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(10)

TECHNICAL NOTES NO. 40

RESINS OTHER THAN LAMINAC 4116 AS BINDERS IN PYROTECHNIC COMPOSITIONS

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JANUARY 1960

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319 700

ORDNANCE PROJECT - NONE

DEPT. OF THE ARMY PROJECT - NONE

COPY 27

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Technical Notes 40

Ordnance Project None

Dept of the Army Project None

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OBJECT

To establish alternates for Laminac resin 4116 as binders in pyrotechnic compositions.

To catalog the physico-chemical characteristics of 32 commercially available resins as a preliminary to the preparation of a specification.

SUMMARY

A study was conducted to determine the physico-chemical characteristics of 31 polyester resins and 1 epoxy resin, and, in addition, the burning characteristics (candlepower, duration, color value) of standard flare compositions containing these resins. The thermal behavior of the resins was also studied, with results which will be published under separate cover. No correlation could be obtained among the physico-chemical, illumination, and thermal characteristics of the resins.

Applying a statistical comparison of tolerance limits at the 95% confidence level indicated that the total integral light values (duration × candlepower) for standard flare compositions containing these resins are essentially the same.

A standard flare composition containing the best resin submitted by each manufacturer was subjected to a 12-month storage surveillance program at both elevated (76°C) and room temperatures. The luminosity and burning rate characteristics of all the compositions surveyed were essentially the same after such storage as those of the Laminac-containing composition.

INTRODUCTION

It was requested that a survey be conducted of commercially available polyester resins to establish alternates for Laminac resin 4116 (Ref 1). The use of Laminac resin 4116 in pyrotechnic compositions has steadily increased since it was first employed some years ago. It has therefore become desirable to have more than one source of supply for this type of material.

The specific physico-chemical parameters analyzed were viscosity, surface tension, hardness, shrinkage, thermal behavior, peak exotherms, gel and cure time duration, and the effect of typical flare composition ingredients on this duration. The effects of the polymers on the burning characteristics of the following composition were also determined and evaluated:

Composition	Percent by Weight
Magnesium, Atomized, 30/50 mesh	57
Strontium nitrate, Grade A, 34 microns	38
Resin (Resin - 98%; Lupersol - 1%; Nuodex - 1%)	5

Liquid organic polymerizable materials for use in pyrotechnic compositions were first developed in Germany during World War II (Ref 2). This work was necessitated by the shortage of presses required to consolidate the older dry-type compositions. It was found that the incorporation of self-hardening resins in flare compositions minimizes and in some instances eliminates the need for high consolidation pressures, and yet produces flares comparable in rigidity to those consolidated under very high pressures. These polyester resins are essentially esters manufactured from glycols and unsaturated acids containing monomeric cross-linking additives, such as styrene and diallyl phthalate, to cure the resin. When the resins are catalyzed, they undergo a transition from liquid to gel to cure (Ref 3).

RESULTS

When illumination characteristics were obtained for standard flare compositions containing the various polyester and epoxy resins, 28 of the 32 resins studied gave essentially the same total integral light values as Laminac resin 4116 (Table 1, p 10). This finding is based on a comparison of tolerance limits at the 95% confidence level (Table 2, p 11). No essential difference was apparent among the color values (C.I.E. coordinates) obtained for the resins evaluated (Table 1).

The polymerization data (Table 3, p 12) gave a wide range of values for the various parameters studied, except in the case of the Shore D hardness, where the majority of the resins approximated a value of 80.

Tests to determine the physical and chemical characteristics of these resins (Table 4, p 13) also yielded a wide range of values.

The effects of magnesium, sodium nitrate, and a magnesium-sodium nitrate mixture on the gel times of the different polymers were determined. Most of the results obtained indicated that the additives tend to prolong gel time (Table 5, p 14).

When the polyester resins were subjected to differential thermal analysis (Ref 4), most of them gave similar thermal degradation curves, the endothermal bands occurring between 250°C and 450°C. Two exceptions were Hetron-92, which was found to contain carbon-chlorine bonds, and ERL-2795, an epoxy resin, which underwent exothermal decomposition.

