter.

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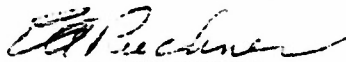
Inert Loading of Munitions

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**U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA**

**Eighteenth Partial Report
on
Explosives Development**

**Final Report
on
Inert Loading of Munitions**

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TABLE I

DATA ON
PORTLAND CEMENT - VERMICULITE - WATER MIXTURES
CLOSED SYSTEM

Per Lb Cement	SERIES A		SERIES B		SERIES C		SERIES D		SERIES E		SERIES F	
	3.5/1.0 Cement-Water 1.0/2.0 w/w	Density, Comp. Str. gm/ml Lbs/in ²	3.0/1.0 Cement-Water 1.0/2.0 w/w	Density, Comp. Str. gm/ml Lbs/in ²	3.5/1.0 Cement-Water 1.0/3.0 w/w	Density, Comp. Str. gm/ml Lbs/in ²	3.5/1.0 Cement-Water 1.0/3.0 w/w	Density, Comp. Str. gm/ml Lbs/in ²	3.5/1.0 Cement-Water 1.0/3.0 w/w	Density, Comp. Str. gm/ml Lbs/in ²	3.5/1.0 Cement-Water 1.0/3.0 w/w	Density, Comp. Str. gm/ml Lbs/in ²
0	2.043	5330	2.030	5510	2.005	5260	2.060	4300	-	-	-	-
5	1.946	5660	1.895	3650	1.905	4840	1.965	4860	1.955	4770	1.988	3960
10	1.876	4640	1.800	2960	1.815	3500	1.880	3800	1.855	3280	1.910	4450
15	1.816	3700	1.710	2400	1.743	2430	1.800	3000	1.763	2370	1.838	3620
20	1.756	2870	1.635	2000	1.575	2120	1.735	2400	1.680	1750	1.763	2800
25	1.700	2300	1.585	1670	1.633	1900	1.670	1920	1.612	1510	1.697	2380
30	1.647	1700	1.540	1350	1.600	1700	1.615	1670	1.555	1300	1.635	2100
35	(4)		1.502	1100	1.574	1520	1.561	1540	1.510	1060	1.575	1830
40	"		1.470	1000	(4)		1.510	1400	1.475	900	1.519	1650
45	"		1.435	1000	"		1.460	1260	(4)		1.475	1420
50	"		1.400	900	"		1.415	1100	"		1.436	1300
55	"		1.365	900	"		1.380	980	"		1.394	1140
60	"		1.335	900	"		(4)		"		(4)	

Notes: (1) w/w Vermiculite
(2) All ratios by weight
(3) Compressive strengths were obtained 14 days after pouring
(4) Mixture too dry to work

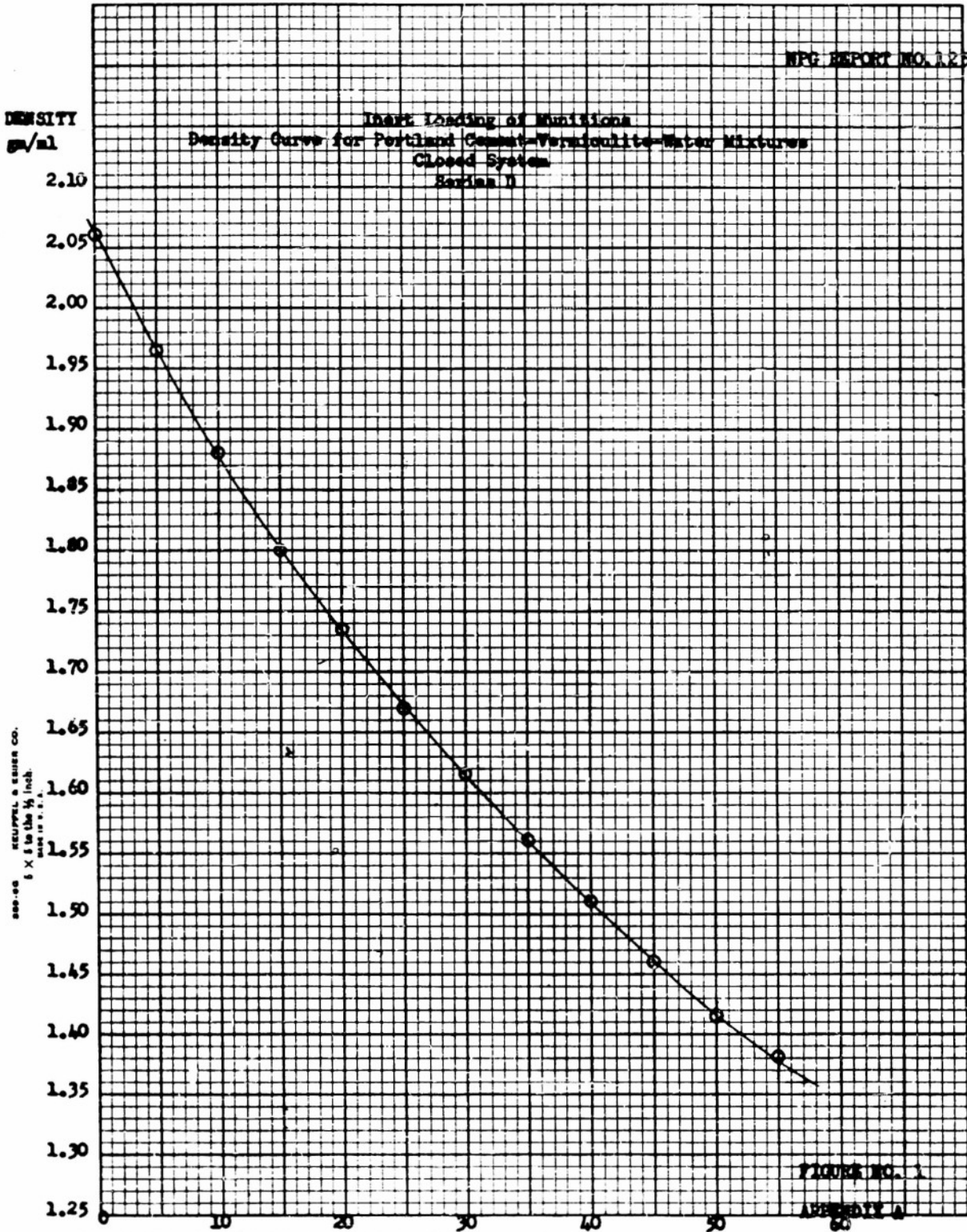


FIGURE NO. 1

APPENDIX A

GMS VERMICULITE/LB PORTLAND CEMENT/129.6 GMS (ml) H₂O PLUS 3 ml H₂O/GM VERMICULITE ADDED

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800-00 KEMPFL & BEISER CO.
5 X 5 to the 1/8 inch
size is P. A.

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TABLE II

PORTLAND CEMENT - VERMICULITE - WATER LOADING
OF MUNITIONS, FIELD RESULTS, CLOSED SYSTEM,
MIXING RATIOS FROM FIGURE 1

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Density of Loading, gm/ml</u>		<u>Deviation, Density, gm/ml</u>
		<u>Desired</u>	<u>Actual</u>	
1000 lb G.P. Low Drag Bomb Ex 10, Mod 1	1	1.55	1.575	+0.025
	1		1.559	+0.009
	1		1.547	-0.003
	1		1.550	-
	1		1.544	-0.006
	1		1.572	+0.022
	1		1.579	+0.029
	1		1.555	+0.005
	1		1.578	+0.028
1000 lb G.P. Low Drag Bomb Ex 10, Mod 2	1	1.55	1.542	-0.008
	1		1.545	-0.005
	1		1.573	+0.023
	1		1.572	+0.022
	1		1.577	+0.027
	1		1.565	+0.015
	1		1.541	-0.009
	1		1.558	+0.008
	1		1.566	+0.016
1000 lb G.P. Low Drag Bomb Ex 10, Mod 3	1	1.55	1.545	-0.005
	1		1.555	+0.005
	1		1.533	-0.017
	1		1.515	-0.035
	1		1.570	+0.020
	1		1.519	-0.031
	1		1.578	+0.028
	1		1.580	+0.030
	1		1.582	+0.032
	1		1.580	+0.030
	1		1.524	-0.026
	1		1.541	-0.009
	1		1.543	-0.007
	1		1.565	+0.015
	1		1.579	+0.029
1	1.549	-0.001		
1	1.550	-		
<u>36</u>			<u>Mean = 1.557</u>	<u>Deviation from Mean =</u> +0.025 to -0.042

Inert Loading of Munitions

TABLE II (Continued)

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Density of Loading, gm/ml</u>		<u>Deviation, Density, gm/ml</u>
		<u>Desired</u>	<u>Actual</u>	
250 lb G.P.	1	1.55	1.538	-0.012
Low Drag Bomb	1		1.587	+0.037
	1		1.562	+0.012
	1		1.562	+0.012
	1		1.562	+0.012
	1		1.587	+0.037
	1		1.587	+0.037
	1		1.578	+0.028
	1		1.563	+0.013
	1		1.547	-0.003
	1		1.556	+0.006
	1		1.547	-0.003
	1		1.571	+0.021
	1		1.531	-0.019
	1		1.516	-0.034
	1		1.531	-0.019
	1		1.531	-0.019
	1		1.545	-0.005
	1		1.531	-0.019
	<u>19</u>		<u>Mean = 1.557</u>	<u>Deviation from Mean =</u> <u>+0.030 to -0.041</u>

Inert Loading of Munitions

TABLE III

DATA ON
 PORTLAND CEMENT - GRANULATED CORK - WATER MIXTURES
CLOSED SYSTEM

<u>gm Cork</u> <u>Per Lb</u> <u>Cement</u>	<u>SERIES H</u>		<u>SERIES I</u>	
	<u>3.0/1.0 Cement - Water;</u> <u>1.0/2.0 Cork - Water</u>	<u>3.5/1.0 Cement - Water;</u> <u>1.0/2.0 Cork - Water</u>	<u>Density,</u> <u>gm/ml</u>	<u>Comp. Str.</u> <u>Lbs/in²</u>
0	2.050	8100	2.075	4723
5	1.946	7140	1.980	5468
10	1.847	5000	1.877	3970
15	1.766	3940	1.796	3670
20	1.695	3230	1.715	3190
25	1.625	2600	1.643	2630
30	1.558	2030	1.585	1910
35	1.496	1460	1.526	1490
40	1.443	1350	Mixture too dry to work	
45	1.393	1170	"	"
50	1.355	1000	"	"
55	1.320	900	"	"

Note: Compressive strengths were obtained 14 days after pouring.

