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NAVORD REPORT 2262

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EFFECT OF LOADING VARIABLES ON THE BURNING
CHARACTERISTICS OF DELAY POWDERS

19 December 1951



U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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EFFECT OF LOADING VARIABLES ON THE BURNING
CHARACTERISTICS OF DELAY POWDERS

Prepared by

E. E. Elzufon

ABSTRACT: A study has been made of the effect of loading variables and obturation on the burning characteristics of delay powders consisting of manganese, barium chromate and lead chromate. The effects of increment size, quantity of igniter used, inside diameter of the delay body, type of loading ram and loading pressure were investigated. Recommended limits for the loading variables are presented. The maximum increment size and also the permissible increment size variation decrease with a decrease in body diameter. The increment size in #203 I.D. delay bodies was varied between 200 and 700 mg without an appreciable effect on the burning rate. The amount of igniter charge can affect the burning characteristics of the delays. Fifty, thirty, twenty, and twenty mgs of igniter are recommended for delays having internal diameters of #203, #156, #125, and #109 respectively. The smaller the diameter of the delay body, the more difficult it is to obtain sustained burning of the slow burning compositions. Although the slowest mixture (.08 inch/sec) burned satisfactorily at -65°F in #203 diameter bodies, the mixture failed to burn in #156 diameter bodies. Loading pressures between 21,200 psi and 38,800 psi were found to have a negligible effect on the burning rate of the delay powder. Obturated delays were found to have a burning rate approximately 30% higher than vented delays. It is concluded that the burning characteristics of the compositions studied are primarily a function of the formulation. The loading variables will not appreciably affect the burning time of the delay providing they are held within the recommended limits.

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This Report outlines the results of a study of one phase of the project, Development of Gasless Fuze Powder (NOL-Re2e-104-2). The investigation was made to determine the effect of varying the loading parameters on the burning characteristics of manganese, lead chromate and barium chromate delay powders; and to recommend limits within which they could be varied without adversely affecting the burning characteristics. The results of this investigation are intended for the use of the Naval Ordnance Laboratory and should be of interest to other activities engaged in developing pyrotechnic delays.

References

- (a) NAVORD Report 1773, The Development of Mixing Procedures for Gasless Fuze Powders, 22 Jan 1951
- (b) NAVORD Report 1814, A Method of Protecting Metal Powders from Deterioration, 18 Apr 1951

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EFFECT OF LOADING VARIABLES ON THE BURNING
CHARACTERISTICS OF DELAY POWDERS

INTRODUCTION

1. A pyrotechnic delay powder composed of manganese, lead chromate, and barium chromate, is at present being considered for use in a variety of ordnance devices. In the design of the required delay elements, knowledge of the effect of various loading variables on the behavior of this powder is required. A study therefore has been made of the effect of the following variables on delay behavior:

- a. increment size in loading
- b. size of igniter charge
- c. body diameter
- d. type of ram
- e. loading pressure
- f. venting and obturation

Procedure

2. In making these studies, a variety of mixtures was used. All were prepared in three pound batches according to the procedure outlined in reference (a), using Mn pretreated according to reference (b), methods f and g. The burning times and the compositions of the mixtures investigated are listed in Table I.

3. These investigations included both vented and obturated delays. The delay bodies, procedure for loading the compositions in the bodies and the delay assemblies are shown in Plates 1 through 5. The delay columns in all cases were loaded at 30,000 psi except when delays were prepared to investigate the effect of loading pressures. In loading bodies using the cone ram, the igniter and the adjoining increments at both ends of the delay powder were pressed together. In flat ram loadings all increments including the igniter were pressed separately.

4. The firing jig for the delays is shown in Plates 6 and 7. The delays were timed using the method outlined in reference (b). Vented bodies were initiated with Dupont S-67 electric squibs. A base charge of about 15 mg of black powder was used in the vented delays. The completely obturated delays were initiated with a low energy electric initiator that contains 5 mg of lead styphnate. The base charge in this case was a smokeless powder pellet or a 70 mg black powder pellet.

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5. Cold tests were run in a temperature controlled room at temperatures varying from -70° to -60°F . The firing jig heated up to about -55°F maximum during the firing runs. High temperature tests were run in a small box with temperatures varying from $+155^{\circ}$ to 170°F . The temperatures of the firing jig were not taken during these runs.

Increment Size Studies

6. In an effort to determine the effect the increment size of the delay powder has on the burning time of these delays, the following tests were carried out. D-7 mixture was loaded in .7203 diameter bodies, in increment sizes as indicated in Table II. These were fired at room temperature and the burning times recorded in Table II and plotted in Plate 8. The results of this test indicate that increment size affects both the height of the delay column and the resulting burning time for a given weight of delay powder. However, Plate 8 indicates that within these limits the burning times in seconds per unit length of delay column is constant regardless of the increment size used.

7. A more thorough study was then made of the effect of increment size on delay burning times and column heights in .7203 bodies. The data taken are shown in Table III and plotted in Plates 9, 10 and 11. Burning time and column height data indicate that if increment size variations are kept within reasonable limits the effect on the burning characteristics of the delay will be negligible. For .7203 bodies it is recommended that delay powder increment sizes be kept between 200 and 700 mg. Burning times of delays loaded as recommended may be considered directly proportional to column height and both in turn proportional to the weight of delay powder used provided that the diameter of the column and the loading pressure are held constant.

8. Mixtures F2, M2, S2 and X2 were loaded in .7156 bodies with increment sizes varying from 100 to 300 mg. These delays were fired and timed and the results recorded in Tables IV, V, VI and VII. These results were plotted on Plate 12. Results indicate that for these mixtures varying the increment sizes from 100 to 300 does not affect the burning times of the delay. It is recommended that for .7156 bodies increment sizes be kept in this range.

9. Mixtures F2 and M2 were loaded in .7125 bodies in 75, 150, and 250 mg increments. These delays were fired and times recorded in Tables VIII and IX and plotted in Plate 13. In mixture M2 the 250 mg increments gave shorter burning times than would be expected. This seems to result from delay powder getting between the ram and the walls of the delay body, thereby causing excess wall friction and reducing the effective loading pressure. It is therefore recommended that in .7125 bodies increment sizes larger than 150 mg be avoided.

10. In a similar manner the data listed in Tables X and XI, and plotted in Plate 14, show that for a .7109 body, increment size of the order of 200 mg produced faster burning rates than expected. It is recommended that in .7109 bodies increment sizes not exceed 125 mg.

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11. The foregoing indicates that the optimum increment size for production loading of delay columns should be selected not only with an eye towards getting the smallest number of increments but also towards getting an increment size that is small enough to eliminate the probability of loading irregularities due to excessive wall friction.

Minimum Igniter Studies

12. In order to determine the minimum amount of igniter powder, which would reliably ignite these delay powders at all temperatures, a slow burning mixture with a specific burning time of over 14.0 seconds per inch was used. These delays were loaded in ".203 bodies using the rams shown in Plate 15 and the methods illustrated in Plate 16.

13. The results of this study (see Table XII) indicate that regardless of the loading procedure used, 20 mg of F33B igniter will give ignition at 77°F. However, at -65°F 20 mg will give ignition only with flat ram loading. However, 50 mg did provide ignition in all delays at all temperatures.

14. It is recommended that in loading delays in ".203 bodies a minimum of 50 mg of igniter be used. In cold box tests of smaller diameter delays (see Tables III through X) smaller charges of igniter were used and found to be satisfactory. The following charges are therefore recommended as minimum for all diameters:

".203	50 mg
".156	30 mg
".125	20 mg
".109	20 mg

Body Diameter Studies

15. At times, because of space limitations, it becomes desirable to decrease the size of the delay body to a minimum. In the design of a delay column it is important to know what burning area is required to provide sufficient heat for the self-burning propagation of the delay column. For this reason, studies were made to attempt to relate the burning characteristics of the delay column with burning rate of the composition, diameter of the burning area and the temperature. Delay bodies having internal diameters of .203, .156, .125 and .109 inches were used in these studies. The delay bodies were loaded with compositions that had burning rates in the order of 0.36 to 0.08 inches per second at room temperatures. Burning rates were calculated graphically from Plates 12, 13, 14 and 19. The results of these tests are shown in Table XIV. The height of delay column, weight of delay powder used and delay column diameter have the relationships shown in Plates 21, 22, 23 for all the mixtures used.

16. The delays were tested at room temperature (77°F and -65°F). Mixture F2 which has a burning rate of approximately 0.35 inches per second burns satisfactorily in all diameters at all temperatures. Mixture M2 with a burning rate of approximately 0.11 inches per second burns satisfactorily in all bodies at 77°F but produced duds when burned in ".125 and ".109 bodies at -65°F.

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Mixture S2 with a burning rate of approximately 0.09 inches per second burns satisfactorily at all temperatures in #203 and #156 bodies but failed to burn in #125 or #109 bodies. Mixture X2, the slowest mixture used in this study at a burning rate of 0.08 inches per second burned at all temperatures in #203 bodies, but only at room temperature, in #156 bodies.

17. The above results indicate that there exists a relationship between burning rate, column diameter and ability to sustain burning at various temperatures. The quantitative determination of this relationship was beyond the scope of this task.

Effect of Different Rams

18. In the ignition of some types of pyrotechnic mixtures a cone or stepped ram is used to increase the ignition area. However, loading with a cone ram is more difficult than with a flat ram due to the tendency of the composition to adhere to the surface of the cone. In order to determine whether a cone ram is necessary for the reliable ignition of this type of delay column, a study was made using two different rams as illustrated in Plate 15 and loaded as previously mentioned in Plate 16. Table XII indicates that there is no significant difference in ignition due to the different rams used. However, a cone ram shortens the effective column length of the delay train thereby giving reduced total burning times. Data given in Table XIII and plotted in Plates 17, 18, 19, and 20 illustrate this point.

Effect of Varying Loading Pressures

19. In order to determine the effect of the loading pressure on the burning characteristics of the delay column, the following test was conducted: Delay columns #203 in diameter were loaded with 50 mg of F33B at the primer end, 30 mg of F33B at the base end, and three increments of 350 mg of M2. Five bodies of each were loaded at varying pressures as shown in Table XV. These data indicate that loading pressures between 21,200 psi and 38,800 psi have a negligible effect on the burning rates of these powders. The main loading pressure of 30,000 psi was varied $\pm 29.4\%$ resulting in burning time changes of $\pm 3.5\%$, burning rate changes of $\pm .08\%$, and variations of packed column heights of $\pm 2.6\%$. Thus for loading pressures in this range (30,000 psi) the effect of changing the loading pressures would be negligible if these variances are kept within $\pm 5\%$.

Effect of Obturation on Burning Rate

20. In the design of delay elements the question of relative behavior of vented and obturated delays arises. In order to get information regarding the effect of obturation on the burning rate of the delay the tests described below were conducted. Bodies shown in Plate 4 were loaded and assembled as indicated in Plate 5 for these tests. All loading was done with flat rams. The over-all length of these bodies was $1.790 \pm .005$, providing a space of approximately 0.910 for the delay column. Two series of bodies were loaded for this test as follows: (1) Series A was loaded with 50 mg of F33B at the primer end. Varying amounts of delay powder mixture M1 were used and any cavity remaining at the base end was filled with F33B powder. (2) Series B was loaded with varying amounts of mixture M1 and 30 mg of F33B at the base end and any cavity remaining at the primer end was filled with F33B.

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21. Burning times are given in Table XVI and the results are plotted in Plate 24. In Plate 24 burning times are plotted against the column length of the delay train. The slope of line A indicates that without an excess of igniter at the primer end a burning time of 6.50 seconds per inch is obtained at room temperature. This compares with a burning time in #203 vented bodies for M1 of about 9.20 seconds per inch at room temperature. Therefore, the obturated delays tested burned approximately at a 30% higher rate than the vented delays. In obturated delays the effect of excess igniter at the primer end is greater than in vented delays. Line B in Plate 24 illustrates that with excess igniter the burning time is not necessarily a linear function of column length. Therefore obturated burning rates greater than 30% above vented burning rates can be expected if excess igniter is used.

Recommendations

22. It is recommended that loading variables be kept within the limits specified in Table XVII. It is further recommended that flat rams be used in all loadings of these delay powders. It is further recommended that vented delays be used whenever possible in the design of fuze trains.

CONCLUSION

23. The burning characteristics of loaded $Mn-PbCrO_4-BaCrO_4$ delay powders are a function primarily of the formulation. It is not feasible to appreciably change the burning rates of delays by varying the loading parameters. Plate 25 indicates that for different mixtures there is a linear relationship between specific burning time in inches per second and the burning time for delays loaded in the same manner.

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TABLE I

Chemical Compositions and Burning Times (at 77°F)
of the Mixtures Used in These Studies

Mixture Designation	<u>Composition (weight %)</u>			Specific Burning time sec. per inch
	Mn	PbCrO ₄	BaCrO ₄	
F-2	43.2	52.3	4.5	3.0
F-1	43.8	53.2	3.0	3.2
M-2	33.4	37.6	29.0	8.6
M-1	35.0	40.0	25.0	9.2
D-7	34.3	37.2	28.5	9.8
S-2	31.4	34.6	34.0	11.0
X-2	29.8	32.2	38.0	12.4
X-1	31.4	34.6	34.0	12.7

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TABLE II

Burning Times and Column Heights of Delays Loaded With
D-7 in Varying Increment Sizes in .203" Bodies

(Igniter: 50 mg F33B Primer End, 30 mg F33B Base End, Flat Ram)

<u>Delay Charge Total Weight</u>	<u>Increments</u>	<u>Symbol on Plate 8</u>	<u>Column Height</u>	<u>Burning Time</u>
1400 mg	2 of 700		.701	5.65
"	"		.676	5.47
"	4 of 350		.650	5.39
"	"		.647	5.24
"	"		.646	5.37
"	7 of 200		.622	4.96
"	"		.638	5.13
"	"		.633	4.91
700 mg	1 of 700		.360	2.77
"	"		.361	2.72
"	2 of 350		.342	2.66
"	"		.350	2.77
"	4 of 175		.341	2.71
"	"		.343	2.68
"	"		.340	2.77
"	3 of 200		.340	2.67
"	1 of 100		.330	2.59
"	"		.340	2.56

TABLE III

D-7 Loaded in .203" Bodies

(Igniter: F33B-100 mg Primer End, 70 mg Base End, Cone Ram)

Increment Size	Mg	350	350	350	350	250	250	450	450
Number of Increment		Average Height	Time	770F	1600F	Average Height	Time	Average Height	Time
0		.208	-650F .22	.18	.19	.108	770F .18	.108	.18
1		.266	1.58	1.39	1.34	.217	1.14	.332	1.98
2		.427	3.40	3.11	3.08	.331	2.31	.520	3.97
3		.573	5.08	4.62	4.53	.436	3.46	.721	6.02
5		.858	8.50	7.75	7.36	.647	5.51	1.089	9.93
7		1.153	11.64	10.36	10.02	.864	7.54	1.523	14.01
9		1.476	15.50	13.71	12.72			1.916	18.41
10						1.197	10.72		
12		1.923	20.49	17.92	17.24				
13						1.507	13.82		
16						1.820	16.33		

TABLE IV
F-2 Loaded in .156" Bodies

Increment Size No. Incr.	(Igniter - F33B - 30 mg Primer End - 20 mg Base - Flat Ram)									
	100	100	200	200	300	300	300	300	200	200
	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time* (seconds)

0	.056	.22	.056	.22	.056	.22				
1	.115	.38		.56	.243	.72				
2	.179	.53	.307	.89	.446	1.27	.307	1.05		
3			.436	1.23	.647	1.79				
4	.300	.88								
5			.693	1.94						
6										
7	.493	1.42								
8										
9										
10	.680	1.91								

* -650P

TABLE V
M-2 Loaded in .156" Bodies

Increment Size No. Incr.	(Igniter - F33B - 30 mg Primer End - 20 mg Base End - Flat Ram)							
	100	100	200	200	300	300	200	200
	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time* (seconds)
0	.056	.22	.056	.22	.056	.22		
1	.124	.87	.199	1.41	.210	2.12		
2			.343	2.76	.509	4.21	.343	3.11
3	.269	2.15	.491	4.09	.730	6.14		
4								
5			.783	6.72				
6								
7	.557	4.71						
8								
9								
10	.770	6.57						

* -65°F.