The candlepower values for compositions containing the various resins varied considerably throughout the storage life of the samples at both normal and elevated temperatures (Tables 6 and 7, pp 15 and 16, Figures 1 and 2, pp 17 and 18). The burning rate values showed considerable variation during the first month of storage at both temperature levels, but thereafter they remained essentially constant (Tables 6 and 7, pp 15 and 16, Figures 3 and 4, pp 19 and 20).

DISCUSSION OF RESULTS

Time-Intensity Characteristics

The time-intensity characteristics of a flare composition containing polyester or epoxy resins are tabulated in Table 1 (p 10). These data indicated that there is no meaningful relationship between the mean candlepower and burning rate values of the resins and their suitability as substitutes for Laminac 4116. To compare the time-luminous intensity values of the polymers, total candleseconds was used as the criterion. Candleseconds are the product of candlepower and burning time. The ratio of candleseconds to total weight (grams) or total volume (cubic centimeters) of composition indicates the efficiency of the flare composition. A cursory examination of the candlesecond values obtained showed that all the polyester resins had given essentially the same values. Since a more critical analysis of these values was desired, a statistical comparison of tolerance limits (Ref 5) was conducted at the 95% confidence level (Table 2, p 11). When the average total integral light figure for Laminac 4116 (3.3×10^6 candleseconds) is used as a standard and the tolerance limit obtained ($\pm 0.5 \times 10^6$ candleseconds) is applied, all integral light figures in the 2.8 to 3.8×10^6 candlesecond range are statistically identical. Hence, 28 of the 32 resins surveyed may be said to yield essentially the same total integral light values as does Laminac 4116. The exceptions are MR28-C, Aropol 7110, and Stypol 405, whose total integral light values (2.6, 2.7, and 2.7 c.s., respectively) fall outside the lower limit of 2.8×10^6 c.s., and Paraplex 43, whose total integral light value of 4.0×10^6 U.S. falls above the upper limit of 3.8×10^6 c.s.

It should be noted that, although the above four polyester resins fall outside statistically acceptable limits, from a practical point of view their performance is sufficiently similar to that of Laminac 4116 to be considered acceptable. In fact, the high integral light value obtained with one of these four resins, Paraplex 43, is the kind of performance that is sought in flare applications.

Resistance to Shock

It has been demonstrated that pyrotechnic compositions containing polyester resins can withstand severe setback forces and rough handling when consolidated at only moderate pressures. The disadvantages of employing polyesters are that they undergo an average shrinkage of some 10% on curing (Table 3, p 12) and that they produce a slag on combustion. Moreover, polyester resins in the final cure state do not have optimum hardness. A low hardness value is most desirable for binder applications. As has been observed, most of the resins have hardness values comparable to that of Laminac 4116 resin, which is classified as brittle. A more resilient resin gives better stability throughout the flare composition column, which is subjected to severe setback forces. In addition to greater resiliency, low shrinkage, such as is shown by Paraplex-444 and Paraplex-

13, is desirable. This quality obviates the need for flare case coatings and minimizes or eliminates the possibility of voids forming in the column.

The rate of polymerization (cure or gel time) of most polyester resins can be varied without incurring any changes in their physico-chemical characteristics. The peak exotherm is also dependent upon the rate of polymerization. Therefore, it is not considered important to discuss these parameters since they can be altered to fit any pot-life requirement. This is not true of the epoxy resin, because, with this material, changes in the ratio of resin and catalyst do result in changed physical and chemical characteristics.

Thermal Decomposition

The thermal decomposition curves of these resins (Ref 4) indicated varying degrees of similarity to Laminac 4116 resin. The resins were classified into four groups in terms of the closeness of similarity of their thermal spectra to that of Laminac 4116 resin (Table 4, p 13), and also into three groups (Table 4) on the basis of similarity of infrared spectra. The resins in group O do not belong in any specific category. The infrared classification showed that the majority of the polymers are similar to Laminac 4116.

Polyester resins for use in pyrotechnic compositions must have low surface tension and high viscosity (Table 4). These qualities make the resin a good wetting agent and enable it to disperse itself readily throughout the composition. These two characteristics tend to improve the quality of mixing and, consequently, the performance of the composition.