DENSITY
gm/ml

Insert Loading of Munitions
Density Curve for Portland Cement-Granulated Cork-Water Mixtures
Closed System
Series H

400-04 EQUIPMENT & SUPPLY CO.
5 X 5 to the 1/2 inch.
MADE IN U.S.A.

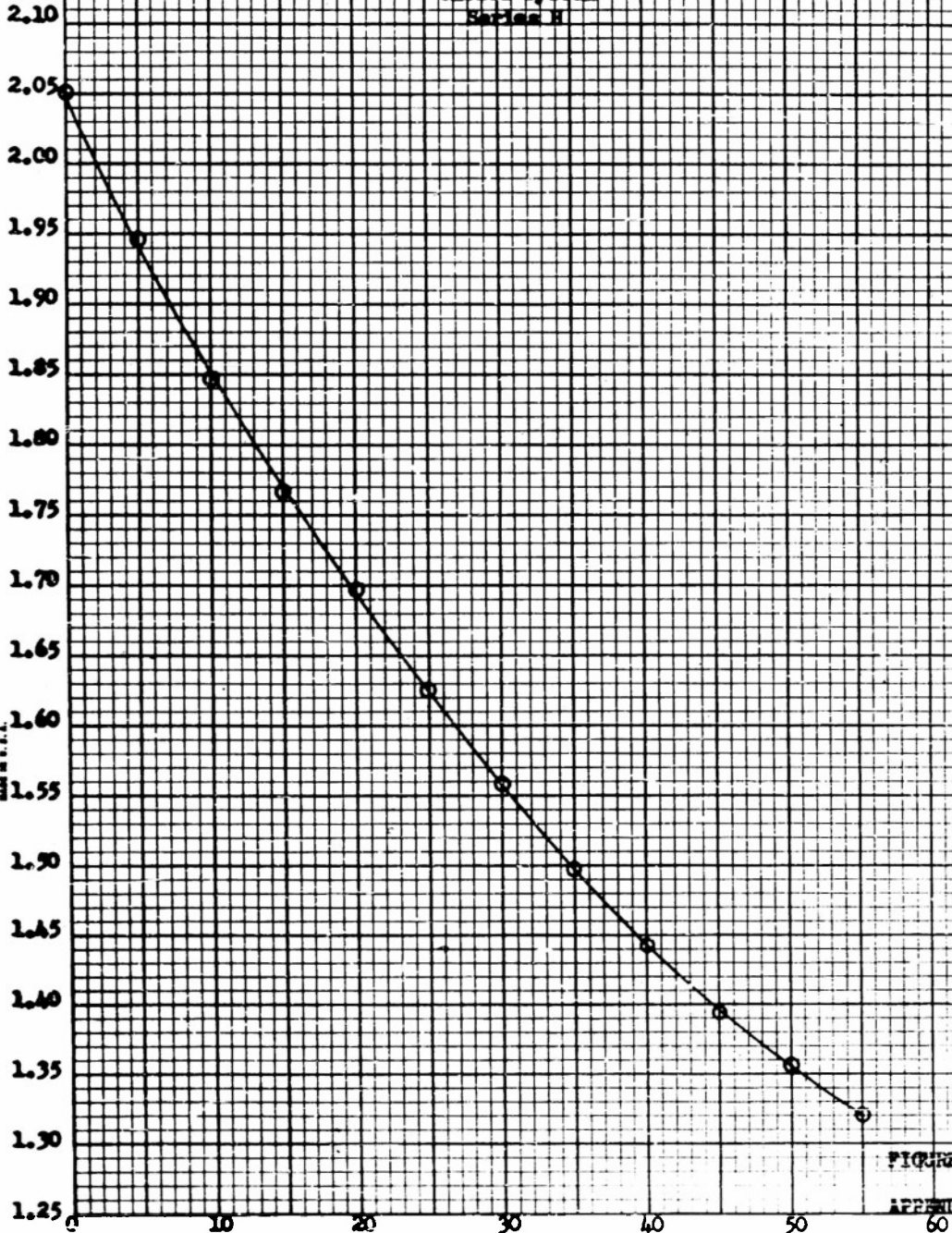


FIGURE NO. 2

APPENDIX B

GMS GRANULATED CORK/LB PORTLAND CEMENT/151.2 GMS (ml) H₂O PLUS 2 ml H₂O/GK GRANULATED CORK ADDED
CONFIDENTIAL

Inert Loading of Munitions

TABLE IV

PORTLAND CEMENT - GRANULATED CORK - WATER LOADING
OF MUNITIONS, FIELD RESULTS, CLOSED SYSTEM,
MIXING RATIOS FROM FIGURE 2

Type of Munition	No. Filled	Density of Loading, gm/ml		Deviation, Density, gm/ml
		Desired	Actual	
2000 lb G.P. Low Drag Bomb Ex 11	1	1.55	1.571	+0.016
	1		1.568	+0.018
	1		1.556	+0.006
	1		1.554	+0.004
	1		1.554	+0.004
	1		1.523	-0.027
	1		1.569	+0.019
	1		1.568	+0.018
	1		1.545	-0.005
	1		1.549	-0.001
	1		1.576	+0.026
	1		1.533	-0.017
	1		1.562	+0.018
	1		1.532	-0.018
	1		1.552	+0.002
	1		1.569	+0.019
	1		1.570	+0.020
	1		1.570	+0.020
	1		1.557	+0.007
	1		1.557	+0.007
	1		1.521	-0.029
	<u>21</u>		Mean = 1.555	Deviation from Mean = +0.021 to -0.034
1000 lb G.P. Low Drag Bomb Ex 10, Mod 4	1	1.55	1.567	+0.017
	1		1.529	-0.021
	1		1.559	+0.009
	1		1.582	+0.032
	1		1.586	+0.036
	1		1.551	+0.001
	1		1.578	+0.028
	1		1.586	+0.036
	1		1.586	+0.036
	1		1.517	-0.033
	1		1.563	+0.013
	<u>11</u>		Mean = 1.564	Deviation from Mean = +0.022 to -0.047

Inert Loading of Munitions

TABLE IV (Continued)

Type of Munition	No. Filled	Density of Loading, gm/ml		Deviation, Density, gm/ml
		Desired	Actual	
1000 lb G.P. Low Drag Bomb Ex 10, Mod 5	1	1.55	1.559	+0.009
	1		1.521	-0.029
	1		1.559	+0.009
	1		1.574	+0.024
	1		1.540	-0.010
	1		1.586	+0.036
	1		1.586	+0.036
	1		1.555	+0.005
	1		1.567	+0.017
	1		1.570	+0.020
	1		1.540	-0.010
	1		1.559	+0.009
	1		1.582	+0.032
	1		1.582	+0.032
14	Mean = 1.561	Deviation from mean = +0.025 to -0.040		
1000 lb G.P. Low Drag Bomb Ex 10, Mod 9	1	1.55	1.573	+0.023
	1		1.517	-0.033
	1		1.529	-0.021
	1		1.544	-0.006
	1		1.556	+0.006
	1		1.517	-0.033
6	Mean = 1.539	Deviation from mean = +0.034 to -0.022		
1000 lb G.P. Low Drag Bomb Ex 10, Mod 8	1	1.65	1.655	+0.005
	1		1.649	-0.001
	1		1.653	+0.003
	1		1.636	-0.014
	1		1.626	-0.024
	1		1.626	-0.024
	1		1.634	-0.016
	1		1.630	-0.020
	1		1.645	-0.005
	1		1.626	-0.024
	1		1.622	-0.028
11	Mean = 1.637	Deviation from mean = +0.018 to -0.015		

Inert Loading of Munitions

TABLE IV (Continued)

Type of Munition	No. Filled	Density of Loading, gm/ml		Final Weight, Lbs		Deviation, Lbs
		Desired	Actual	Desired	Actual	
8" HC, Mk 25, Mod 1	15		1.724		260.0	-
	10		1.655		260.0	-
	<u>5</u>		1.586		260.0	-
	30					
Anti-Sub. Projectile, Type Ex 30	1		1.674	75.0	74.90	-0.10
	1		1.816		74.80	-0.20
	1		1.837		75.10	+0.10
	1		1.879		74.80	-0.20
	2		Not Determined		75.00	-
	1		"		74.90	-0.10
	1		"		74.95	-0.05
	1		"		74.90	-0.10
	1		"		75.10	+0.10
	1		"		75.20	+0.20
	1		"		75.25	+0.25
	<u>1</u>				<u>75.15</u>	<u>+0.15</u>
	13				Mean = 74.93	Deviation from Mean = +0.32 to -0.13

Final Weight, grains

20mm Ex 8, Mod 0	49	1.70	1674±15	1676±13, -10
20mm Ex 8, Mod 1	49	1.67	1553±15	1555±13, -11

Inert Loading of Munitions

TABLE V

DATA ON
PORTLAND CEMENT - PERLITE - WATER MIXTURES
CLOSED SYSTEM

<u>SERIES J</u>		
<u>gm Perlite</u>	<u>3.0/1.0 Cement - Water</u>	<u>1.0/3.0 Perlite - Water</u>
<u>Per Lb</u>	<u>Density,</u>	<u>Comp. Str.</u>
<u>Cement</u>	<u>gm/ml</u>	<u>Lbs/in²</u>
0	1.958	3650
5	1.870	4150
10	1.788	4900
15	1.711	4430
20	1.647	3700
25	1.590	2700
30	1.540	2370
35	1.495	-
40	1.455	1870
45	1.415	1720
50	1.375	1590
55	1.335	1370
60	1.296	1175

Note: Compressive strength data, 14 days after pouring.