TABLE VI

S-2 Loaded in .156" Bodies

(Igniter: F33B-30 mg Primer End, 20 mg Det. End, Flat Ram)

Increment Size	Mg	100	200	300	400	500	600	700	800	900	1000
		Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time* (seconds)
0											
1		.127	1.17	.203	1.94	.283	2.58				
2				.355	3.73	.529	5.22	.355	3.88		
3				.511	5.40	.766	7.69				
4		.350	3.62								
5				.819	8.69						
6											
7		.567	5.89								
8											
9											
10		.787	8.13								

* -650P

TABLE VII
X-2 Loaded in .156" Bodies

Increment Size	(Igniter - F3B - 30 mg Primer End - 20 mg Base End - Flat Ram)									
	100	100	200	200	300	300	300	300	200	200
	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time* (seconds)
0										
1	.127	1.42	.208	2.29	.296	4.32				
2			.361	4.11	.506	6.07	.361			4.55
3			.518	6.36	.776	9.03				
4	.357	4.26								
5										
6			.834	10.92						
7	.589	7.09								
8										
9										
10	.814	7.59								

* at -65°F. (unreliable, since some duds occurred)

TABLE VIII

Mixture F-2 Loaded in .125" Bodies

Increaser Size No. Incr.	(Igniter - F33B - 20 mg Primer End - 12 mg Base End - Flat Ram)				(-50F. Mixture F-1)			
	75	150	250	500	75	150	250	500
	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)	Height (inches)	Time (seconds)

0								
1	.126	.40	.203	.65	.319	.92	.216	.66
2					.606	1.71		
3			.485	1.30	.885	2.00	.517	1.59
4	.304	.96						
5			.826	2.25				
6								
7	.567	1.53						
8								
9								
10	.779	2.10						

TABLE IX
Mixture M-2 Loaded in .125" Bodies

(Igniter - F33B - 20 mg Primer End - 12 mg Base End - Flat Ram)										
Increment	75		150		250		250		(-65°F Mixture M-1)	
Size	Height		Time		Height		Time		Height	
No. Incr.	(inches)	(seconds)	(inches)	(seconds)	(inches)	(seconds)	(inches)	(seconds)	(inches)	Time
									150	150
0										
1	.138	0.96	.229	1.79	.367	2.91	.236	1.96		
2										
3	.311	2.60	.564	4.91	.692	5.58	.589	5.51		
4										
5	.481	4.21	.935	8.31	1.055	8.46				
6										
7										
8										
9										
10	.915	8.17								

TABLE X

Mixture F-2 Loaded in .109" Diam. Bodies

(Igniter - F33B - 20 mg Primer End - 12 mg Base End - Flat Ram)

Increment		60		125		200		250		300		350		400		450		500		550		600		650		700		750		800		850		900		950		1000		1050		1100		1150		1200		1250		1300		1350		1400		1450		1500		1550		1600		1650		1700		1750		1800		1850		1900		1950		2000		2050		2100		2150		2200		2250		2300		2350		2400		2450		2500		2550		2600		2650		2700		2750		2800		2850		2900		2950		3000		3050		3100		3150		3200		3250		3300		3350		3400		3450		3500		3550		3600		3650		3700		3750		3800		3850		3900		3950		4000		4050		4100		4150		4200		4250		4300		4350		4400		4450		4500		4550		4600		4650		4700		4750		4800		4850		4900		4950		5000		5050		5100		5150		5200		5250		5300		5350		5400		5450		5500		5550		5600		5650		5700		5750		5800		5850		5900		5950		6000		6050		6100		6150		6200		6250		6300		6350		6400		6450		6500		6550		6600		6650		6700		6750		6800		6850		6900		6950		7000		7050		7100		7150		7200		7250		7300		7350		7400		7450		7500		7550		7600		7650		7700		7750		7800		7850		7900		7950		8000		8050		8100		8150		8200		8250		8300		8350		8400		8450		8500		8550		8600		8650		8700		8750		8800		8850		8900		8950		9000		9050		9100		9150		9200		9250		9300		9350		9400		9450		9500		9550		9600		9650		9700		9750		9800		9850		9900		9950		10000		10050		10100		10150		10200		10250		10300		10350		10400		10450		10500		10550		10600		10650		10700		10750		10800		10850		10900		10950		11000		11050		11100		11150		11200		11250		11300		11350		11400		11450		11500		11550		11600		11650		11700		11750		11800		11850		11900		11950		12000		12050		12100		12150		12200		12250		12300		12350		12400		12450		12500		12550		12600		12650		12700		12750		12800		12850		12900		12950		13000		13050		13100		13150		13200		13250		13300		13350		13400		13450		13500		13550		13600		13650		13700		13750		13800		13850		13900		13950		14000		14050		14100		14150		14200		14250		14300		14350		14400		14450		14500		14550		14600		14650		14700		14750		14800		14850		14900		14950		15000		15050		15100		15150		15200		15250		15300		15350		15400		15450		15500		15550		15600		15650		15700		15750		15800		15850		15900		15950		16000		16050		16100		16150		16200		16250		16300		16350		16400		16450		16500		16550		16600		16650		16700		16750		16800		16850		16900		16950		17000		17050		17100		17150		17200		17250		17300		17350		17400		17450		17500		17550		17600		17650		17700		17750		17800		17850		17900		17950		18000		18050		18100		18150		18200		18250		18300		18350		18400		18450		18500		18550		18600		18650		18700		18750		18800		18850		18900		18950		19000		19050		19100		19150		19200		19250		19300		19350		19400		19450		19500		19550		19600		19650		19700		19750		19800		19850		19900		19950		20000		20050		20100		20150		20200		20250		20300		20350		20400		20450		20500		20550		20600		20650		20700		20750		20800		20850		20900		20950		21000		21050		21100		21150		21200		21250		21300		21350		21400		21450		21500		21550		21600		21650		21700		21750		21800		21850		21900		21950		22000		22050		22100		22150		22200		22250		22300		22350		22400		22450		22500		22550		22600		22650		22700		22750		22800		22850		22900		22950		23000		23050		23100		23150		23200		23250		23300		23350		23400		23450		23500		23550		23600		23650		23700		23750		23800		23850		23900		23950		24000		24050		24100		24150		24200		24250		24300		24350		24400		24450		24500		24550		24600		24650		24700		24750		24800		24850		24900		24950		25000		25050		25100		25150		25200		25250		25300		25350		25400		25450		25500		25550		25600		25650		25700		25750		25800		25850		25900		25950		26000		26050		26100		26150		26200		26250		26300		26350		26400		26450		26500		26550		26600		26650		26700		26750		26800		26850		26900		26950		27000		27050		27100		27150		27200		27250		27300		27350		27400		27450		27500		27550		27600		27650		27700		27750		27800		27850		27900		27950		28000		28050		28100		28150		28200		28250		28300		28350		28400		28450		28500		28550		28600		28650		28700		28750		28800		28850		28900		28950		29000		29050		29100		29150		29200		29250		29300		29350		29400		29450		29500		29550		29600		29650		29700		29750		29800		29850		29900		29950		30000		30050		30100		30150		30200		30250		30300		30350		30400		30450		30500		30550		30600		30650		30700		30750		30800		30850		30900		30950		31000		31050		31100		31150		31200		31250		31300		31350		31400		31450		31500		31550		31600		31650		31700		31750		31800		31850		31900		31950		32000		32050		32100		32150		32200		32250		32300		32350		32400		32450		32500		32550		32600		32650		32700		32750		32800		32850		32900		32950		33000		33050		33100		33150		33200		33250		33300		33350		33400		33450		33500		33550		33600		33650		33700		33750		33800		33850		33900		33950		34000		34050		34100		34150		34200		34250		34300		34350		34400		34450		34500		34550		34600		34650		34700		34750		34800		34850		34900		34950		35000		35050		35100		35150		35200		35250		35300		35350		35400		35450		35500		35550		35600		35650		35700		35750		35800		35850		35900		35950		36000		36050		36100		36150		36200		36250		36300		36350		36400		36450		36500		36550		36600		36650		36700		36750		36800		36850		36900		36950		37000		37050		37100		37150		37200		37250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TABLE XI
Mixture M-2 Loaded in .109" Bodies

Increment Size	(Igniter - F33B - 20 mg Primer - 12 mg Base End - Flat Ram)			
	Mg.	60	125	200
		Height (inches)	Height (inches)	Height (inches)
		Time (seconds)	Time (seconds)	Time (seconds)
0				
1	.157	1.02	.267	1.93
2				
3			.652	5.49
4	.413	3.46	.860	7.23
5				
6				
7	.688	6.12		
8				
9				
10	.976	8.43		
			.415	3.03
			.771	5.87

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TABLE XII

Results of Minimum Igniter Studies in .203"Bodies

Type Loading	Amount of Igniter	Room Temperature (77°F)					Cold Box (-65°F)		
		70 mg	50 mg	30 mg	20 mg	10 mg	50 mg	30 mg	20 mg
Cone up		+	+	+	+	0	+	0	0
		+	+	+	+	0	+	+	0
		+	+	+	+	0		0	0
Cone down		+	+	+	+	+	+	+	+
		+	+	+	+	+	+	0	0
		+	+	+	+	+	+	+	0
Flat ram		+	+	+	+	0	+	+	+
		+	+	+	+	0	+	+	+
		+	+	+	+	0	+	+	+

0 Duds

+ Satisfactory Ignition

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TABLE XIII

Burning Times and Column Heights as a Function of
Different Rams for all Mixtures Loaded in .203" Diameter Bodies

(Igniter-F33B-100 mg Primer End, 70 mg Base End, Cone Ram)

Mixture No. Increment	F-2		M-2		S-2		X-2	
	Ht. (In.)	Time (Sec.)	Ht. (In.)	Time (Sec.)	Ht. (In.)	Time (Sec.)	Ht. (In.)	Time (Sec.)
(350 mg)								
1								
2	.383	1.02	.407	2.68	.426	3.39	.434	3.86
3	.516	1.40	.570	4.06	.581	4.97	.595	5.92
4								
5	.769	2.08	.869	6.60	.904	8.54	.916	9.94

(Igniter-F33B-50 mg Primer End, 30 mg Base End, Flat Ram)

(350 mg)								
1								
2	.312	1.00	.349	2.79	.359	3.61	.342	4.25
3	.444	1.36	.497	4.10	.516	5.34	.527	6.16
4								
5	.711	2.10	.792	6.62	.836	8.79	.845	10.10

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TABLE XIV

Burning Characteristics as a Function of Body I.D.

Mixture	Diameter in.	Cross Section Area in.	Room Temperature		Burning*	
			Burning Time (sec/in)	Burning Rate (in/sec)	Room Temperature	-65°F
F-2	.203	.0305	3.00	0.33	B	B
"	.156	.0192	2.80	0.36	B	B
"	.125	.0123	2.50	0.40	B	B
"	.109	.0093	2.80	0.36	B	B
M-2	.203	.0305	8.50	0.116	B	B
"	.156	.0192	8.80	0.114	B	B
"	.125	.0123	9.10	0.110	B	F
"	.109	.0093			B	F
S-2	.203	.0305	10.90	.092	B	B
"	.156	.0192	11.00	.091	B	B
"	.125	.0123			F	F
"	.109	.0093			F	F
X-2	.203	.0305	12.40	.081	B	B
"	.156	.0192			B	F
"	.125	.0123			F	F
"	.109	.0095			F	F

*B = Burned Satisfactorily

*F = Failed to Burn

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TABLE XV

Effect of Loading Pressure on Packed
Density and Burning Rate of Delay Powders

(.203" Bodies, M-2 Mixture, Flat Ram 3 Increments of 350 mg 50 + 30 mg of F33B)

Dial Reading	Pressure (psi)	Average Column Height (inches)	Average Burning Time (seconds)	Average Burning Rate (inches/second)
29	21,200	.518	4.18	.124
35	25,600	.511	4.14	.124
41	30,000	.505	4.04	.125
47	34,400	.496	4.00	.124
53	38,800	.492	3.91	.126

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TABLE XVI
Burning Times of Sealed Bodies

Shot	Series	F33B Primer End	Weight Delay Powder	F33B Base End	Delay* Column Length (inches)	Burning Time (Seconds)
1	A + B	50	0	1400	.050	.20
		50	0	1400	.050	.21
		50	0	1400	.050	.22
2	A	50	350	1200	.190	1.17
3	A	50	700	950	.350	2.10
		50	700	950	.350	2.13
4	A	50	1050	700	.495	3.17
		50	1050	700	.495	3.00
5	A	50	1200	580	.560	3.59
		50	1200	580	.560	3.60
6	A	50	1400	450	.645	4.14
7	A	50	1750	200	.795	5.14
		50	1750	200	.795	5.15
8	A + B	50	2100	30	.945	6.11
		50	2100	30	.945	6.07
		50	2100	30	.945	6.06
2a	B	1200	350	30	.190	.93
3a	B	700	1050	30	.495	2.38
		700	1050	30	.495	2.44
7a	B	250	1750	30	.795	4.34
		250	1750	30	.795	4.41