Acidity of Polymer

Of all the physical and chemical parameters studied, probably the most important and most frequently overlooked is the acidity of the polymer. The total acidity of the resins studied (Table 4) varied from 0 to 245, based on milligrams of sodium hydroxide per gram of resin. Acidic substances in flare compositions oxidize the metallic magnesium, thereby reducing the available fuel and, consequently, lowering the candlepower and burning rate. It can be seen from Table 4 that Laminac 4116 resin yielded an acid number of 25. Approximately 50% of the resins gave acid numbers lower than that of Laminac resin, which is desirable in view of the premise discussed above.

The use of additives can influence the gel time of the resins under test by either catalyzing or retarding the rate of polymerization of the resin (Table 5, p 14). As has been mentioned above, the rate of polymerization can be adjusted to individual needs without any deleterious effects, except in the case of ERL-2795 epoxy resin.

Storage Stability

A 12-month surveillance program was conducted on at least one resin received from each manufacturer. Samples were stored at both elevated (76°C) and room temperatures. Burning rate and candlepower values for standard flare compositions containing the assorted polymers are summarized in Tables 6 and 7. It may be observed from Figures 1 through 4 (pp 17 through 20) that the luminous intensities of the flare compositions varied considerably throughout their storage life at both elevated and normal temperatures. The burning rates of these systems varied during the first month of storage at both temperature levels, after which they remained essentially constant. It is noted that the same type of performance was obtained with the composition containing Laminac 4116 resin and the binary blend containing no resin. Since the binary mixture containing no polyester resin gave a significant variation in light output with storage time, it would appear that the use of polyester resins is not responsible for these variations, although they may well contribute to them. Another possibility that should be mentioned is that a substantial experimental error is inherent in the instrumentation that was used to obtain the luminosity values. It can be observed from the graphical illustrations that, for very large changes in candlepower, there is essentially no change in burning rate. This defies all logical reasoning since experience has shown that candlepower and burning rate are interdependent variables. On the basis of these findings, it is apparent that the polymers tested are comparable to Laminac 4116 resin in stability at elevated and normal temperatures.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the data obtained in this investigation, it is concluded that a majority of the polyester resins studied give stability and time-intensity data comparable to that of Laminac 4116. The wide range of values obtained for various physico-chemical parameters is believed to indicate that optimum performance can be obtained by using polyester resins whose physical and chemical properties fall within the following limits:

Acidity, milligrams of sodium hydroxide per gram of resin	0 - 120
Gel time, minutes	10 - 25
Maximum shrinkage, %	10
Viscosity, centipoises	300 - 600
Surface tension, dynes per centin..ter	36 - 65
Styrene content, %	25 - 40
Specific gravity at 25°C	1.01 - 1.16

It is recommended that these values be used in the preparation of a specification on "Polyester Resins for Use in Pyrotechnic Illuminant Compositions," for use in procuring such resins.

EXPERIMENTAL PROCEDURE

All experimental, blending and loading procedures were maintained constant throughout the program.

Materials Used

Magnesium, atomized, PA-PD-265, Type A, 30/50 mesh, 350 ± 50 microns, Golwynne Chemical Company

Strontium nitrate, nonhygroscopic, Grade A, 34 microns, AXS-1792, Davies Nitrate Company.

Sodium nitrate, double refined, USP, PA-PD-495, 38 microns, Davies Nitrate Company.

Lupersol DDM (Methylethylketone peroxide), Novadel-Agene Corporation. Nuodex (Cobalt naphthenate), Nuodex Corporation

Hardener-ZZLD-0814, Bakelite Company.

Resins:

MR-28C - Celanese Corporation

Selectron - 5027 - Pittsburgh Plate Glass Company

Aropol - 7110 - Archer - Daniels - Midland Company

Stypol - 405 - H.H. Robertson Company

Stypol - 4051 - H.H. Robertson Company

I.C. - 1154 - Interchemical Corporation

MX - 314 - Celanese Corporation

I.C. - 312 - Interchemical Corporation

Vibrin - 117 - Naugatuck Chemical Company

Laminac - 4134 - American Cyanamid Company

Paraplex - 49 - Rohm and Haas Company

Vibrin - 1088 B - Naugatuck Chemical Company

PLL - 4262 - Bakelite Company

ED - 199 - Archer-Daniels - Midland Company

Aropol - 7300 - Archer-Daniels - Midland Company

Polylite - 8007 - Reichhold Chemical Company

I.C. - 937 - Interchemical Company

Polylite - 8001 - Reichhold Chemical Company

Aropol - 7120 - Archer-Daniels - Midland Company

Pleogen - 1150 - American Petrochemical Corporation

I.C. - 401 - Interchemical Company

Glidpol - 1001-A - Glidden Company

Paraplex - 47 - Rohm and Haas Company

Paraplex - 13 - Rohm and Haas Company

Laminac - 4116 - American Cyanamid Company

Paraplex - 444 - Rohm and Haas Company

Paraplex - 43 - Rohm and Haas Company

ERL - 2795 - Bakelite Company

Hetron - 92 - Hooker Electrochemical Company

I.C. - 1191 - Interchemical Company

I.C. - 730 - Interchemical Company

Pleogen - 1006 - American Petrochemical Corporation

Blending

The strontium nitrate was weighed on a laboratory triple beam balance and transferred to a conductive rubber container. The magnesium was weighed and allowed to remain on the balance pan. The resin composition[1] was placed on top of the magnesium and weighed by difference. The mixture was then transferred directly to the Simpson Intensive Mixer, Model No 1. The mixer was operated for three minutes by remote control, stopped, and scraped down with a brass spatula. The remaining ingredients were then added and allowed to blend for a total uninterrupted period of 13 minutes. The flare composition was discharged into a safety-approved receptacle.

Loading

Each composition was consolidated into 1.3-inch-I.D. paper cases in one increment of 150 grams at a pressure of 4000 psi. The inside walls of the flare cases were coated with paraffin wax before loading.

Testing

Time-Luminous Intensity Characteristics

The time-luminous intensity characteristics of the flares were determined in accordance with Specification MIL-P-20464, except that a black background was used instead of a white one. The color characteristics were determined by the C.I.E. method.

Infrared Spectroscopy

The infrared spectra of the resin samples were obtained with a Perkin-Elmer Model 21 infrared spectrophotometer equipped with rock salt optics. Samples were mounted as laminar films between two salt plates.

Surface Tension

A Du Nouy tensiometer was used to determine surface tension.

[1] All of the resin compositions except ERL-2795 consisted of 98.5% resin, 1% Lupersol DDM, and 0.5% cobalt naphthenate. ERL-2795 contained 79.4% resin and 20.6% ZZLD-0814 hardener.

Viscosity

Viscosity was determined with a Brookfield viscosimeter.

Moisture Content

Polymerized Material. The procedure described in G.L.R. 56-HI-2014 was used.

Unpolymerized Material. The procedure described in Specification PA-PD-181 was used.

Chlorine

The chlorine content of the Hetron-92 resin was determined in accordance with the procedure described in Specification MIL-P-20307.

Total Acidity

The procedure used was taken from a Bjorksten Research Laboratories, Inc. report (p 234) titled "Polyesters and Their Applications," Reinhold Publishing Corporation, New York, 1956, except that sodium hydroxide was used instead of potassium hydroxide.

Carbon, Hydrogen, Oxygen Content

Percentages of these elements were determined in accordance with the procedure described in G.L.R. 56-HI-857.

Hardness

Hardness was determined with a Shore D hardness tester.

pH Value

The procedure described in Specification MIL-R-3745, para. 4.6., was used to determine all pH values.

Shrinkage

The percent shrinkage of each resin was determined by placing a known volume of catalyzed resin in a glass bottle and allowing it to polymerize. After polymerization, the sample was vibrated to loosen any material that might be stuck to the walls of the container. Distilled water was then titrated into the bottle to bring its contents back to their original volume. The difference between initial and final volumes was computed to determine percent shrinkage.

Heat of Combustion

The heat of combustion was determined in accordance with the procedure described in C.L.R. 127815.

Effect of Kind of Filler on Gel Time

The effect of different fillers on the gel time of resins was determined by blending equal weights of filler and catalyzed resin in a test tube and allowing the mixture to gel. The time to gel was determined by visual observation.

Gel and Cure Times

These values were determined by visual observation of the samples containing a 1% concentration of Lupersol

DDM and 0.5% concentration of Nuodex. The cure time was taken as the time to a tack-free sample.

Peak Exotherm

The peak exotherm developed during curing of the liquid resin to a solid resin was determined with a 20-gram sample of catalyzed activated resin. The exotherm curve of each resin was measured at room temperature (25°C).