Unit Loading of Mixtures
Density Curve for Portland Cement-Perlite-Water Mixtures
Closed System
Series J

DENSITY
gm/ml

2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25

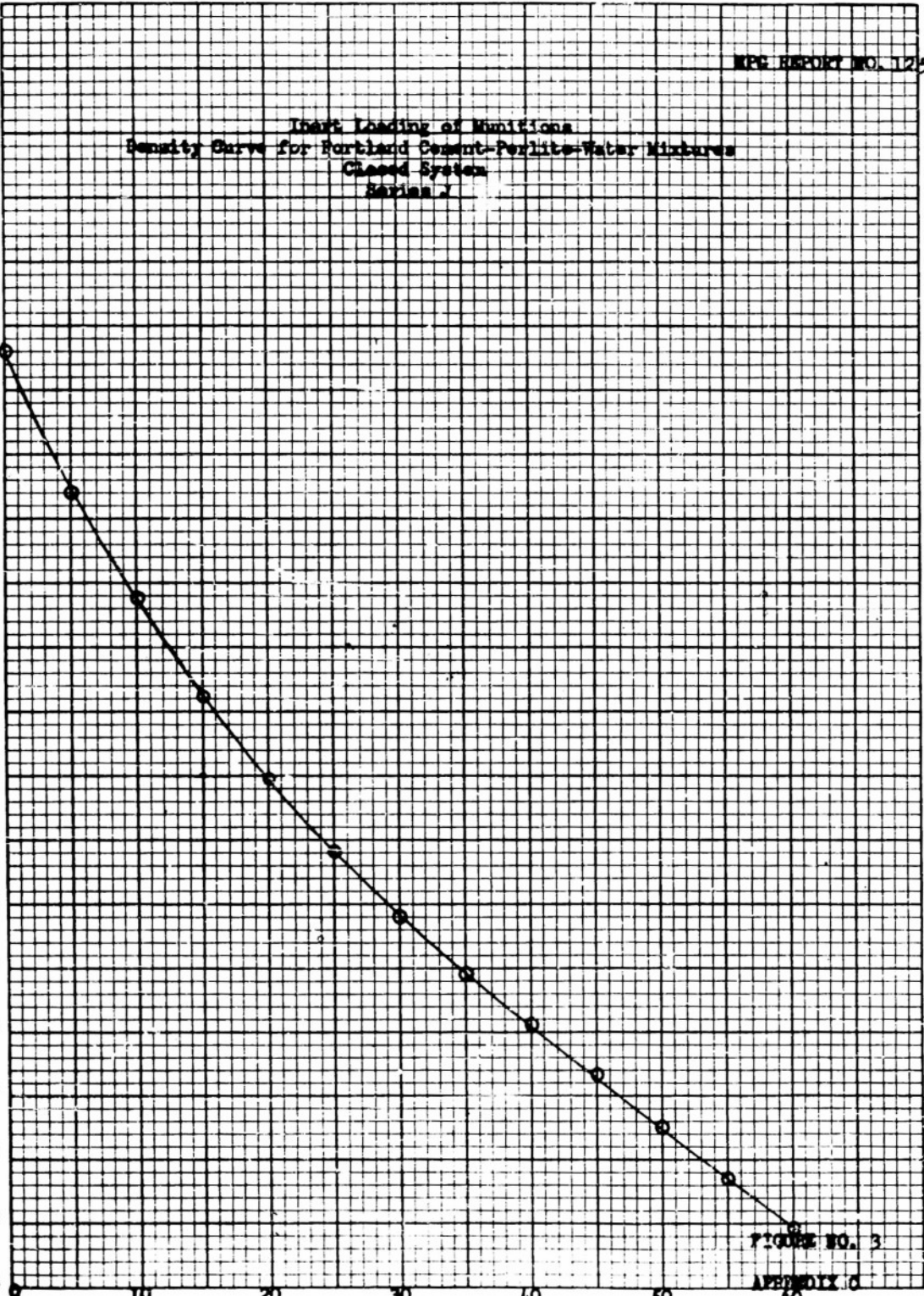


FIGURE NO. 3

APPENDIX C

GMS PERLITE/LB PORTLAND CEMENT/151.2 GMS (ml) H₂O PLUS 3 ml H₂O/GM PERLITE ADDED

CONFIDENTIAL

Inert Loading of Munitions

TABLE VI

PORTLAND CEMENT - PERLITE - WATER LOADING OF
MUNITIONS, FIELD RESULTS, CLOSED SYSTEM,
MIXING RATIOS FROM FIGURE 3

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Density of Loading, gm/ml</u>		<u>Deviation, Density, gm/ml</u>
		<u>Desired</u>	<u>Actual</u>	
1500 lb Warhead Modified for gun fire, T23E1	1	1.71	1.706	-0.006
	1		1.712	+0.002
1000 lb G.P. Low Drag Bomb Ex 10, Mod 6	1	1.65	1.684	+0.034
	1		1.658	+0.008
	1		1.669	+0.019
	1		1.658	+0.008
	1		1.670	+0.020
	1		1.634	-0.016
	<u>6</u>		Mean = 1.662	Deviation from mean = +0.022 to -0.028
1000 lb G.P. Low Drag Bomb Ex 10, Mod 9	1	1.65	1.653	+0.003
	1		1.629	-0.021
	1		1.645	-0.005
	1		1.607	-0.043
	1		1.637	-0.013
	1		1.664	+0.014
	<u>6</u>		Mean = 1.639	Deviation from mean = +0.025 to -0.032
1000 lb G.P. Low Drag Bomb Ex 10, Mod 15	1	1.65	1.654	+0.004
	1		1.679	+0.029
	1		1.670	+0.020
	1		1.679	+0.029
	1		1.660	+0.010
	1		1.672	+0.022
	1		1.659	-0.006
	1		1.672	+0.022
	<u>8</u>		Mean = 1.668	Deviation from mean = +0.011 to -0.014

Inert Loading of Munitions

TABLE VI (Continued)

Type of Munition	No. Filled	Density of Loading, gm/ml		Deviation,	
		Desired	Actual	Lbs	Density
1000 lb AN-M65A1	1	1.55	1.541		-0.009
	1		1.522		-0.028
	1		1.565		+0.015
	1		1.554		+0.004
	1		1.528		-0.022
	1		1.528		-0.022
	1		1.510		-0.040
	1		1.564		+0.014
	1		1.570		+0.020
	1		1.535		-0.015
	<u>10</u>		Mean = 1.542		Deviation from Mean = +0.028 to -0.32
250 lb Low Drag Bomb, Ex 2, Mod 0	1	1.55	1.540		-0.010
	1		1.581		+0.031
	1		1.540		-0.010
	1		1.540		-0.010
	1		1.556		+0.006
	1		1.556		+0.006
	1		1.556		+0.006
	<u>7</u>		Mean = 1.553		Deviation from Mean = +0.028 to -0.013

Inert Loading of Munitions

TABLE VII

DATA ON
 PORTLAND CEMENT - IRON FILINGS - WATER MIXTURES
CLOSED SYSTEM

<u>SERIES K</u>		
<u>gm Iron Filings Per Lb Cement</u>	<u>2.0/1.0 Cement - Water Ratio; Iron Filings as indicated Density gm/ml</u>	<u>Comp. Str. Lbs/in²</u>
100	2.07	Not Determined
150	2.19	"
200	2.30	"
250	2.40	"
300	2.485	"
350	2.56	"
400	2.64	"
450	2.705	"
500	2.77	"
550	2.825	"
600	2.88	"
650	2.935	"

CONFIDENTIAL

NAVORD REPORT NO. 1337
NPG REPORT NO. 1258

Inert Loading of Munitions

TABLE VIIa

DATA ON
PORTLAND CEMENT - IRON FILINGS - WATER MIXTURES
CLOSED SYSTEM

SERIES K

<u>gm Iron Filings Per 20 gm Cement Per 10 ml Water</u>	<u>Density gm/ml</u>	<u>Comp. Str. Lbs/in²</u>
3	2.01	Not Determined
6	2.16	"
9	2.31	"
12	2.44	"
15	2.55	"
18	2.65	"
21	2.74	"
24	2.82	"
27	2.89	"
30	2.96	"

CONFIDENTIAL

APPENDIX D

DENSITY
gm/ml

MPC REPORT NO. 1258

Inert Loading of Emulsions
Density Curves for Portland Cement-F_o Filings-Water Mixtures
Closed System
Series K