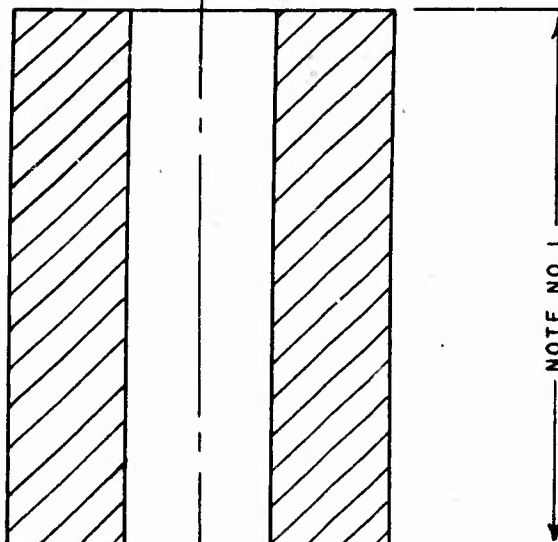
*Delay Column Length = Length for Delay Powder + Length for 80 mg F33B
(50 Primer End 30 Det. End)

TABLE XVII
Recommended Limits for Loading Variables

Body Size I.D.	Increment		Igniter Charge	Pressure	
	Maximum	Minimum		Maximum	Minimum
.203"	700	200	50	31,500	28,500
.156"	300	150	30	31,500	28,500
.125"	150	65	20	31,500	28,500
.109"	125	50	20	31,500	28,500

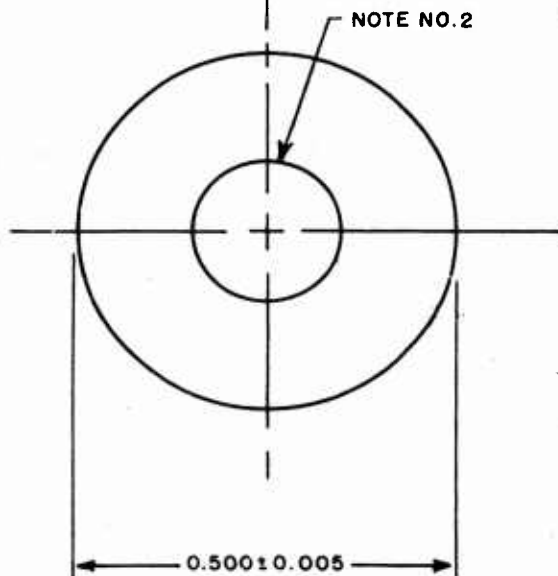
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PLATE 1
VENTED BODIES



NOTE 1 - OVERALL LENGTHS VARY
ACCORDING TO SIZE
OF DELAY COLUMN

NOTE 2 - HOLE REAMED AS FOLLOWS:



NORMAL BODY SIZE	HOLE DIMENSION
0.109	$0.109^{+0.001}_{-0.000}$
0.125	$0.125^{+0.001}_{-0.000}$
0.156	$0.156^{+0.001}_{-0.000}$
0.203	$0.203^{+0.001}_{-0.000}$

MATERIAL VARIED AS FOLLOWS:

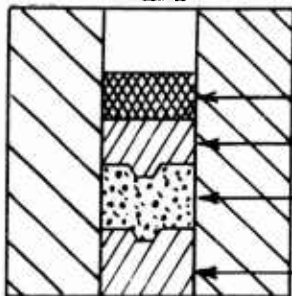
- a - BRASS
- b - COPPER
- c - STAINLESS STEEL

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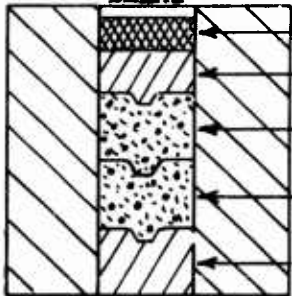
PLATE 2
LOADING PROCEDURE
VENTED BODIES, CONE RAM

1-INCREMENT
DELAY



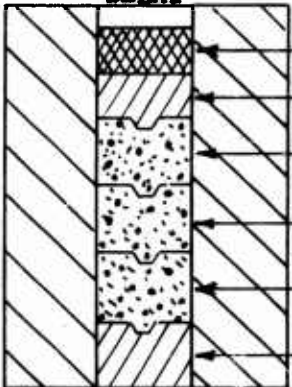
A-5 BLACK POWDER, 30,000 PSI, FLAT RAM.
BASE IGNITER, MACH. PRESS 30,000 PSI,
FLAT RAM.
DELAY, 1-INCREMENT, HAND PRESSED, CONE
RAM.
F-33-B PRIMER END, HAND PRESSED, CONE
RAM.

2-INCREMENT
DELAY



A-5 BLACK POWDER, 30,000 PSI, FLAT RAM.
BASE IGNITER, MACH. PRESS 30,000 PSI,
FLAT RAM.
2ND DELAY INCREMENT, HAND PRESS, CONE RAM.
1ST DELAY INCREMENT, MACH. PRESS 30,000 PSI
CONE RAM.
IGNITER PRIMER END, HAND PRESS, CONE RAM.

3-INCREMENT
DELAY



A-5 BLACK POWDER, 30,000 PSI, FLAT RAM.
BASE IGNITER, 30,000 PSI MACH. PRESS, FLAT
RAM.
LAST DELAY INCREMENT, HAND PRESS, CONE
RAM.
2ND DELAY INCREMENT, MACH. PRESS 30,000 PSI,
CONE RAM.
1ST DELAY INCREMENT, MACH. PRESS 30,000 PSI,
CONE RAM.
PRIMER END IGNITER, HAND PRESS, CONE RAM

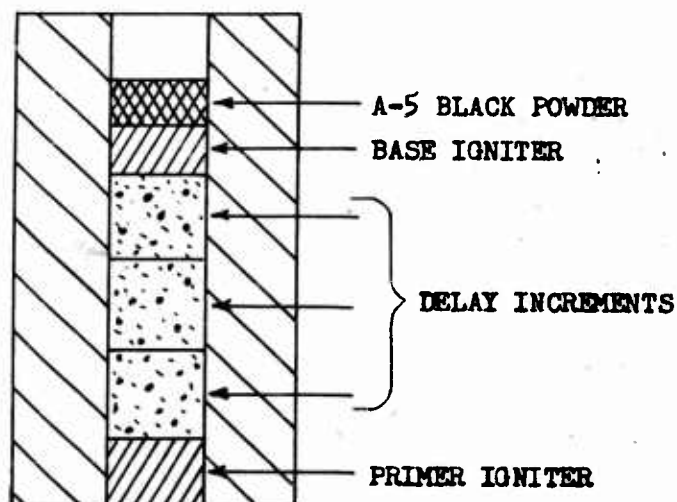
AS NUMBER OF DELAY INCREMENTS INCREASE, LOADING IS UNCHANGED.
(ALL ADDITIONAL DELAY INCREMENTS MACHINE PRESSED AT 30,000
PSI, AND LAST INCREMENT HAND PRESSED BEFORE BEING PRESSED
TOGETHER WITH BASE IGNITER).

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PLATE 3

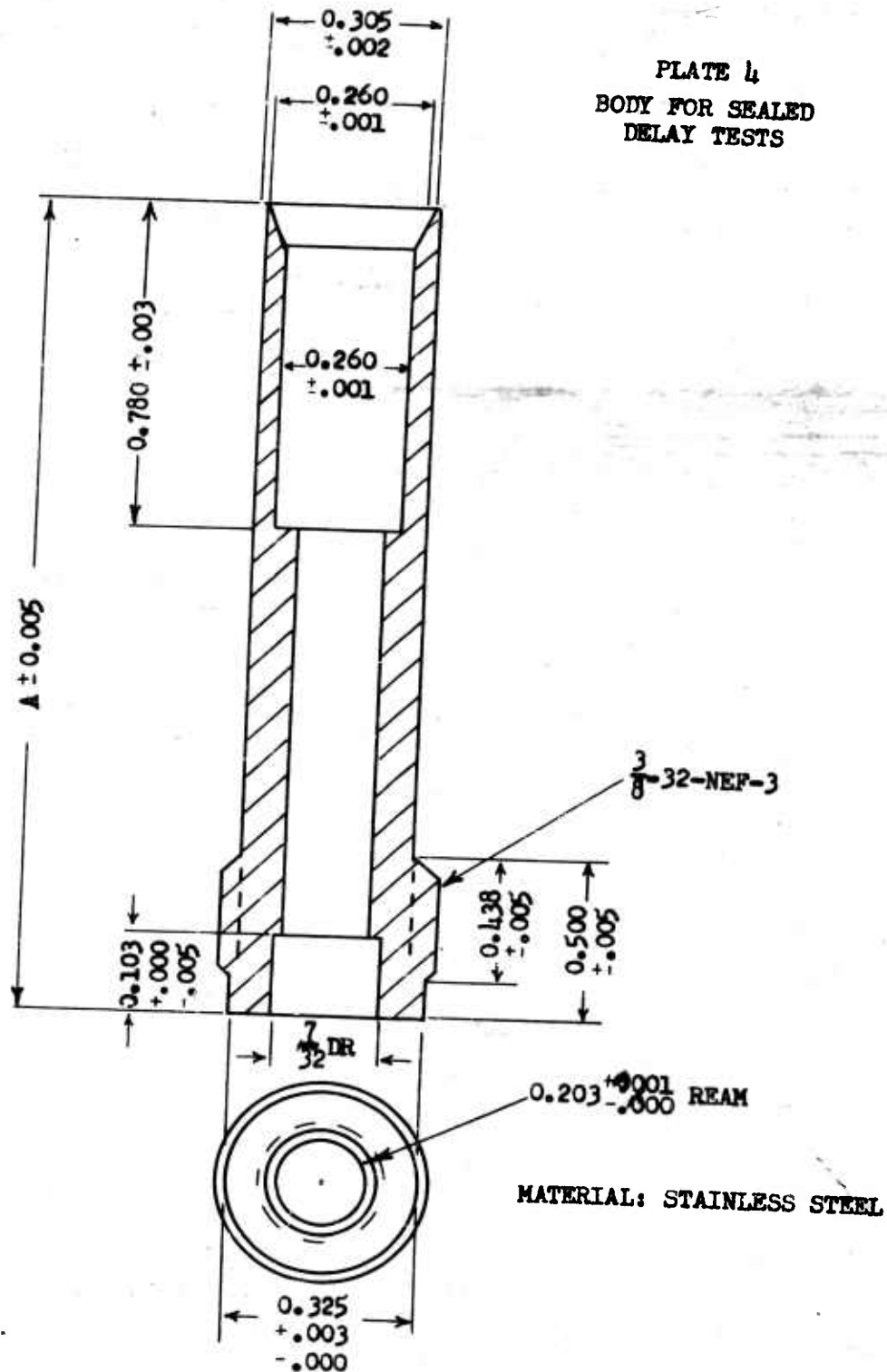
LOADING PROCEDURE
VENTED BODIES, FLAT RAM



ALL INCREMENTS, REGARDLESS OF NUMBER,
IGNITER, DELAY OR A-5 BLACK POWDER
PRESSED SEPARATELY WITH FLAT RAM AT
30,000 PSI

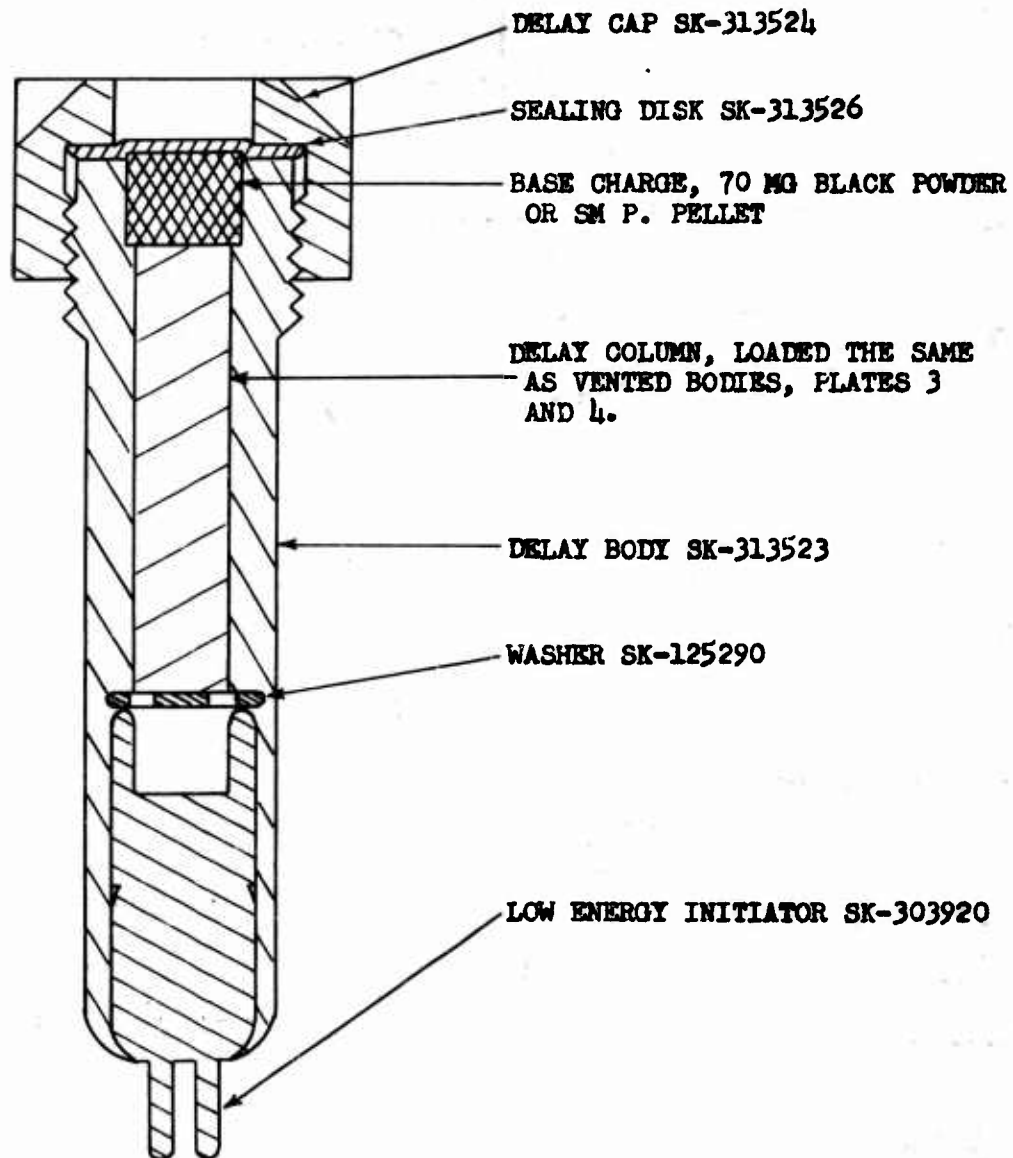
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PLATE 4
BODY FOR SEALED
DELAY TESTS



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PLATE 5
SEALED DELAY ASSEMBLY