REFERENCES

1. Belitsky, E., *Alternates for Laminac 4116 Resin,* Industrial Engineering Division Memorandum, Picatinny Arsenal, May 14, 1956

2. Eppig, H.J., and J.D. Strachan, *Self-Hardening Pyrotechnic Compositions,* Picatinny Arsenal Technical Report 1801, December 1950

3. Bjorksten Research Laboratories, Inc., *Polyesters and Their Applications,* Reinhold Publishing Corporation, New York, N.Y., 1956, pp 21-34

4. Anderson, D.A., and E.S. Freeman, *Differential Thermal Analysis of Saturated Polyesters,* Pyrotechnics Laboratory Technical Note No. 19, Picatinny Arsenal, March 1958

5. Dixon, W.J., and F.J.Massey, *Introduction to Statistical Analysis,* First Edition, McGraw-Hill Book Co., New York, N.Y., 1951, pp 110-111, 315 (Table 8) and 334 (Table 16)

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TABLE 1

Radiation Characteristics

Polyester Resins	Candlepower 1000 candles	Burning Rate inch/minute	Total Integral Light, 10^6c-s	CIE Coordinates x	CIE Coordinates y
Hetron-92	84.0	4.4	3.7	0.52	0.35
Paraplex-43	70.3	3.5	4.0	0.54	0.35
Paraplex-444	65.0	4.2	3.2	0.50	0.35
Laminac 4116	64.5	3.8	3.3	0.51	0.36
Paraplex-13	62.5	3.3	3.7	0.53	0.35
Paraplex-47	62.0	3.4	3.5	0.52	0.36
Glidpol-1001-A	61.2	3.5	3.4	0.52	0.35
Interchemical-401	60.5	3.9	3.5	0.57	0.32
Pleogen-1150	60.3	4.0	3.2	0.54	0.34
Aropol-7120	60.0	3.8	3.5	0.56	0.33
Polylite-8001	59.3	4.1	3.3	0.56	0.33
Interchemical-937	58.0	4.0	3.3	0.57	0.33
Polylite-8007	56.8	3.8	3.2	0.55	0.34
4116- 85%: 4134-15%	56.6	4.1	3.2	0.55	0.33
Aropol-7300	56.4	4.3	3.0	0.56	0.33
Pleogen-1006	56.4	4.1	3.0	0.55	0.34
ED-199	56.2	4.1	3.2	0.57	0.32
PLL-4262	56.0	4.1	3.1	0.58	0.32
Vibrin-1088-B	54.5	3.4	3.4	0.56	0.33
Paraplex-49	54.4	3.4	3.1	0.52	0.35
Laminac-4134	53.7	3.9	3.0	0.55	0.34
Vibrin-117	52.9	3.9	3.0	0.55	0.33
Interchemical-312	51.7	4.1	2.9	0.56	0.32
Celanese-MX-314	51.4	4.0	2.8	0.55	0.34
Interchemical-1191	51.4	4.0	2.9	0.56	0.33
Interchemical-730	51.4	3.7	3.1	0.57	0.32
Interchemical-1154	50.2	4.0	2.9	0.56	0.33
Stypol-4051	49.5	3.8	2.8	0.55	0.33
Stypol-405	49.1	4.0	2.7	0.55	0.34
Aropol-7110	49.0	4.2	2.7	0.56	0.33
Selectron-5027	48.4	3.7	2.9	0.55	0.34
Celanese MR 28-C	46.0	4.0	2.6	0.55	0.34
Epoxy Resin					
Bakelite ERL-2795	**81.2**	**5.1**	**3.8**	**0.59**	**0.30**