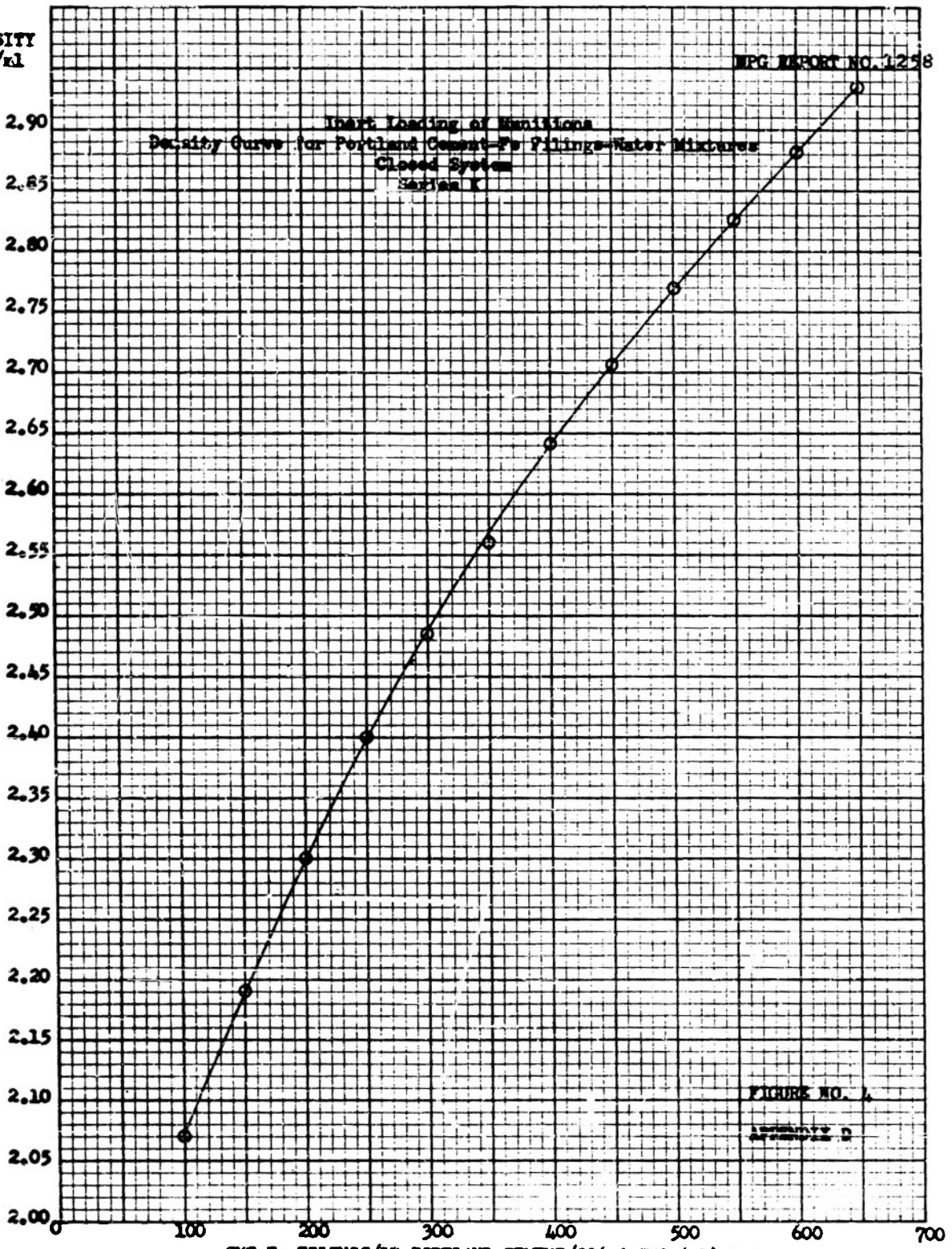


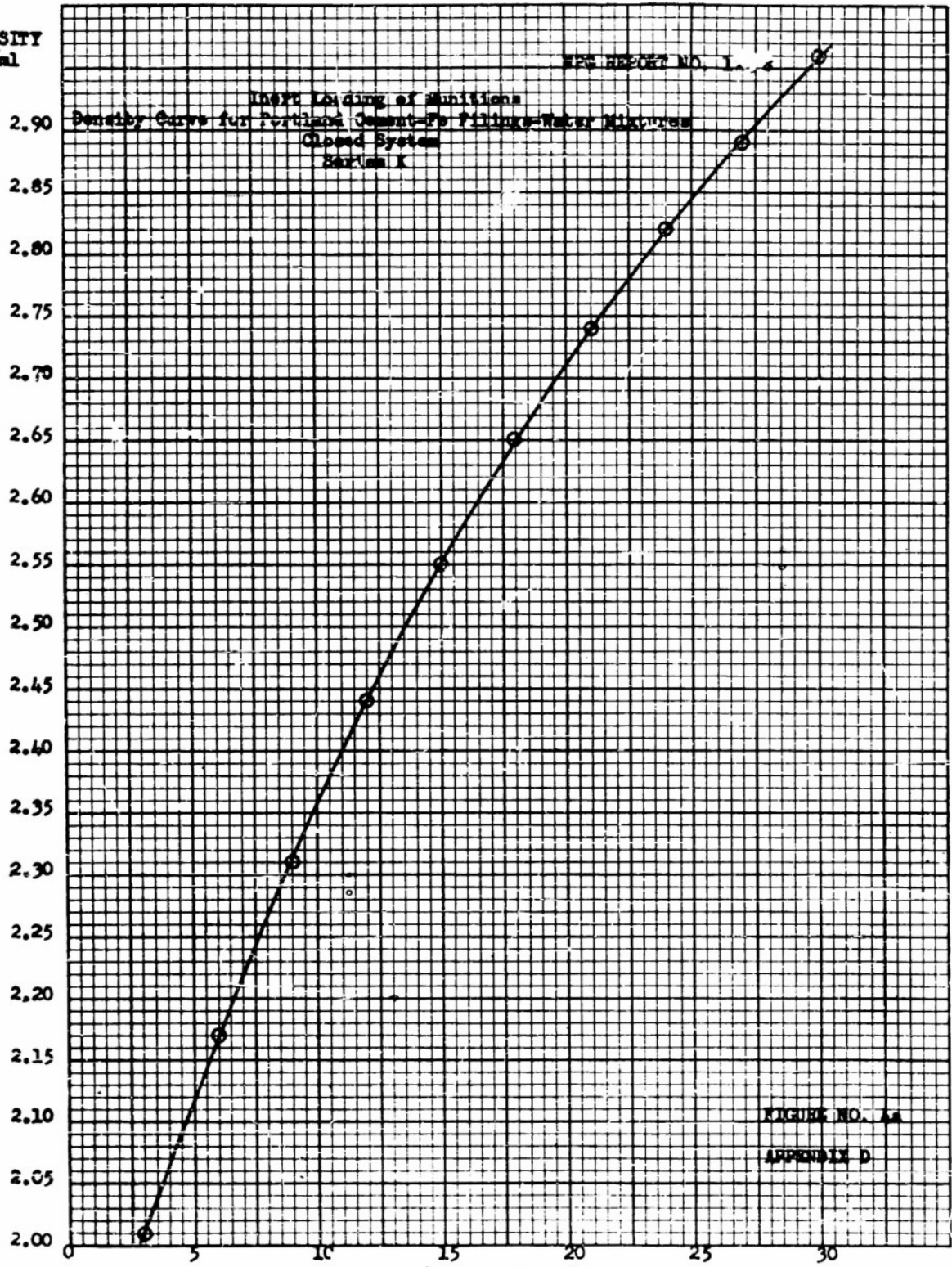
FIGURE NO. 1

APPENDIX B

CONFIDENTIAL

GMS F_o FILINGS/LB PORTLAND CEMENT/226.8 GMS (ml) H₂O

DENSITY
gm/ml



WFO REPORT NO. 1

Insert Loading of Munitions
Density Curve for Portland Cement-Pb Filings-Water Mixtures
Closed System
Series K

FIGURE NO. 4a
APPENDIX D

CONFIDENTIAL

GMS Pb FILINGS/20 GMS CEMENT/10 GMS (ml) H₂O

Inert Loading of Munitions

TABLE VIII

PORTLAND CEMENT - IRON FILINGS - WATER LOADING OF
MUNITIONS, FIELD RESULTS, CLOSED SYSTEM,
MIXING RATIOS FROM FIGURE 4 OR 4a

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Final Weight, Lbs</u>		<u>Deviation Lbs</u>
		<u>Desired</u>	<u>Actual</u>	
3"/70 A.P. Projectile, Type 1, Mod 2	1	15	15.01	+0.01
	1		15.00	-
	1		14.99	-0.01
	1		14.99	-0.01
	1		15.00	-
	1		15.06	+0.06
	1		15.06	+0.06
	1		15.05	+0.05
	1		15.04	+0.04
	1		15.06	+0.06
	1		15.04	+0.04
	1		15.03	+0.03
	12		Mean = 15.03	Deviation from mean = +0.03, -0.04
				<u>Deviation Grains</u>
20mm T282E1 Projectile with T196 Fuze	1	1533±15	1524	-9
	1		1520	-13
	1		1525	-8
	1		1528	-5
	1		1533	-
	1		1526	-7
	1		1527	-6
	1		1534	+1
	1		1522	-11
	1		1528	-5
	1		1533	-
	1		1536	+3
	1		1536	+3
	1		1528	-5
1		1531	-2	
1		1525	-8	
1		1527	-6	

Inert Loading of Munitions

TABLE VIII (Continued)