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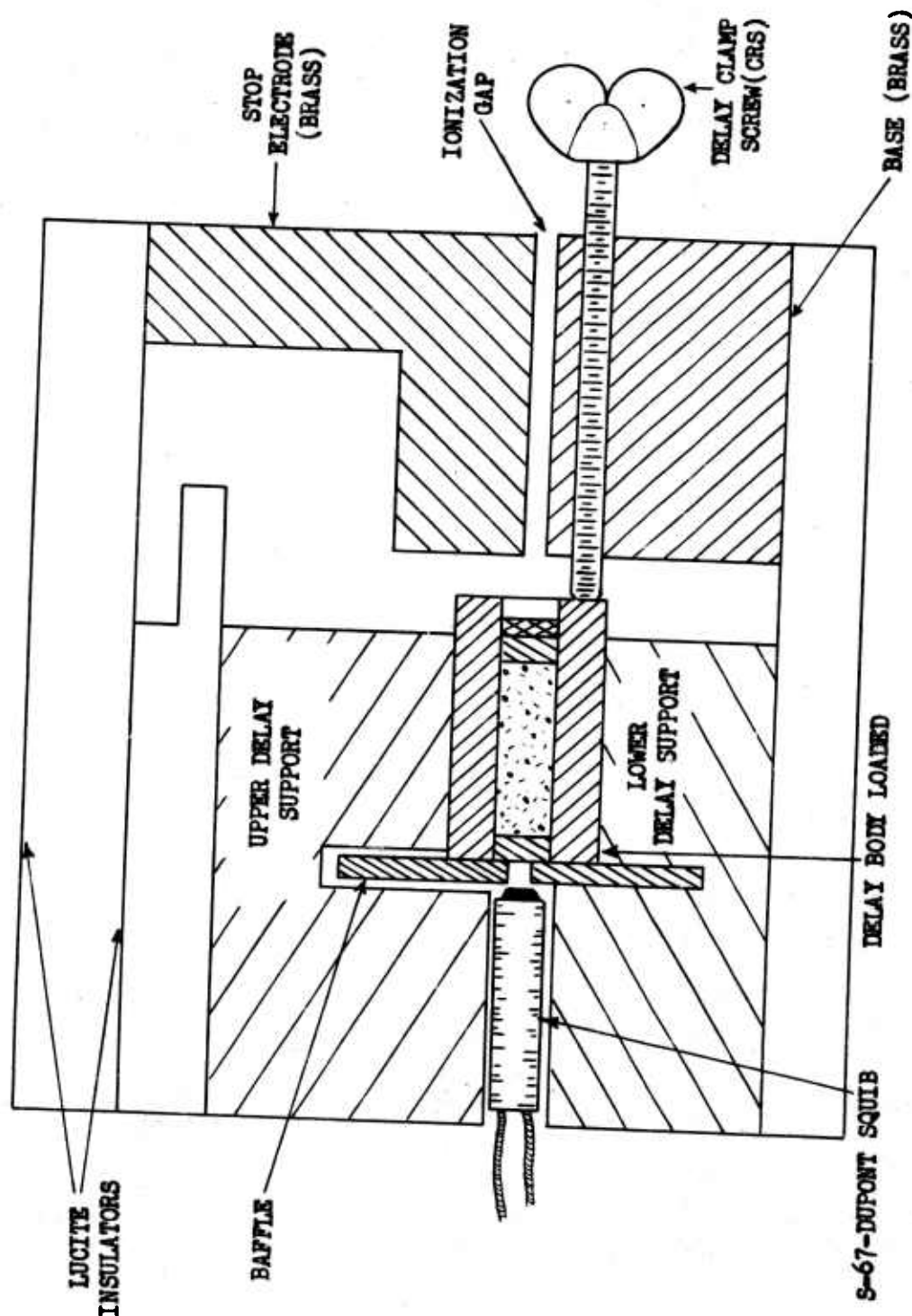
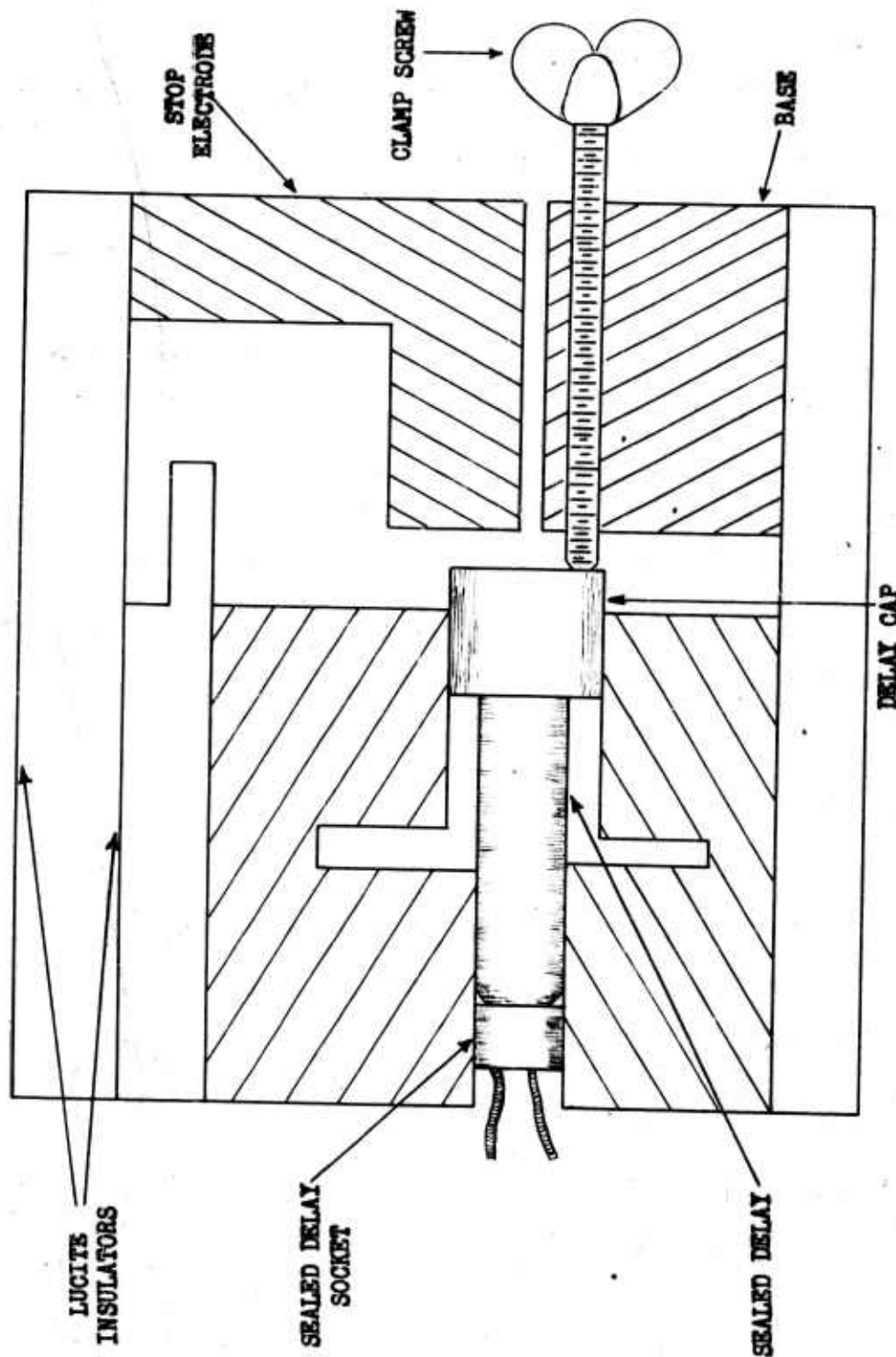


PLATE 6
VENTED BODY FIRING ARRANGEMENT



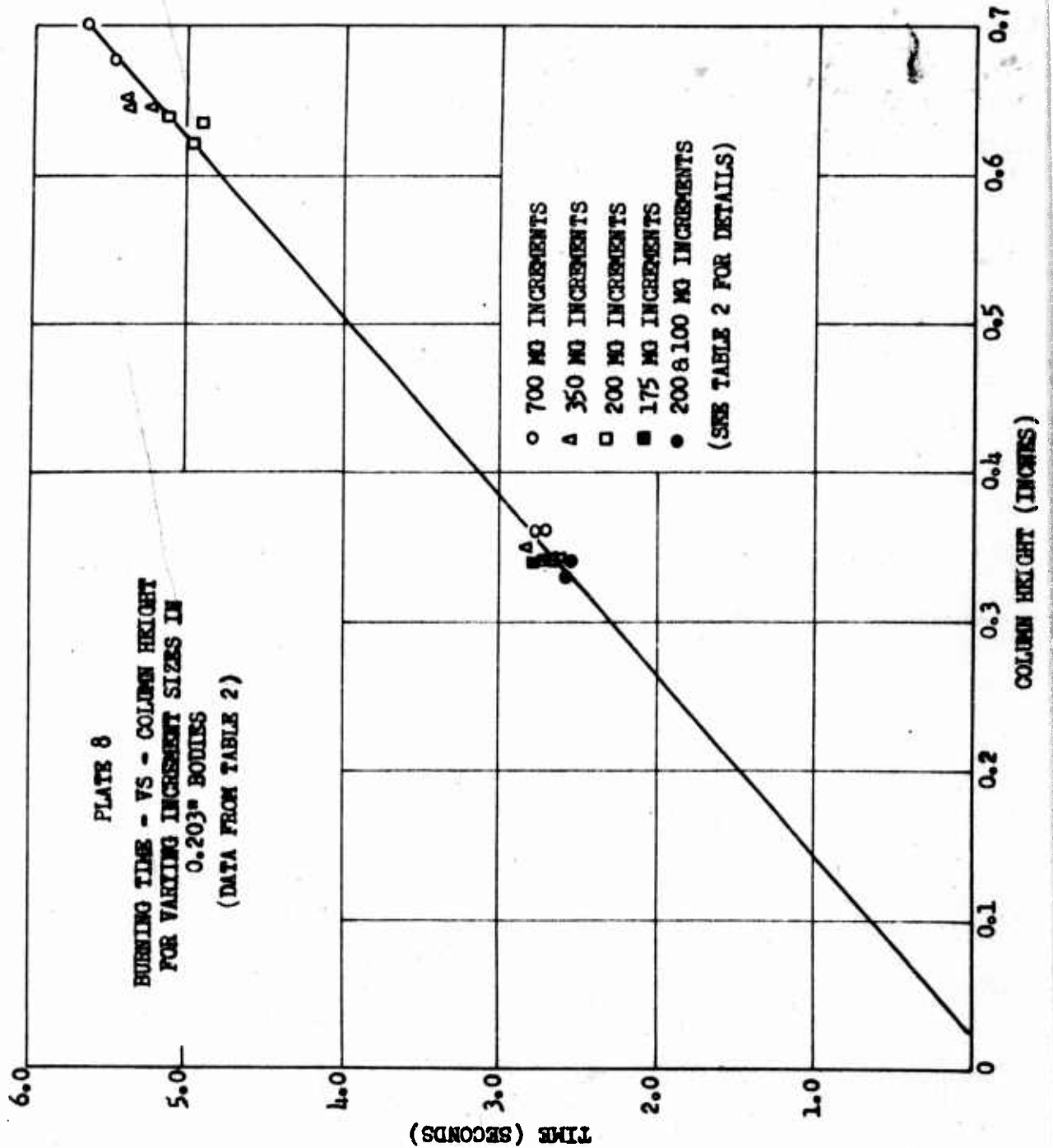
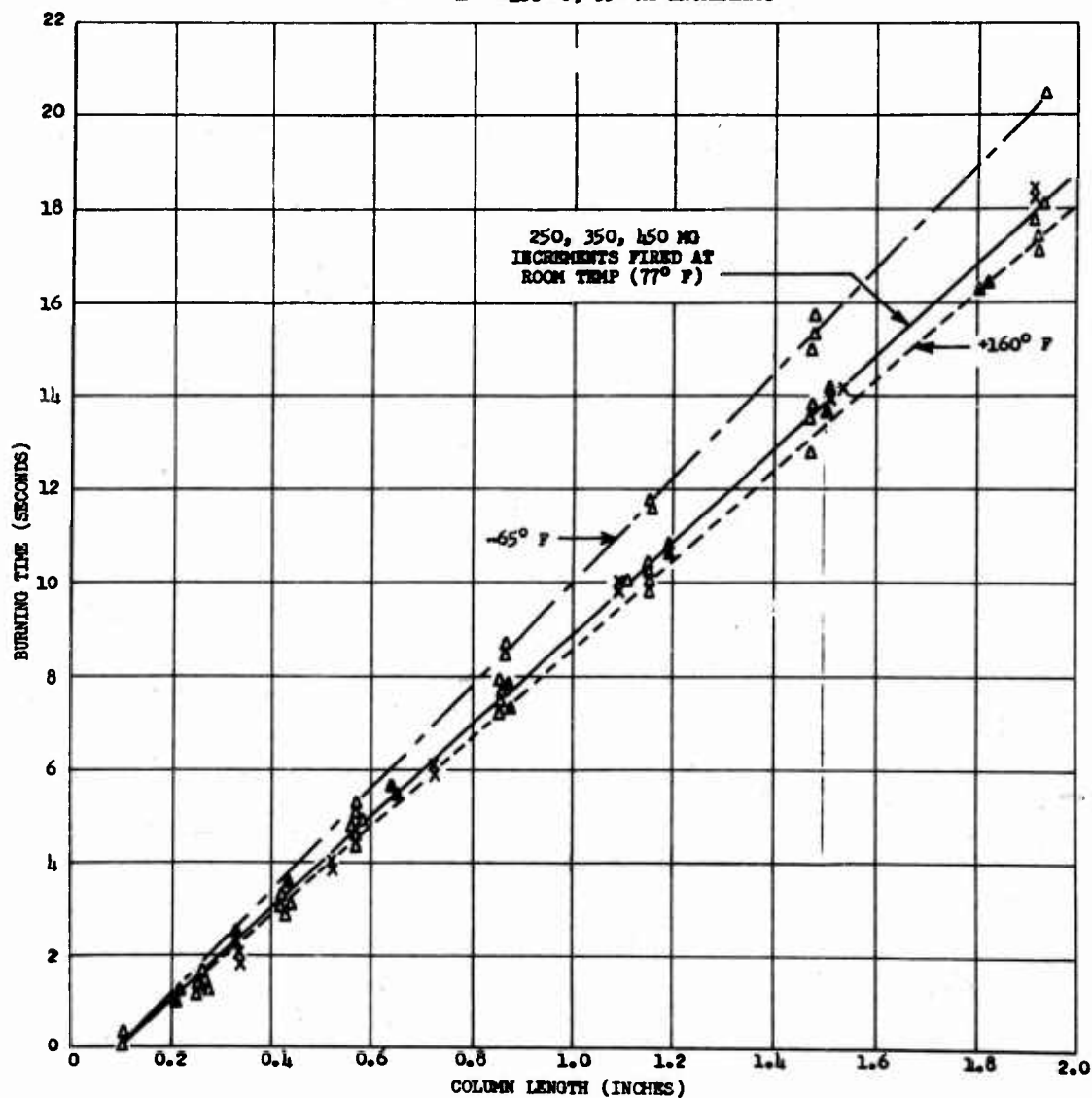