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Final Weight, Grains</u>		<u>Deviation Grains</u>	
20mm T282E1 Projectile with T196 Fuze	1	1533±15	1543	+10	
	1		1531	-2	
	1		1522	-11	
	1		1527	-6	
	1		1536	+3	
	1		1530	-3	
	1		1519	-14	
	1		1544	+11	
	1		1535	+2	
	1		1536	+3	
	1		1526	-7	
	1		1537	+4	
	1		1546	+13	
	1		1527	-6	
	1		1529	-4	
	1		1541	+8	
	1		1526	-7	
	1		1530	-3	
	1		1521	-12	
	1		1536	+3	
	1		1537	+4	
	1		1536	+3	
	1		1533	-	
	1		1542	+9	
	1		1548	+15	
	1		1547	+14	
	1		1533	-	
	1		1536	+3	
	1		1523	-10	
	1		1543	+10	
	1		1546	+13	
		<u>48</u>		<u>Mean = 1532</u>	<u>Deviation from mean = +16, -13</u>

Inert Loading of Munitions

TABLE IX

DATA ON
PORTLAND CEMENT - GRANULAR LEAD - WATER MIXTURES
CLOSED SYSTEM

<u>SERIES L</u>		
<u>gm Granular Pb Per Lb Cement</u>	<u>1.67/1.0 Cement - Water Ratio; Granular Lead as Indicated</u>	
	<u>Density, gm/ml</u>	<u>Comp. Str. Lbs/in²</u>
500	2.90	Not Determined
1000	3.73	"
1500	4.28	"
2000	4.80	"
2500	5.30	"
3000	5.75	"
3500	6.16	"
4000	6.54	"

Inert Loading of Munitions
-----TABLE IXaDATA ON
PORTLAND CEMENT - GRANULAR LEAD - WATER MIXTURES
CLOSED SYSTEMSERIES I

<u>gm Granular Lead</u> <u>Per 20 gm Cement</u> <u>Per 10 ml Water</u>	<u>Density</u> <u>gm/ml</u>	<u>Comp. Str.</u> <u>Lbs/in²</u>
20	2.85	Not Determined
30	3.25	"
40	3.60	"
50	3.88	"
60	4.15	"
80	4.60	"
100	5.05	"
120	5.50	"
140	5.90	"
160	6.25	"
180	6.57	"

DENSITY
gm/ml

Inert Loading of Munitions
Density Curves for Portland Cement-Granular Pb-Water Mixtures
Closed System
Series I.

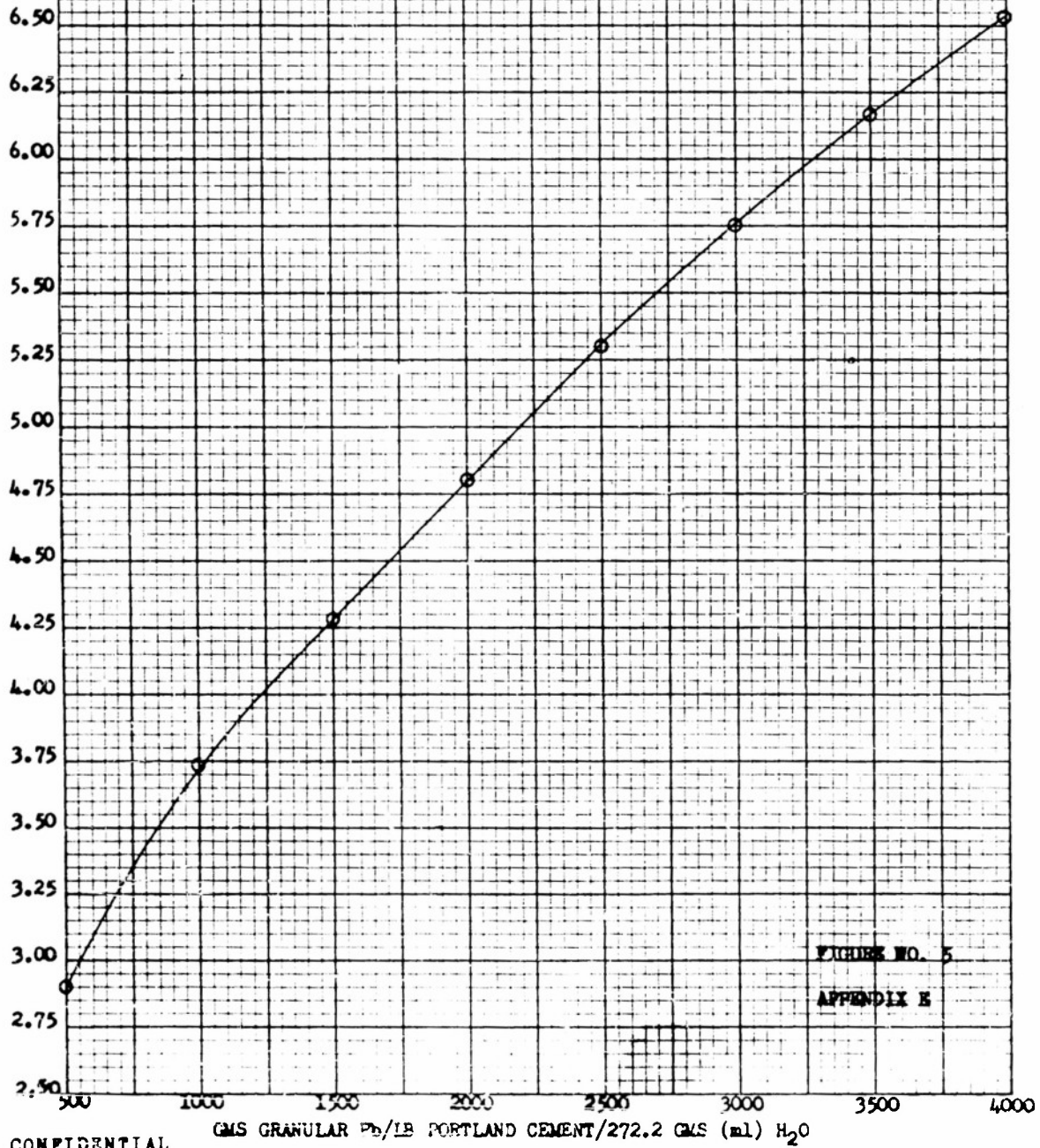


FIGURE NO. 5

APPENDIX E

CONFIDENTIAL

GMS GRANULAR Pb/LB PORTLAND CEMENT/272.2 GMS (ml) H₂O

DENSITY
g/ml

Inert Loading of Munitions
Density Curve for Portland Cement-Granular Pb-Water Mixtures
Closed System
Series I.

000-00 REUFPEL & ESSER CO.
1 X 4 to the 1/2 inch.
made in U.S.A.

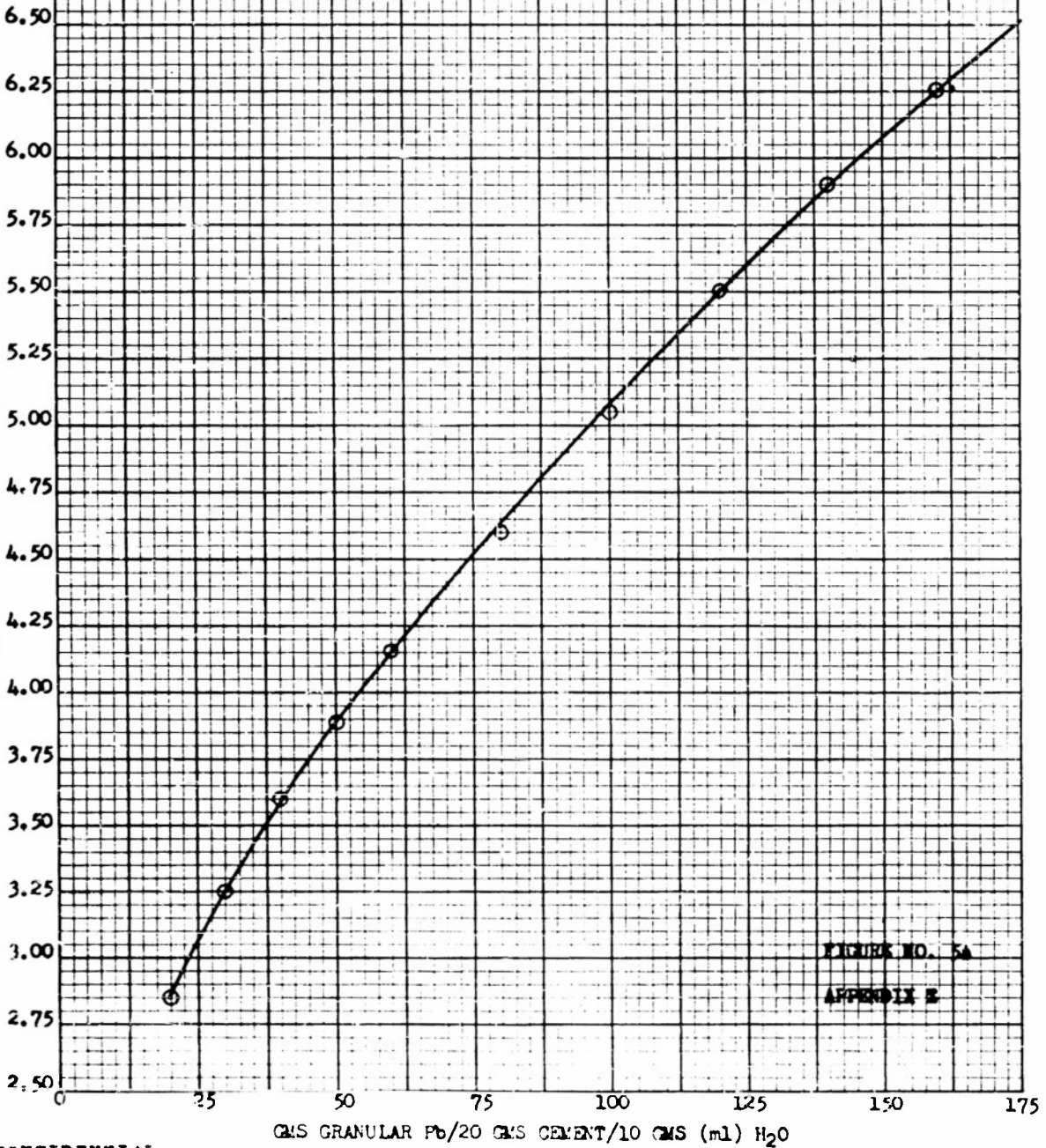


FIGURE NO. 5A
APPENDIX B

Inert Loading of Munitions

TABLE X

DATA ON
PORTLAND CEMENT - VERMICULITE DRY MIXTURES
CLOSED SYSTEM

SERIES M

<u>gm Vermiculite Per lb Cement</u>	<u>Density, gm/ml</u>
10	0.975
20	0.920
30	0.870
40	0.823
50	0.785
60	0.755
70	0.725
80	0.700
90	0.675
100	0.652
110	0.628

DENSITY
gm/ml

Part Loading of Mixtures
Density Curve for Portland Cement-Vermiculite Dry Mixtures
(Closed System)
Series X

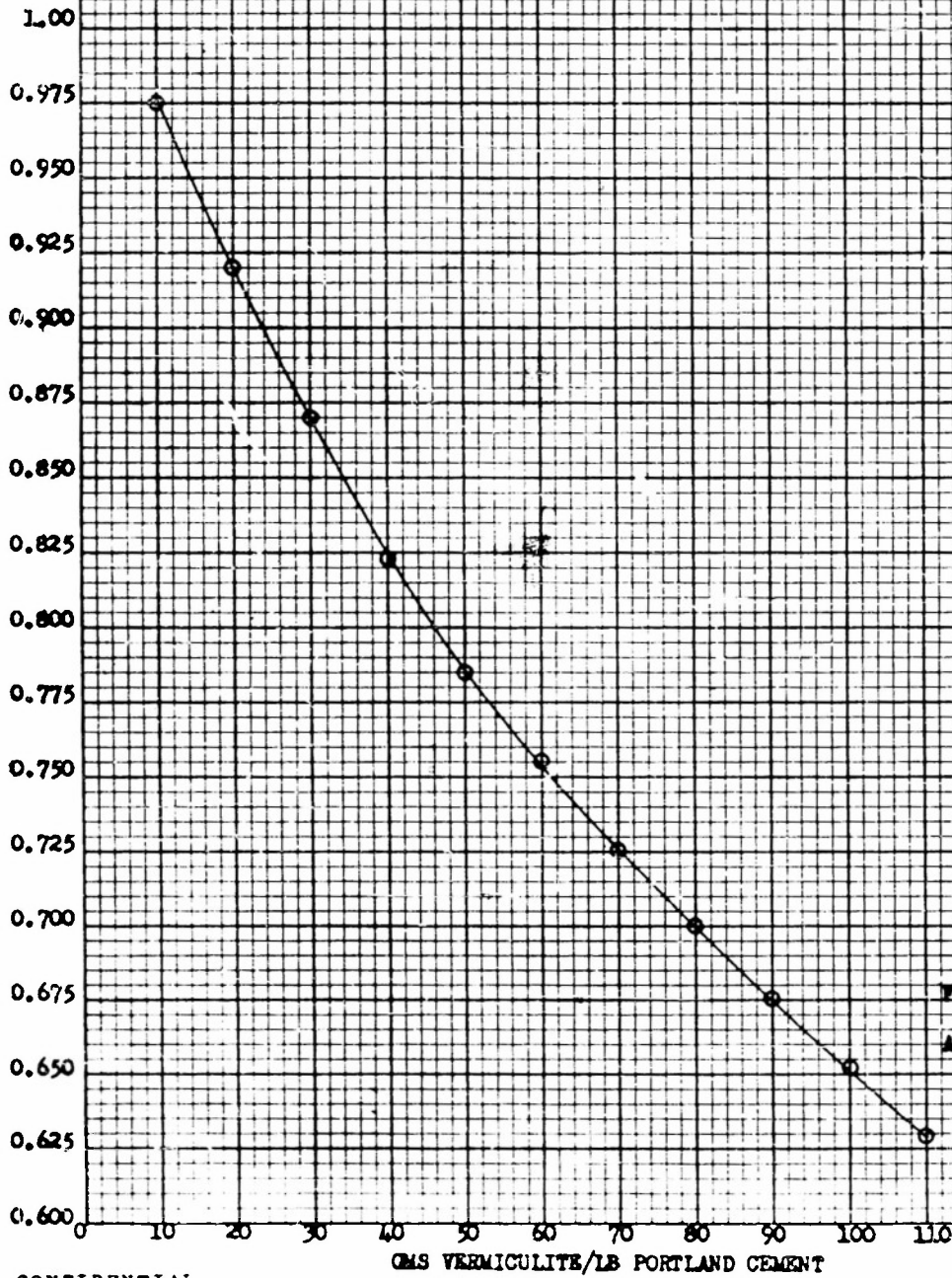


FIGURE NO. 6

APPENDIX F

CONFIDENTIAL

Inert Loading of Munitions
-----TABLE XIDATA ON
PORTLAND CEMENT - GRANULATED CORK DRY MIXTURES
CLOSED SYSTEM

<u>SERIES N</u>	
<u>gm Cork</u> <u>Per Lb Cement</u>	<u>Density,</u> <u>gm/ml</u>
10	1.043
20	0.944
30	0.872
40	0.817
50	0.770
60	0.730
70	0.691
80	0.657
90	0.625
100	0.595
110	0.565

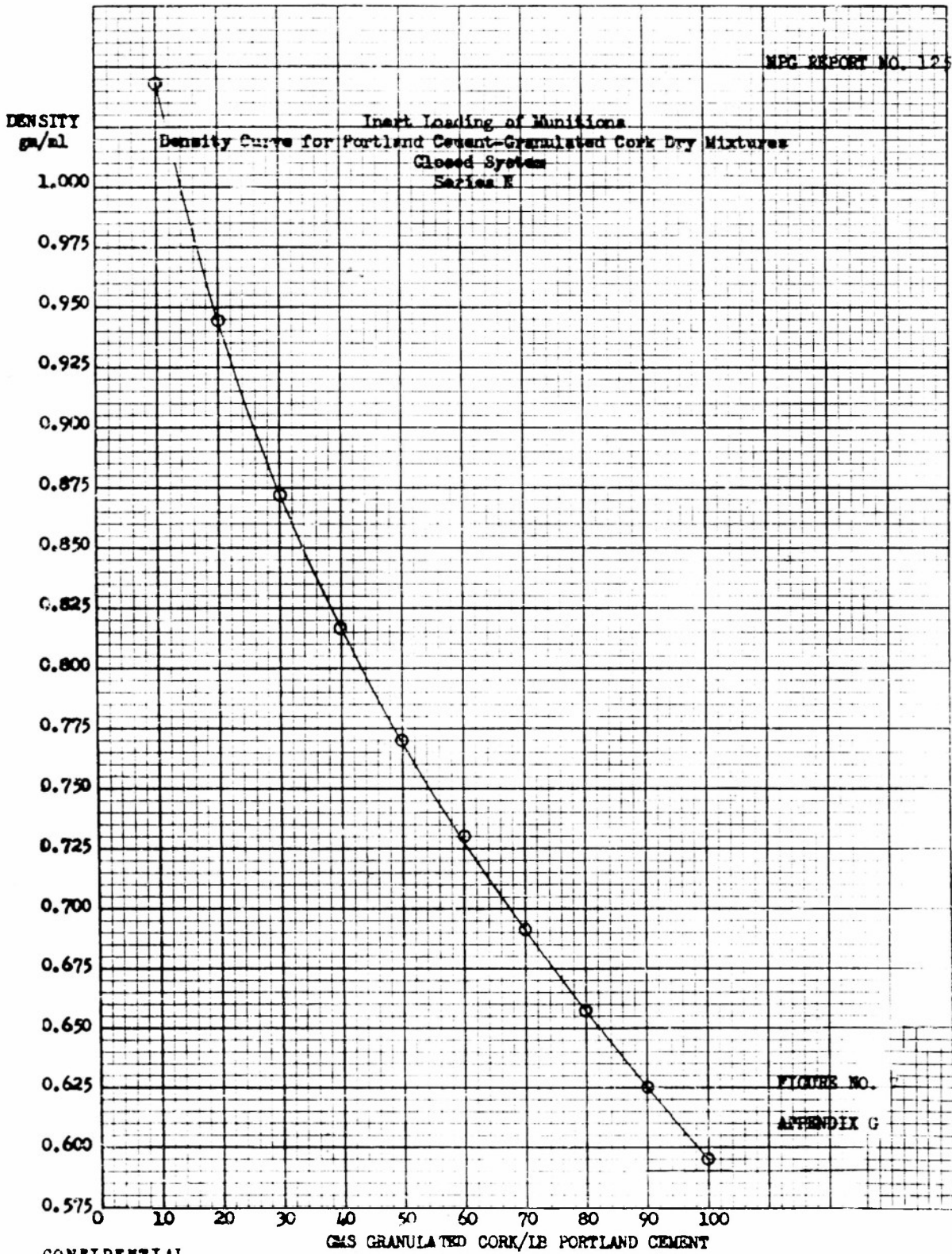


FIGURE NO.
APPENDIX G

CONFIDENTIAL

Inert Loading of Munitions

TABLE XII

PORTLAND CEMENT - GRANULATED CORK DRY LOADING
OF MUNITIONS, FIELD RESULTS, CLOSED SYSTEM,
MIXING RATIOS FROM FIGURE 7

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Density of Loading, gm/ml</u>		<u>Deviation Density</u>
		<u>Desired</u>	<u>Actual</u>	
Mk 77 Mod O Fire Bomb	1	0.70	0.689	-0.011
	1		0.688	-0.012
	1		0.688	-0.012
	1		0.689	-0.011
	1		0.688	-0.012
	1		0.688	-0.012
	1		0.693	-0.007
	1		0.691	-0.009
	1		0.689	-0.011
	1		0.693	-0.007
	1		0.690	-0.010
	1		0.690	-0.010
	1		0.691	-0.009
	1		0.689	-0.011
14		Mean = 0.690		Deviation from mean = +0.003 to -0.002