PLATE 9

BURNING TIME - VS - COLUMN LENGTH
FOR STANDARD D-7 MIXTURE

0.203" BODY, CONE RAM
100 MG F33B PRIMER END
70 MG F33B BASE END

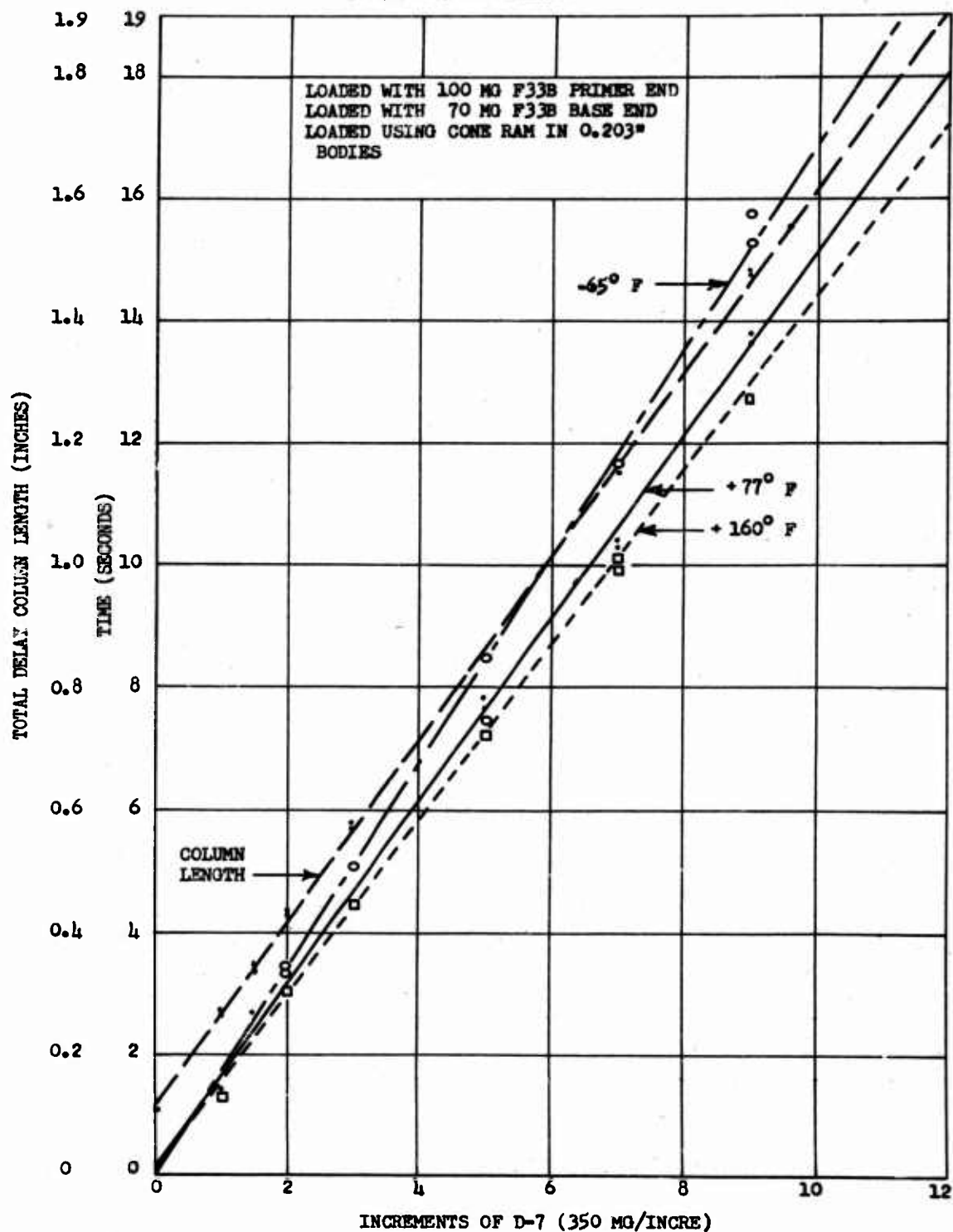
X 150 MG INCREMENTS
Δ 250 MG INCREMENTS
Δ 350 MG INCREMENTS
----- Δ -65° F, 350 MG INCREMENTS
----- Δ +160° F, 350 MG INCREMENTS



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PLATE 10

BURNING TIME & COLUMN LENGTH VS
NUMBER OF INCREMENTS DELAY (D-7)
(350 MG INCREMENTS)

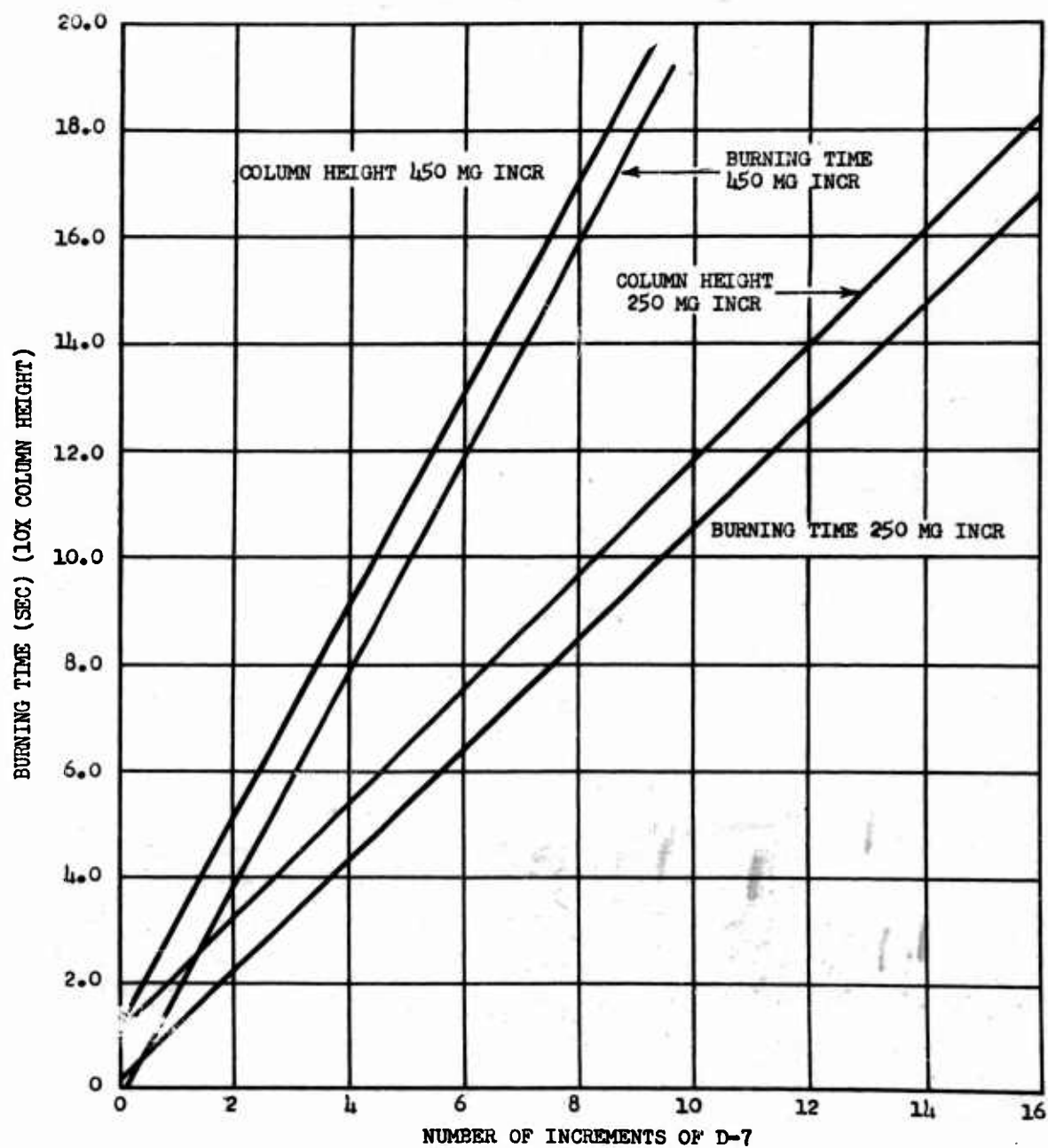


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PLATE 11
BURNING TIME AND COLUMN HEIGHT
FOR 250 MG AND 450 MG INCREMENTS
(STANDARD D-7 MIX.)

0.203 DIAM CONE RAM
100 MG F33B PRIMER END
70 MG F33B BASE END



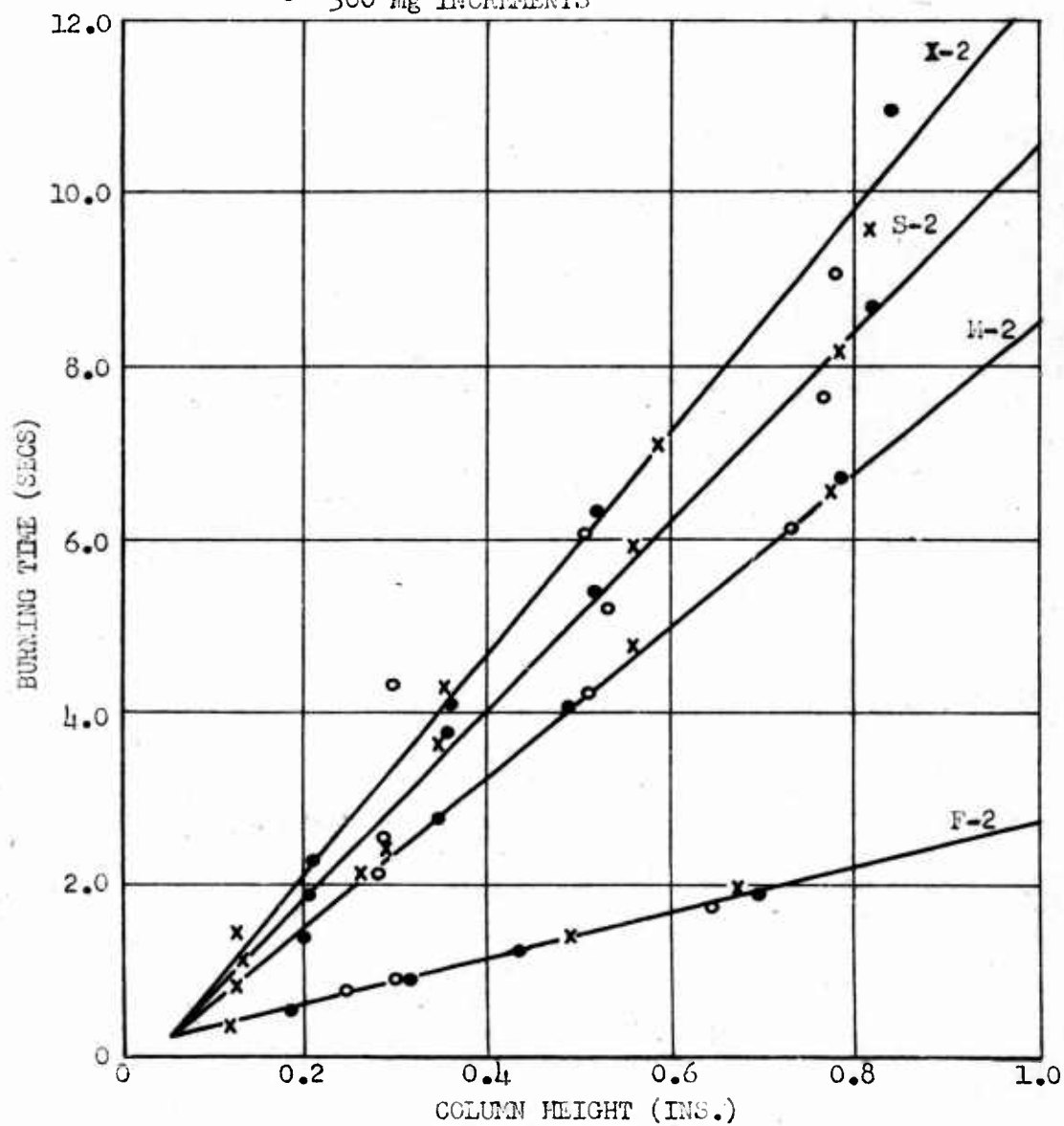
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PLATE 12 BURNING TIME vs COLUMN HEIGHT