Inert Loading of Munitions
-----TABLE XIIIDATA ON
PORTLAND CEMENT - PERLITE DRY MIXTURES
CLOSED SYSTEM

<u>SERIES 0</u>	
<u>gm Perlite Per Lb Cement</u>	<u>Density, gm/ml</u>
10	1.035
20	0.955
30	0.890
40	0.833
50	0.780
60	0.733
70	0.695
80	0.660
90	0.630
100	0.603
110	0.575

DENSITY
g/ml

Inert Loading of Munitions
Density Curve for Portland Cement-Perlite Dry Mixtures
Closed System
Series 0

980-06
KEMPFEL & EBER CO.
5 X 6 in. dia. 1/2 inch

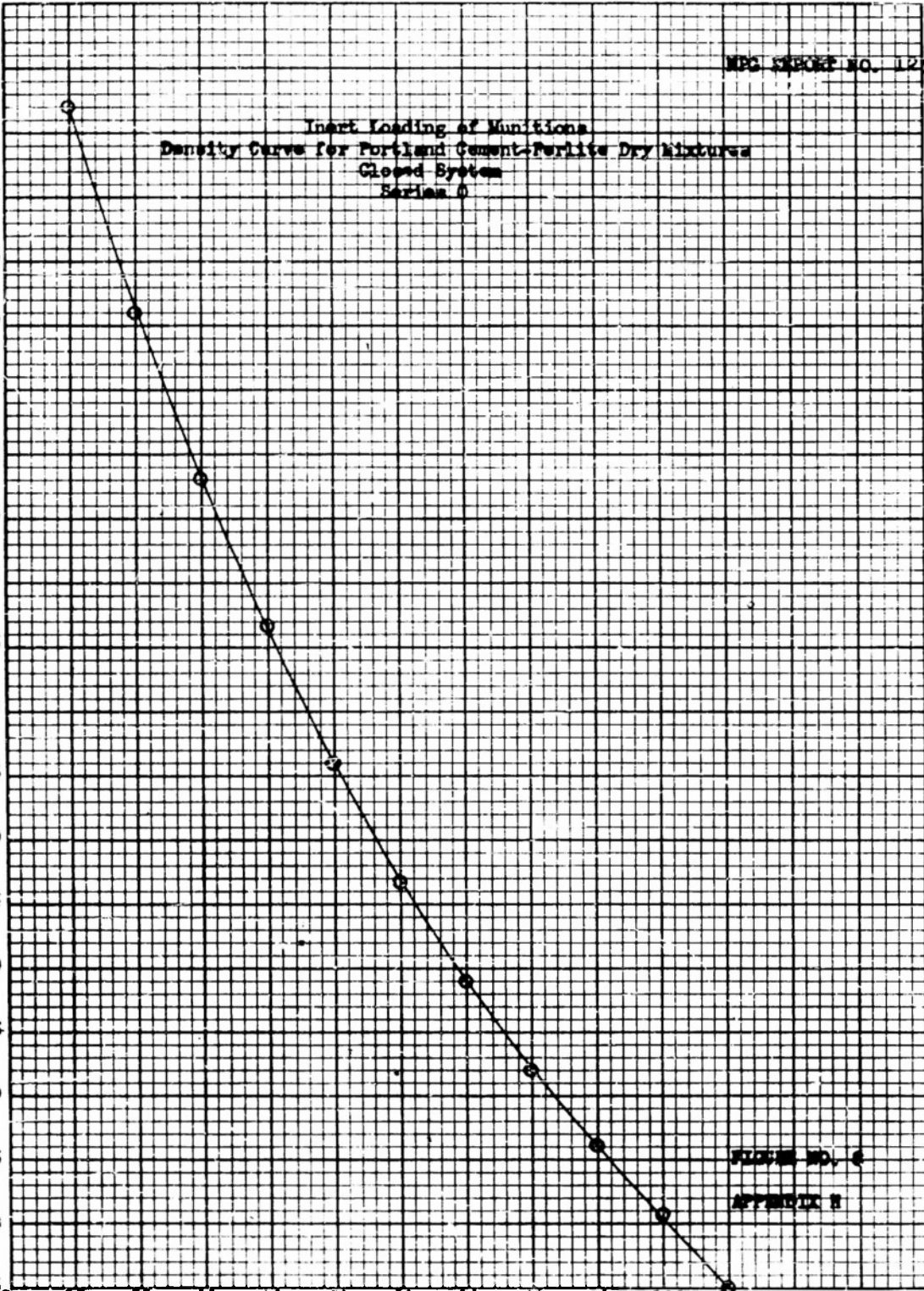


FIGURE NO. 6

APPENDIX II

Inert Loading of Munitions

TABLE XIV

PORTLAND CEMENT - PERLITE - DRY MIXTURES,
FIELD RESULTS, CLOSED SYSTEM,
MIXING RATIOS FROM FIGURE 8

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Density of Loading, gm/ml</u>		<u>Final Weight, Lbs</u>		<u>Deviation, Lbs</u>
		<u>Actual</u>		<u>Desired</u>	<u>Actual</u>	
Mk 77, Mod 0 Fire Bomb	3	0.687		750	750	None

Note: These bombs were filled to weight with little or no vacant space remaining after filling.

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Inert Loading of Munitions

TABLE XV

DATA ON
PORTLAND CEMENT - IRON FILINGS DRY MIXTURES
CLOSED SYSTEM

<u>SERIES P</u>	
<u>gm Iron Filings Per Lb Cement</u>	<u>Density, gm/ml</u>
200	1.46
400	1.75
600	1.97
800	2.16
1000	2.35
1200	2.52
1400	2.69

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APPENDIX I

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Inert Loading of Munitions

TABLE XVa

DATA ON
PORTLAND CEMENT - IRON FILINGS - DRY MIXTURES
CLOSED SYSTEM

<u>SERIES P</u>	
<u>gm Iron Filings</u> <u>Per 100 gm Cement</u>	<u>Density</u> <u>gm/ml</u>
50	1.51
100	1.82
150	2.05
200	2.26
250	2.46
300	2.66

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APPENDIX I

DENSITY
g/ml

Weight Loading of Munitions
Density Curve for Portland Cement-Iron Filings Dry Mixtures
Closed System
Series F

100-00
5 X 5 in the 1/2 inch
KUPPEL & KUPPEL CO.

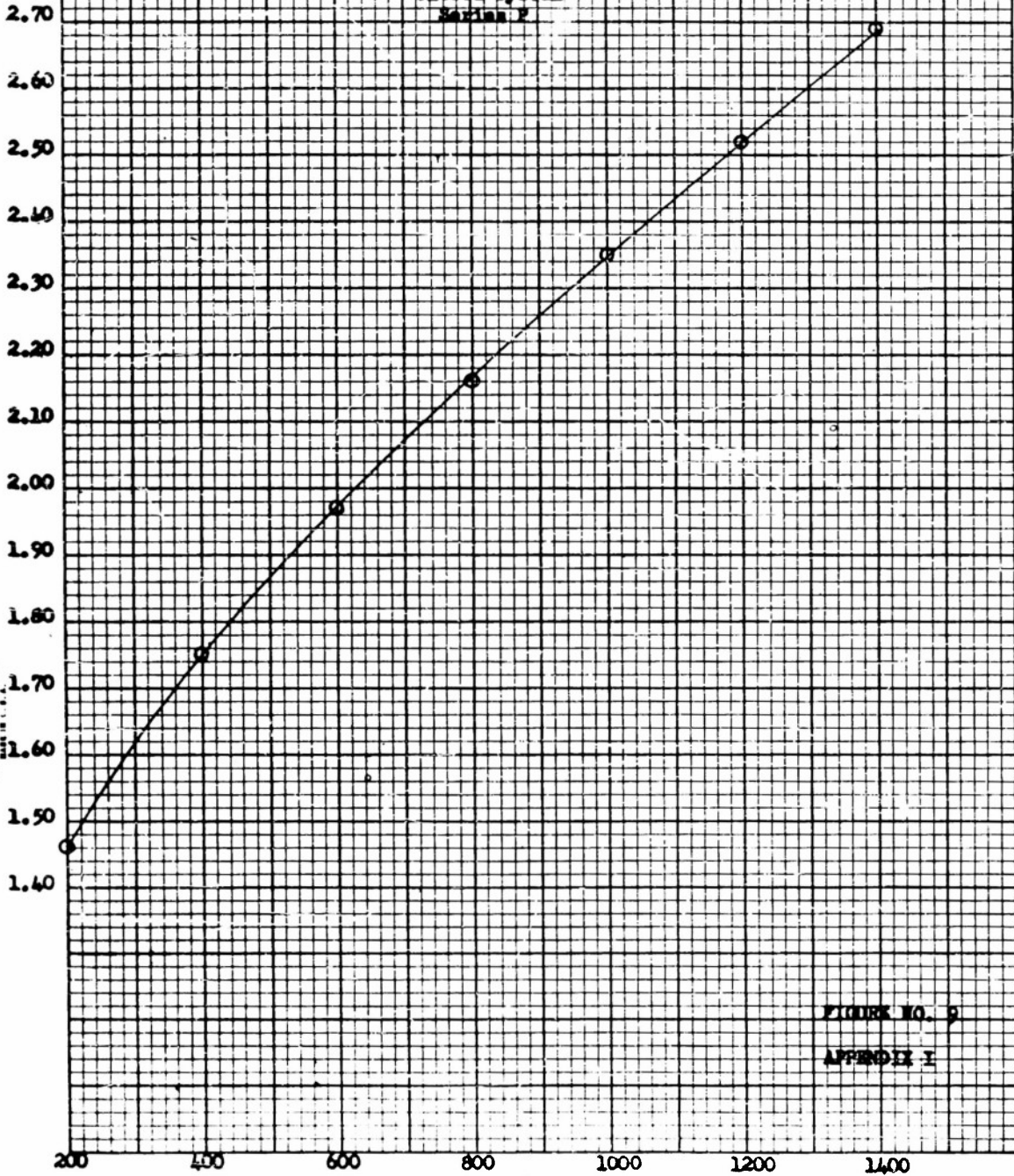


FIGURE NO. 9
APPENDIX I

DENSITY
gn/al

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Inert Loading of Munitions
Density Curve for Portland Cement-Iron Filings Dry Mixtures
Closed System
Series F

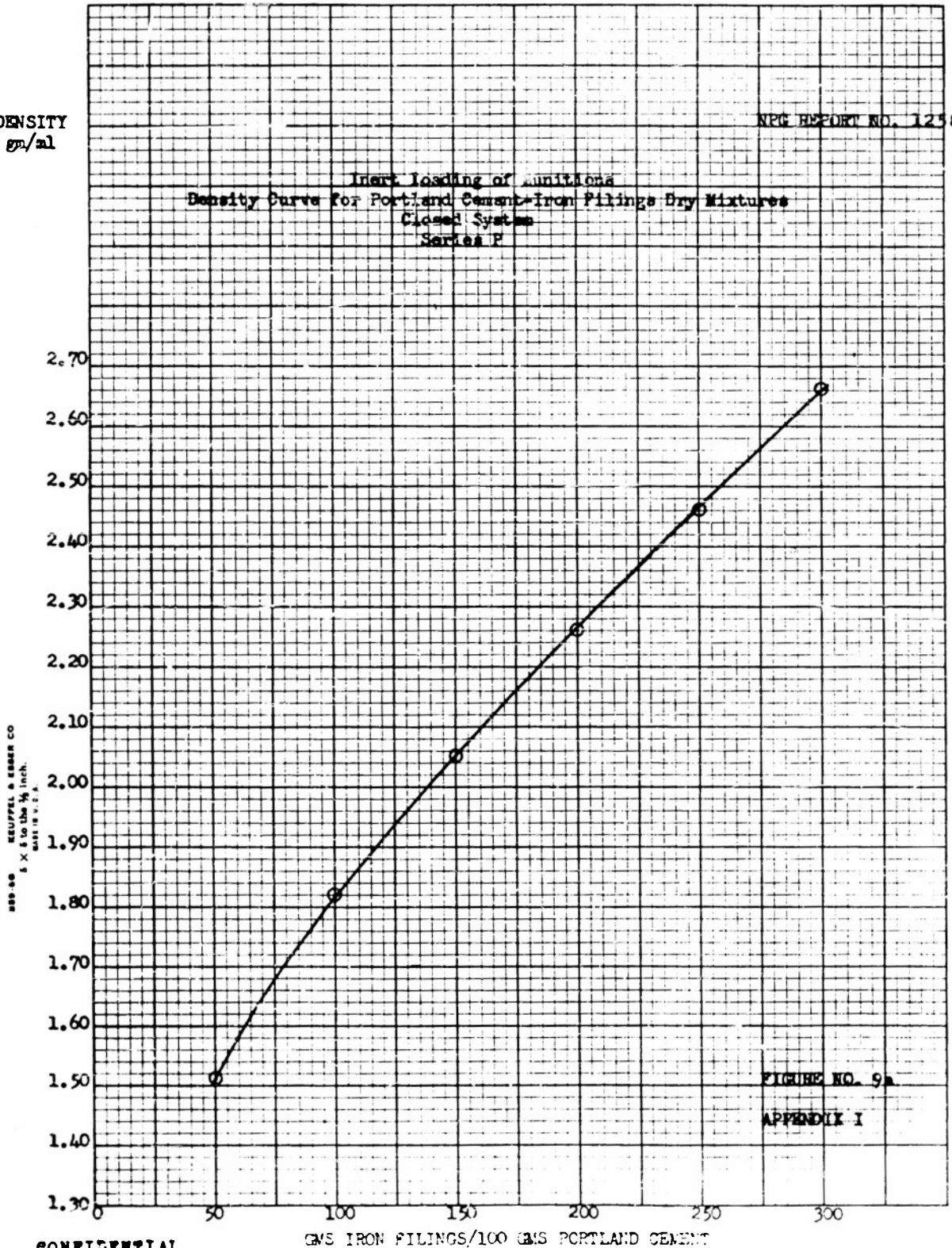


FIGURE NO. 9a

APPENDIX I

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GMS IRON FILINGS/100 GMS PORTLAND CEMENT

Inert Loading of Munitions

TABLE XVI

PORTLAND CEMENT - IRON FILINGS - DRY LOADING
OF MUNITIONS, FIELD RESULTS, CLOSED SYSTEM,
MIXING RATIOS FROM FIGURE 9 OR 9a

<u>Type of Munition</u>	<u>No. Filled</u>	<u>Density of Loading, gm/ml</u>		<u>Final Weight, Grains</u>		<u>Deviation, Grains</u>
		<u>Desired</u>	<u>Actual</u>	<u>Desired</u>	<u>Actual</u>	
20mm, EX 8, Mod 1 Projectile, Body only, Fuze weight constant	1	1.62	1553*20	1560	+7	
	1	1.62	1553*20	1556	+3	
	1	1.62	1553*20	1556	+3	
	1	1.62	1553*20	1558	+5	
	1	1.62	1553*20	1558	+5	
	1	1.62	1553*20	1556	+3	
	1	1.62	1553*20	1559	+6	
	1	1.62	1553*20	1557	+4	
	1	1.62	1553*20	1556	+3	
	1	1.62	1553*20	1550	-3	
	1	1.63	1553*20	1561	+8	
	1	1.63	1553*20	1547	-6	
	1	1.63	1553*20	1533	-20	
	1	1.63	1553*20	1535	-18	
	1	1.63	1553*20	1539	-14	
	1	1.63	1553*20	1567	+14	
	1	1.63	1553*20	1546	-7	
	1	1.63	1553*20	1561	+8	
	1	1.63	1553*20	1545	-8	
	1	1.63	1553*20	1560	+7	
	1	1.63	1553*20	1556	+3	
	1	1.63	1553*20	1556	+3	
	1	1.63	1553*20	1555	+2	
	1	1.63	1553*20	1554	+1	
	1	1.63	1553*20	1555	+2	
	1	1.63	1553*20	1556	+3	
	1	1.63	1553*20	1556	+3	
	1	1.63	1553*20	1551	-2	
	1	1.63	1553*20	1557	+4	
	1	1.63	1553*20	1557	+4	
<u>1</u>		<u>1.63</u>	<u>1553*20</u>	<u>1557</u>	<u>+4</u>	
30				Mean = 1554	Deviation from mean = +13, -21	

Inert Loading of Munitions

TABLE XVI (Continued)

Type of Munition	No. Filled	Density of Loading, gm/ml	Final Weight, Grains		Deviation Grains
		Desired	Desired	Actual	
20mm T282E1 Projectile, Body only, Fuze weight constant	1	2.03	1533±20	1537	+4
	1	2.03	1533±20	1537	+4
	1	2.03	1533±20	1536	+3
	1	2.03	1533±20	1534	+1
	1	2.03	1533±20	1539	+6
	1	2.03	1533±20	1520	-5
	1	2.03	1533±20	1530	-3
	1	2.03	1533±20	1539	+6
	1	2.03	1533±20	1533	0
	1	2.03	1533±20	1532	-1
	1	2.02	1533±20	1541	+8
	1	2.02	1533±20	1529	-4
	1	2.02	1533±20	1538	+5
	1	2.02	1533±20	1537	+4
	1	2.02	1533±20	1534	+1
	1	2.02	1533±20	1531	-2
	1	2.02	1533±20	1531	-2
	1	2.02	1533±20	1538	+5
	1	2.02	1533±20	1530	-3
	1	2.02	1533±20	1531	-2
	<u>20</u>			Mean = 1534	Deviation from mean = +7, -4
20mm Mk 12 Projectiles, Body only, Fuze weight constant	1	1.63	1700±15	1697	-3
	1	1.63	1700±15	1697	-3
	1	1.63	1700±15	1698	-2
	1	1.63	1700±15	1697	-3
	1	1.63	1700±15	1698	-2
	1	1.63	1700±15	1700	0
	1	1.63	1700±15	1699	-1
	1	1.63	1700±15	1697	-3
	1	1.63	1700±15	1701	+1
	1	1.63	1700±15	1704	+4
	<u>10</u>			Mean = 1699	Deviation from mean = +5, -2

Inert Loading of Munitions
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