0.156" BODIES, FLAT RAM

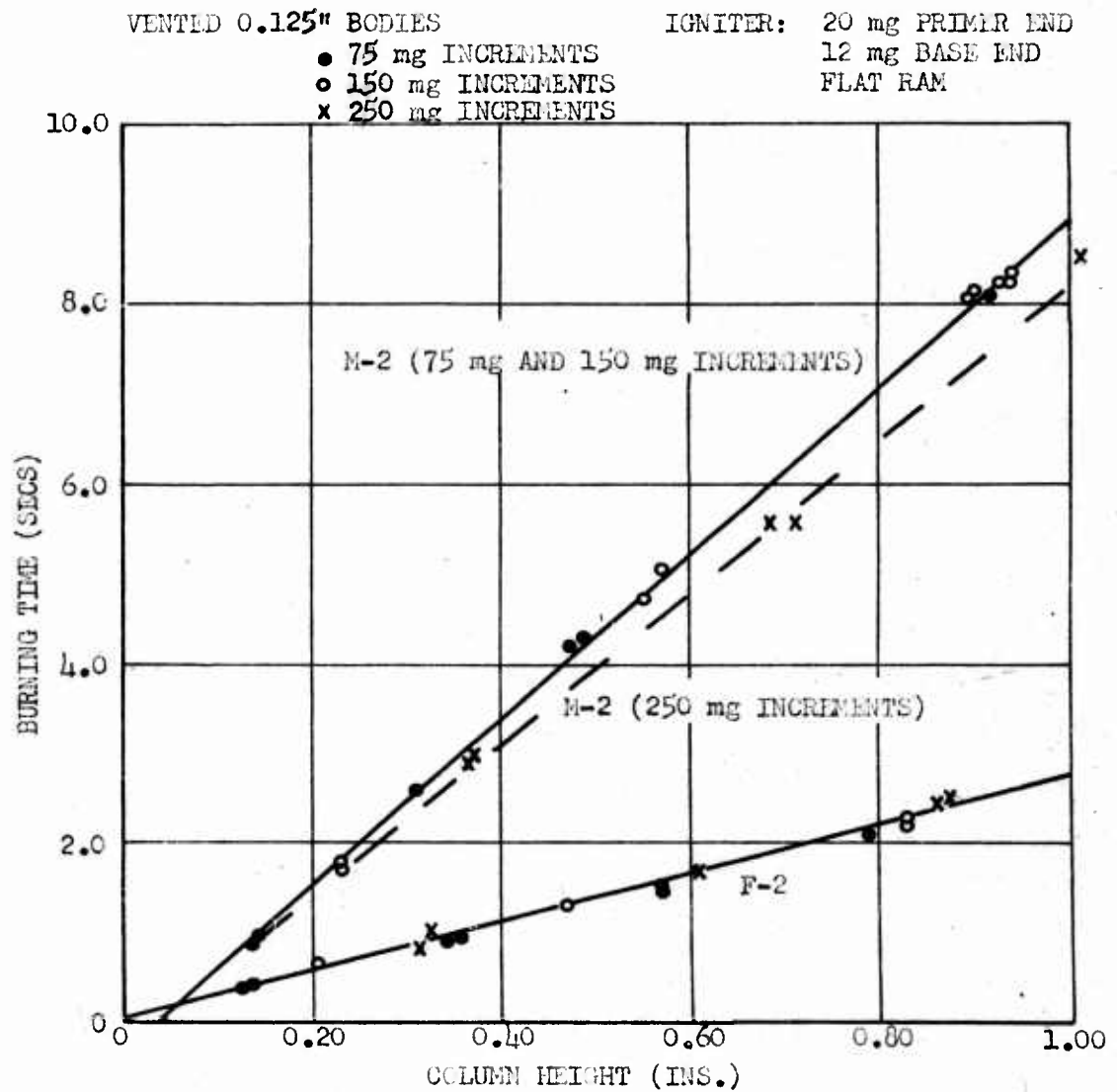
ALL FIRED AT ROOM TEMPERATURE — IGNITER: 30 mg PRIMER END
 x 100 mg INCREMENTS 20 mg BASE END
 • 200 mg INCREMENTS
 o 300 mg INCREMENTS



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PLATE 13 BURNING TIME vs COLUMN HEIGHT



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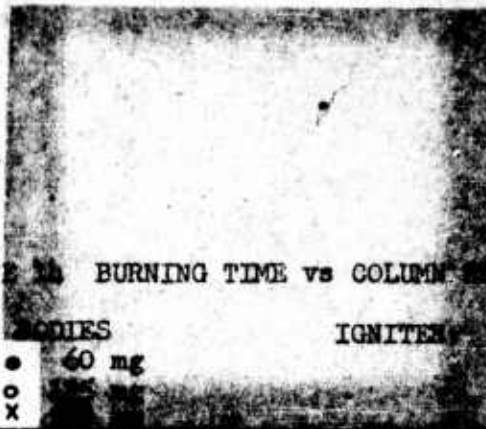
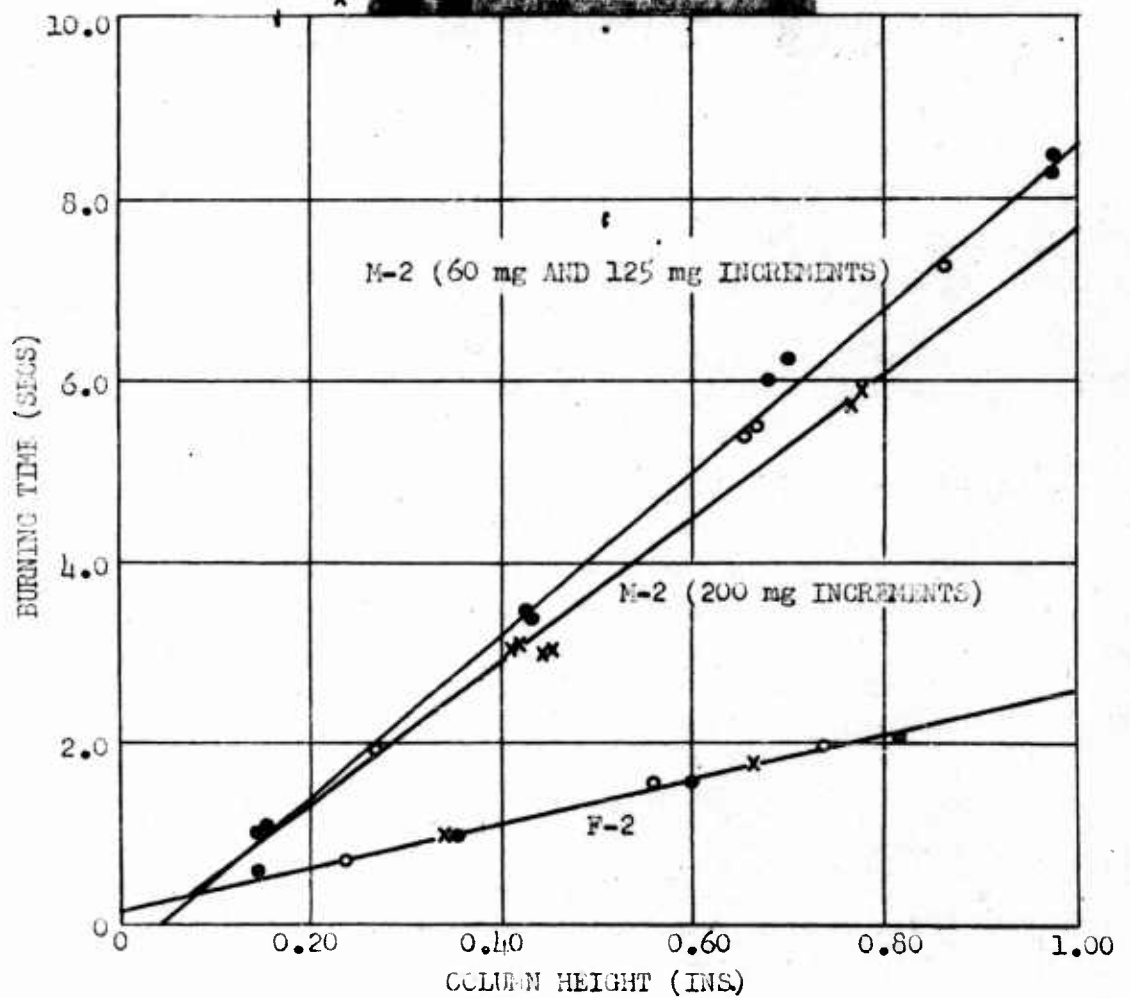


PLATE 1A BURNING TIME vs COLUMN HEIGHT

VENTED 0.109" HOLES

IGNITER 20 mg PRIMER END
12 mg BASE END
FLAT RAM



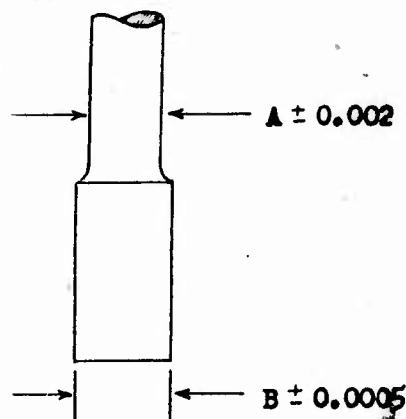
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PLATE 15
DIMENSIONS OF RAMS

1 - FLAT RAM

BODY TO BE LOADED	DIMENSIONS	
	A	B
0.203"	0.201	0.175
0.156"	0.154	0.135
0.125"	0.124	0.110
0.109"	0.108	0.090



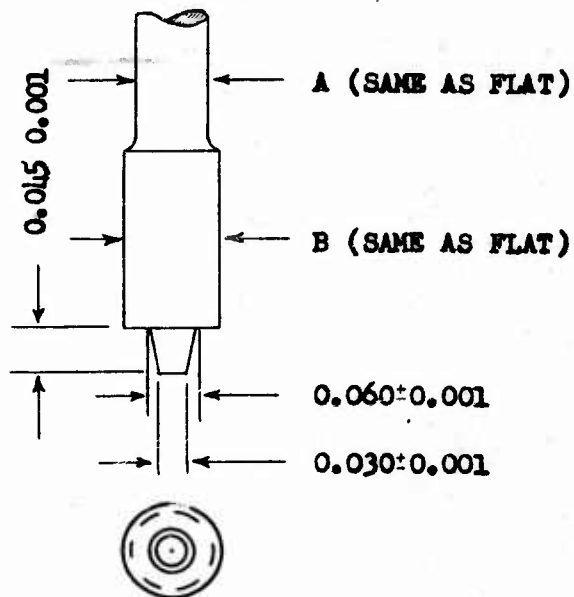
2 - CONE RAM

CONE RAM USED ONLY IN 0.203"
DIAMETER BODY

FOR FULL DETAILS OF RAMS SEE:

NOL-SK-313190

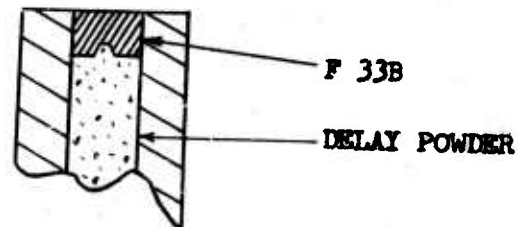
SK-313188



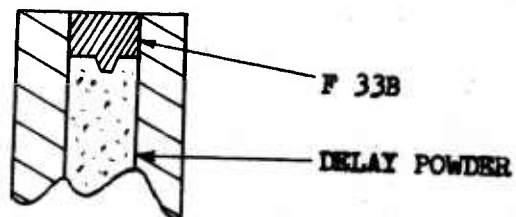
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PLATE 16
MINIMUM IGNITER STUDIES

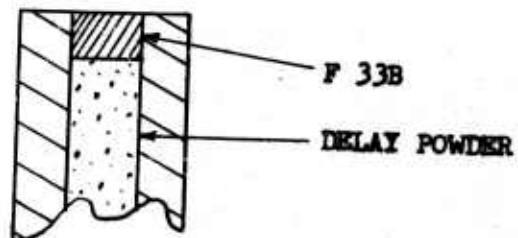
CONE UP



CONE DOWN



FLAT RAM

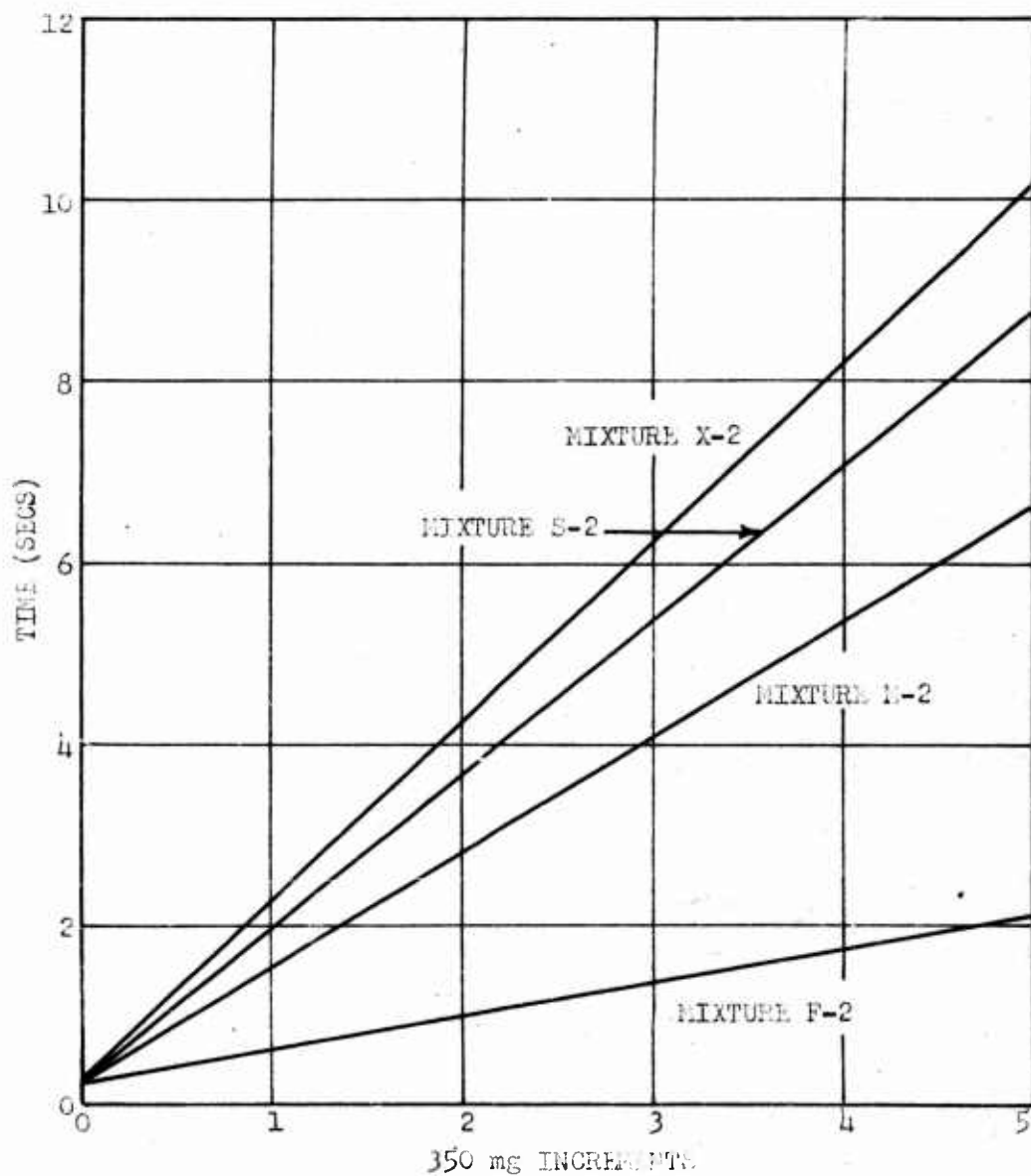


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PLATE 17 BURNING TIME vs NUMBER OF INCREMENTS

(LOADED WITH 50 mg F33B PRIMER RND
AND 30 mg F33B BASE RND USING FLAT RND.)

0.203" BODIES

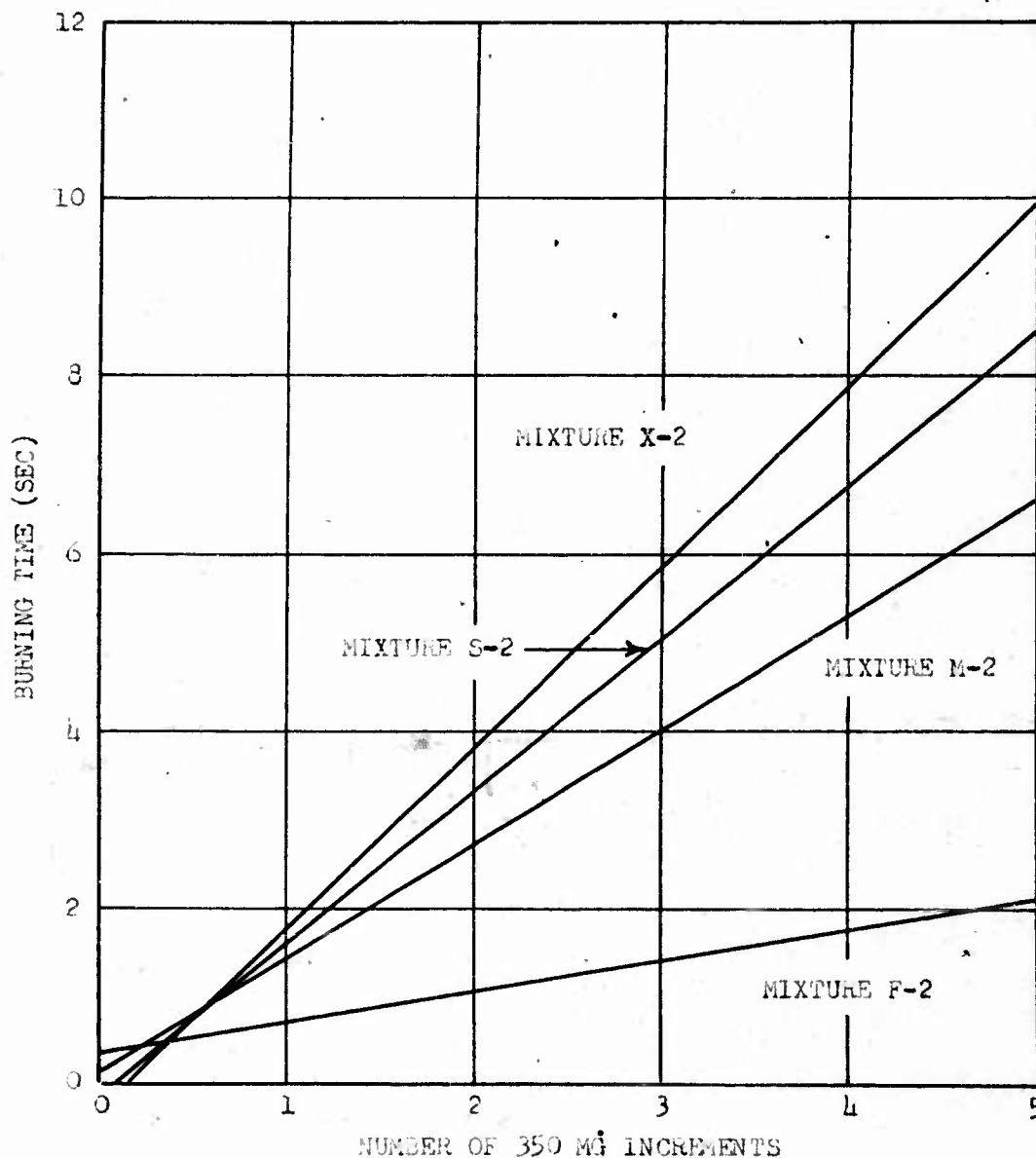


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PLATE 18

BURNING TIME VS NUMBER OF INCREMENTS
(LOADED WITH 100 MG F33B PRIMER END
LOADED WITH 70 MG F33B BASE END
LOADED USING CONE RAM.)

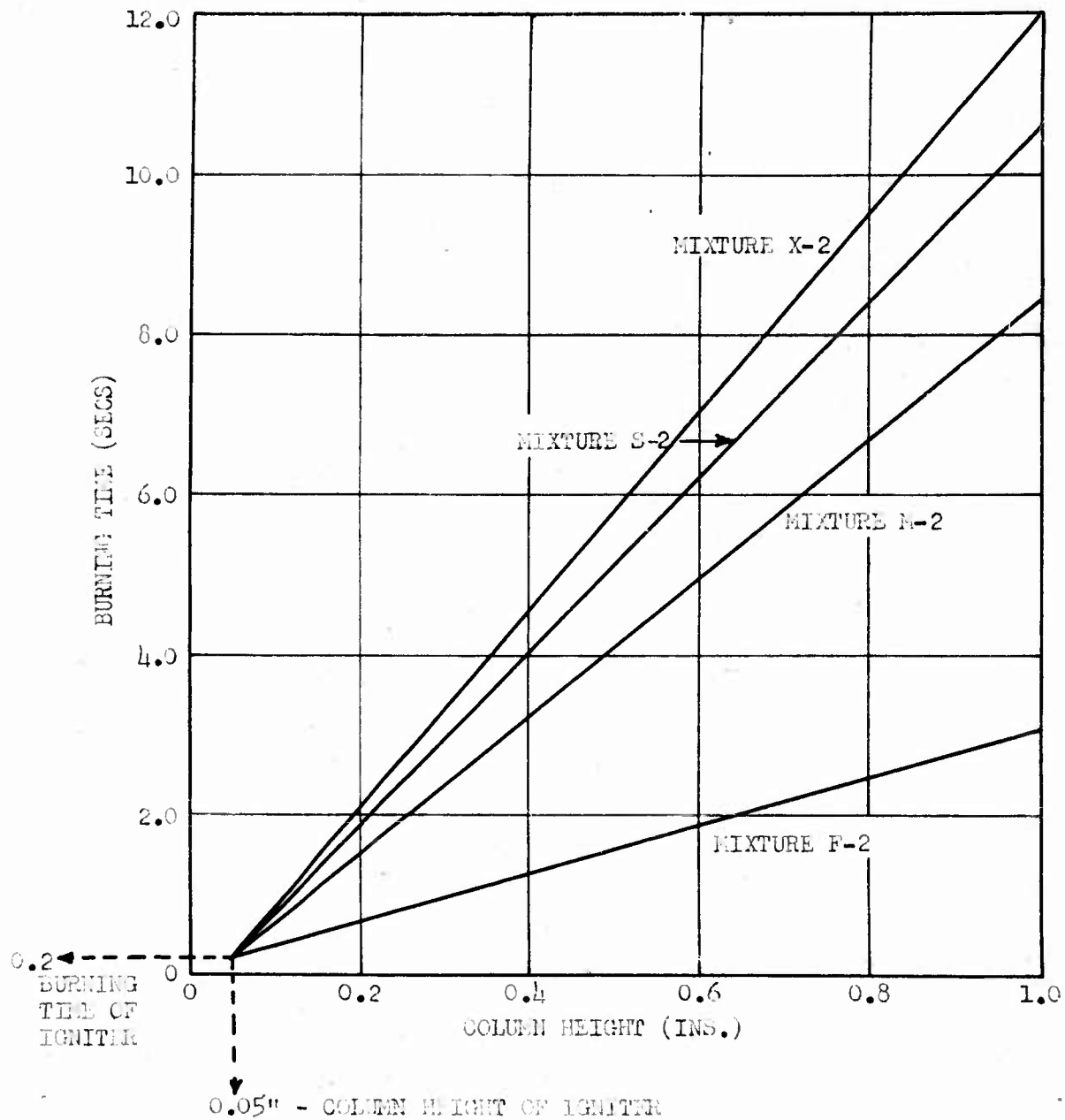
0.203" BODIES



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PLATE 19. BURNING TIME vs COLUMN HEIGHT

FLAT RAM - 0.203" BODIES
350 mg INCREMENTS
50 mg F33B PRIMER END
30 mg F33B BASE END



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PLATE 20

BURNING TIME VS COLUMN HEIGHT
CONE RAM LOADING IN 0.203" BODIES, 350 MG INCREMENTS

100 MG F33B PRIMER END
70 MG F33B BASE END

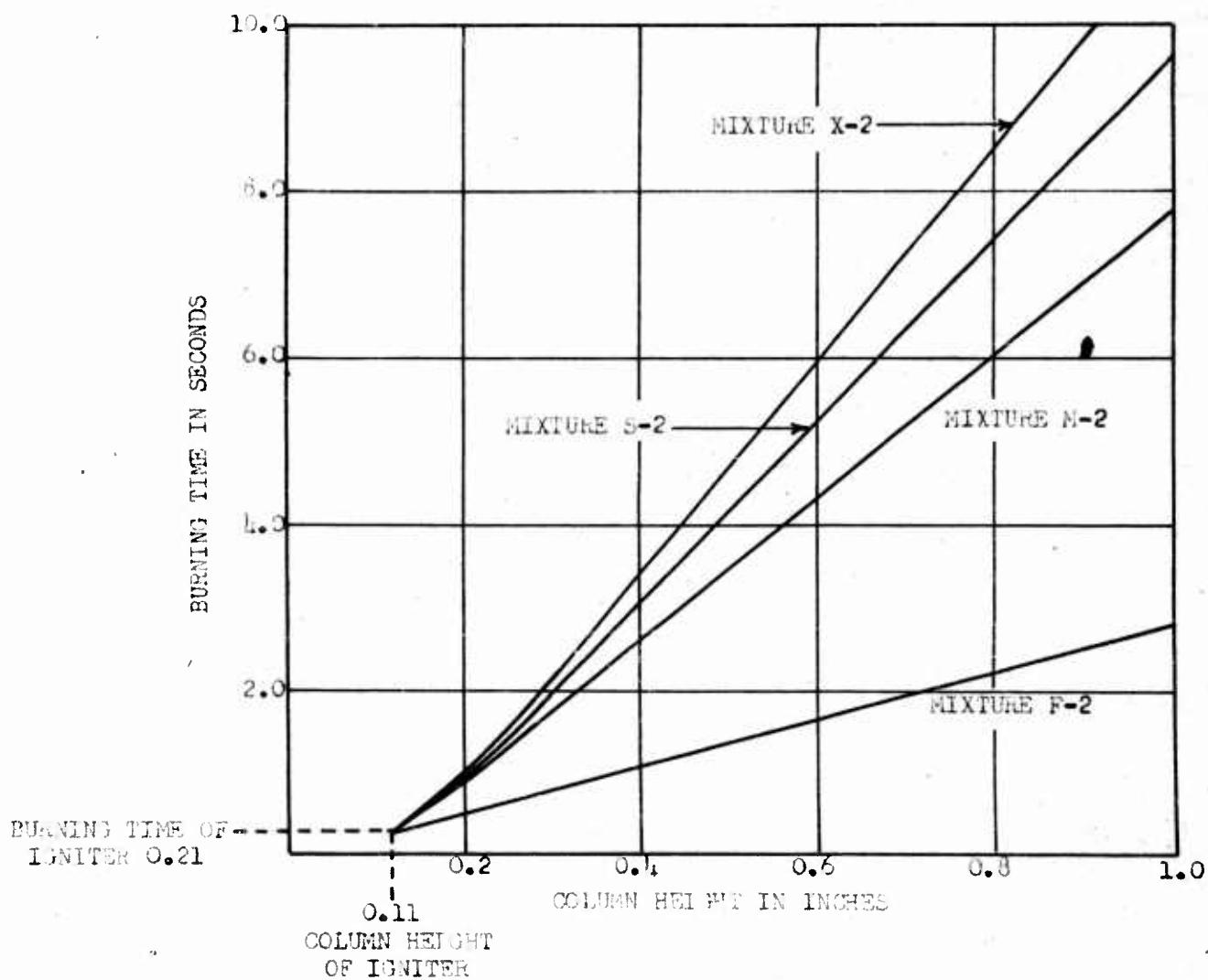


PLATE 21 COLUMN HEIGHT vs WEIGHT OF DELAY
0.203" BODIES

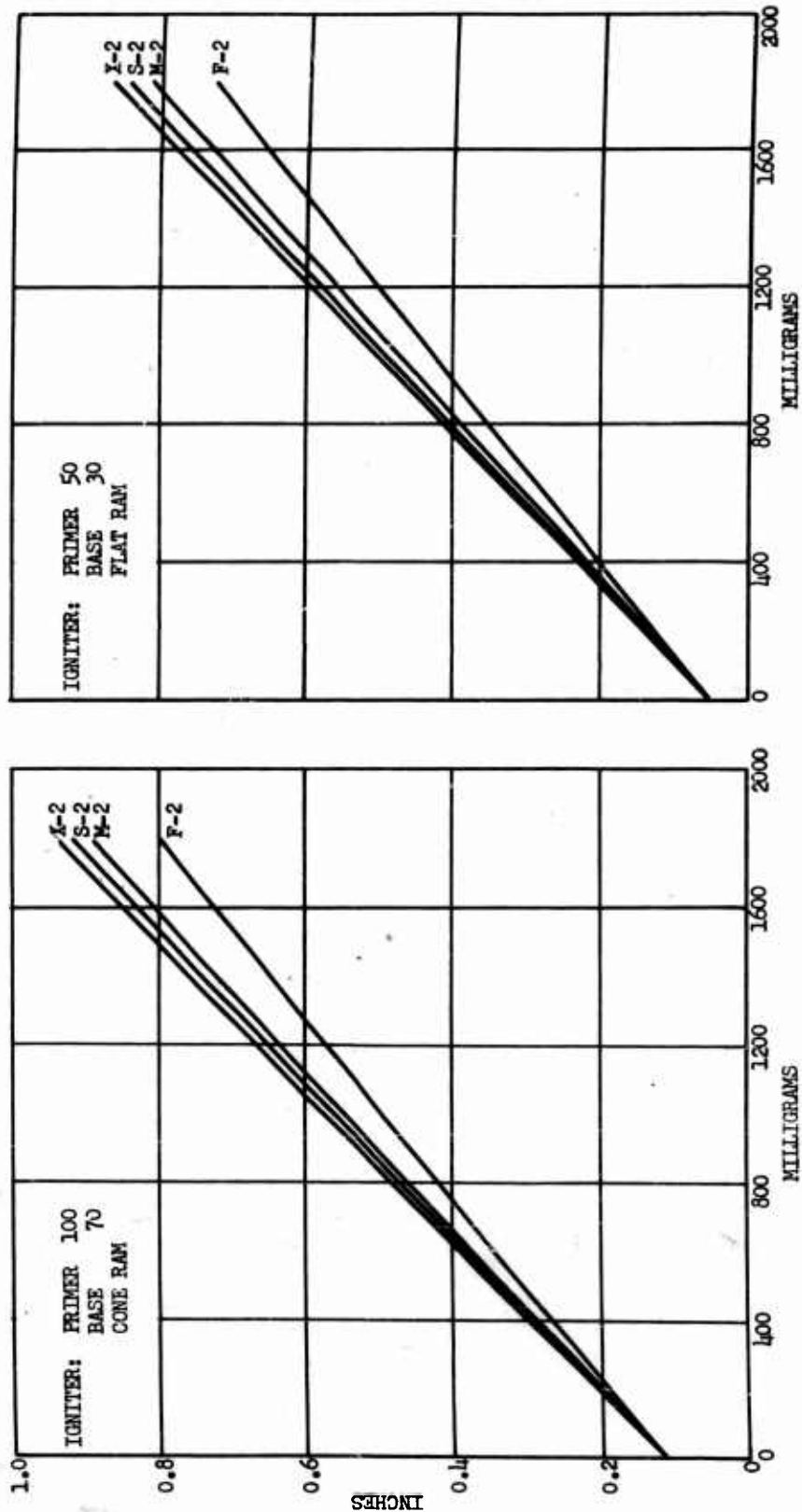


PLATE 22

HEIGHT OF DELAY
COLUMN VS WEIGHT DELAY POWDER
0.156" BODY

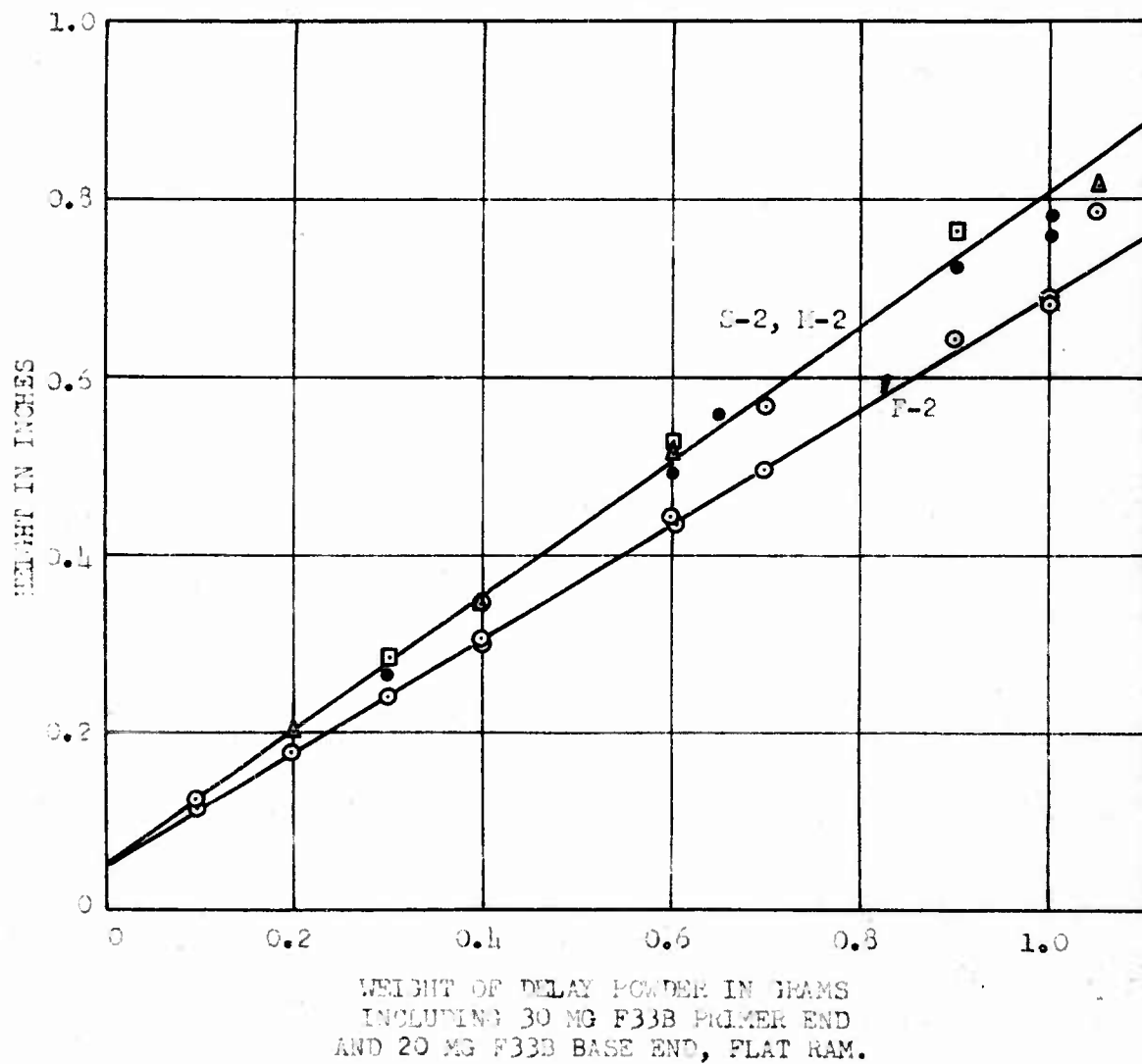


PLATE 23 HEIGHT OF COLUMN vs WEIGHT OF DELAY POWDER

IGNITER: 20 mg PRIMER
12 mg BASE END

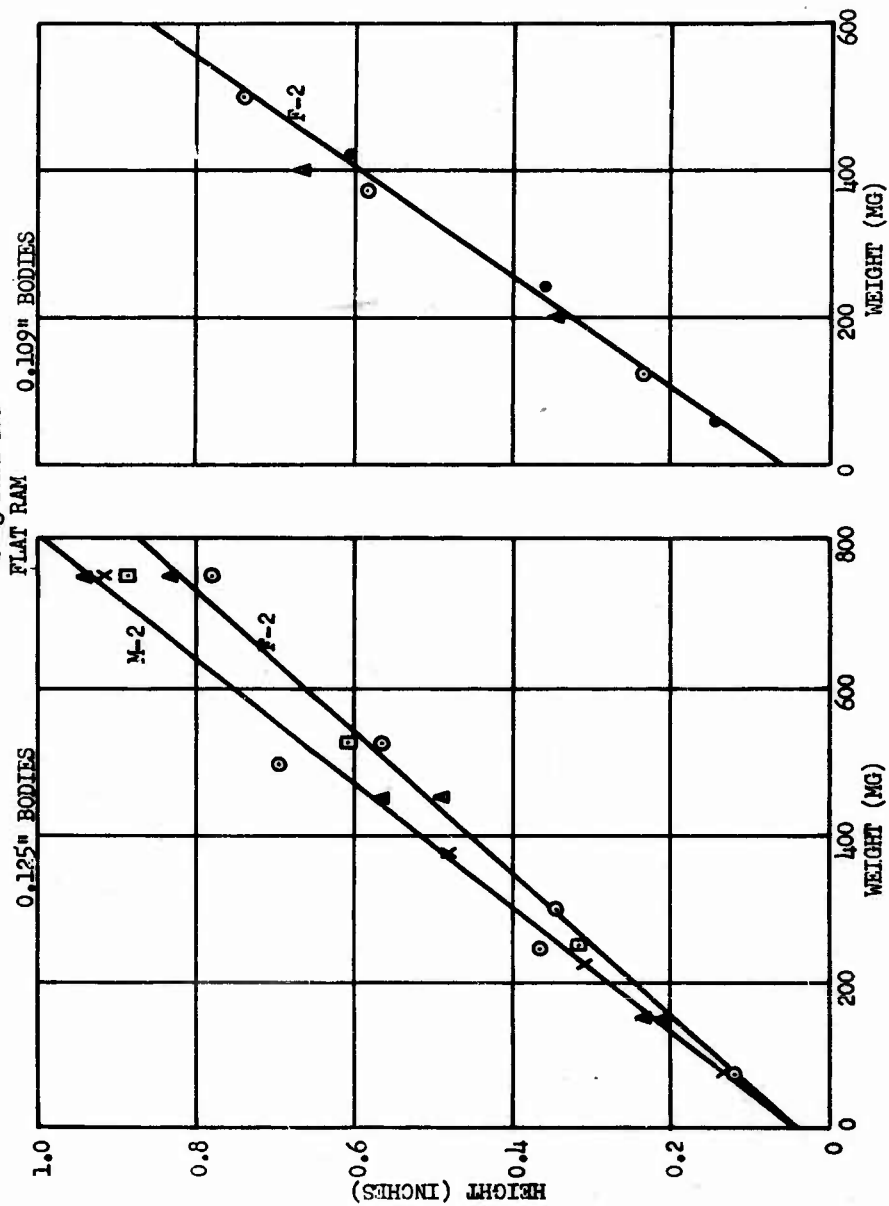
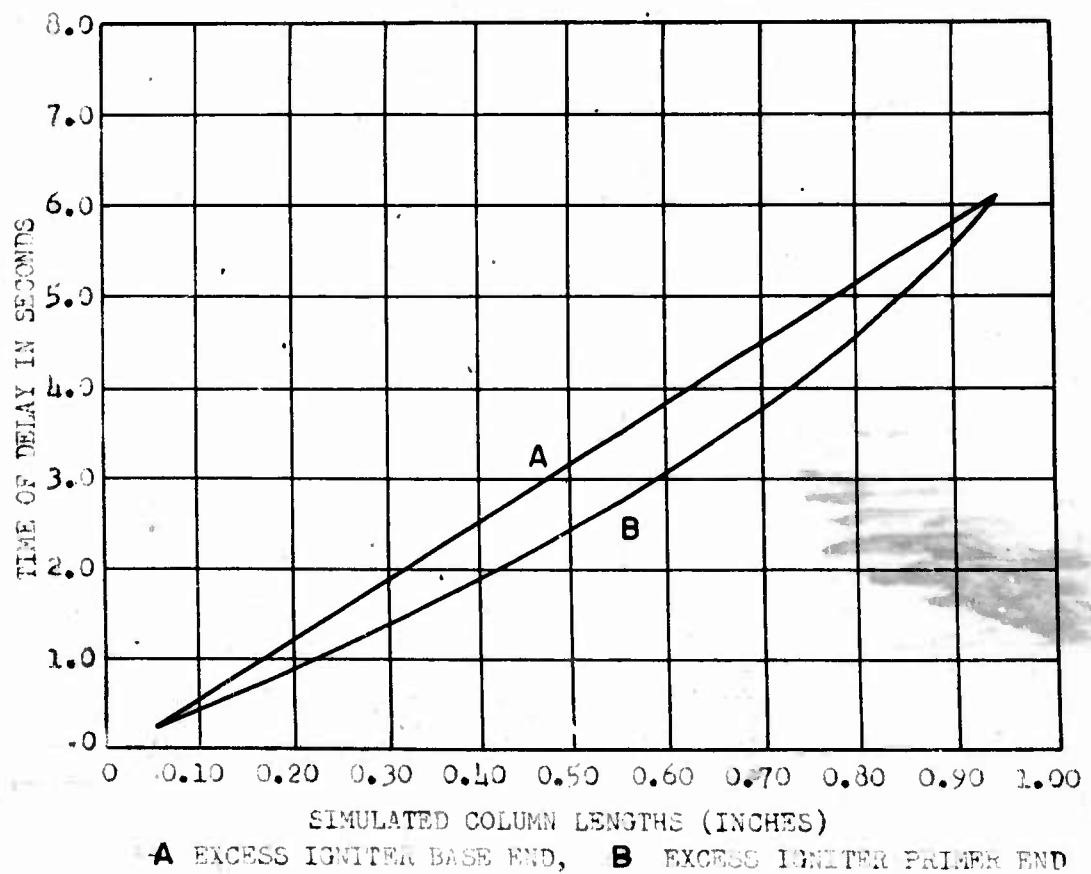


PLATE 24

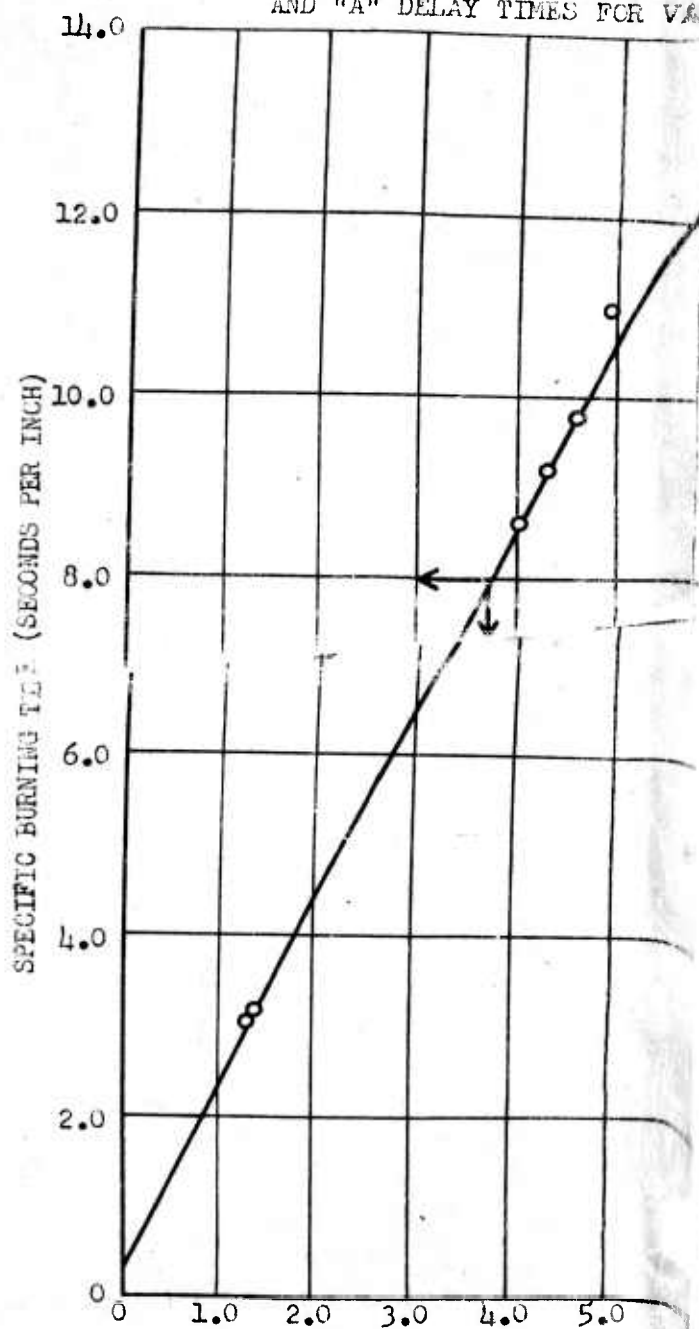
BURNING TIME OF DELAY VS SIMULATED COLUMN LENGTHS
IN OBTURATED BODIES. USING MIXTURE M-1



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PLATE 25 RELATION BETWEEN SPECIFIC BURNING TIME AND "A" DELAY TIMES FOR VARIOUS



"A" DELAY TIME (SECONDS)
A DELAY = 100 mg F33B + THREE 350 mg DEL

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