TABLE 2

Statistical Analysis of Total Integral Light Data*

Polyester Resins	Total Integral Light (candleseconds × 10^6) Maximum-Minimum Individual Values (R_i)
Hetron-92	0.5
Paraplex-43	0.8
Paraplex-444	0.1
Laminac-4116-21	0.7
Paraplex-13	1.4
Paraplex-47	0.4
Glidpol-1001-A	0.7
Interchemical-401	0.7
Pleogen-1150	0.4
Aropol-7120	0.7
Polylite-8001	0.5
Interchemical-937	1.2
Polylite-8007	0.6
4116-85%; 4134-15%	2.6
Aropol-7300	1.5
Pleogen-1006	0.8
ED-199	1.6
PLL-4262	0.7
Vibrin-1088-B	0.7
Paraplex-49	0.7
Laminac 4134	1.9
Vibrin-117	1.3
Interchemical-312	0.6
Celanese-MX-314	0.7
Interchemical-1191	0.6
Interchemical-730	1.3
Interchemical-1154	1.7
Stypol-4051	1.1
Stypol-405	0.5
Aropol-7110	0.8
Selectron-5027	0.9
Celanese MR28-C	1.3
Epoxy Resin	
Bakelite ERL-2795	1.4

Total Integral Light (ΣR_i values) = 31.4

Pooled Variance

$$Sp = \frac{-\Sigma R_i \times K}{n-1}$$

where: Sp = pooled variance
n = number of samples
ΣR_i = sum of R_i values
K = constant = 0.430

$$Sp = \frac{(31.4)(0.430)}{32} = 0.423$$

Tolerance Limits at 95% Confidence Level:

$$\bar{X} = \pm \frac{2.524 \times Sp}{\sqrt{n}}$$

where:
$\bar{X}$ = tolerance limit
Sp = pooled variance
n = number of samples in each group

$$\bar{X} = \pm \frac{(2.524)(0.423)}{\sqrt{5}} = \pm 0.478 = \pm 0.5$$

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*Dixon, W. J., and Massey, F. J., "*Introduction to Statistical Analyses,*" First Edition, McGraw-Hill Book Co., Inc. pp 110-111, 315 (Table 8) and 334 (Table 16), 1951

TABLE 3

Polymerization Data

Polyesters Resins	Gel Time minutes	Cure Time minutes	Peak Exotherm °C	Shrinkage Percent, (%)	Hardness Shore D
Hetron-92	11	25	127	7	88
Paraplex-43	80	217	Room Temp.	9	80
Paraplex-444	>1440	>1440	Room Temp.	2	75
Laminac-4116	13	50	132	8	81
Paraplex-13	37	248	Room Temp.	3	28
Paraplex-47	13	17	42	8	82
Glidpol-1001-A	14	18	132	8	82
Interchemical-401	–	–	–	8	25
Pleogen-1150	27	35	154	8	80
Aropol-7120	11	15	40	12	82
Polylite-8001	25	38	27	10	83
Interchemical-937	12	21	42	11	85
Polylite-8007	21	37	36	8	85
4116-85%; 4134-15%	9	18	69	8	55
Aropol-7300	23	32	36	10	20
Pleogen-1006	30	38	124	9	80
ED-199	16	20	32	13	80
PLL-4262	15	24	32	11	80
Vibrin-1088-B	24	34	46	8	85
Paraplex-49	5	9	42	8	88
Laminac-4134	17	45	83	7	25
Vibrin-117	12	38	54	8	85
Interchemical-312	7	13	42	11	85
Celanese-MX-314	38	48	28	11	25
Interchemical-1191	8	18	56	8	85
Interchemical-730	11	20	48	11	75
Interchemical-1154	16	25	38	7	75
Stypol-4051	26	41	134	9	86
Stypol-405	6	45	45	8	85
Aropol-7110	7	10	94	13	82
Selectron-5027	6	17	115	7	85
Celanese MR 28-C	27	38	50	13	85
Epoxy Resin					
Bakelite ERL-2795	17	18	208	0	80

TABLE 4

Physico-chemical Data

Polyester Resins	Surface Tension dyne/cm	Viscosity centipoise	Heat of Combustion, calorie/g	Infrared Group	Thermal Spectra Group	% Carbon	% Hydrogen	% Oxygen	% Chlorine	Total Acidity mg of sodium hydroxide per gram of resin
Hetron-92	47.0	4,000	5334	0	4	40.31	3.43	28.11	28.15	210
Paraplex-43	44.3	4,500	6643	1	3	64.78	5.48	29.74		60
Paraplex-444	54.7	5,300	5613	0	3	56.55	4.95	38.50		48
Laminac-4116	38.5	600	7160	1	1	51.22	4.44	44.34		25
Paraplex-13	36.6	600	7742	0	4	62.65	7.46	29.89		129
Paraplex-47	39.3	3,000	6722	3	3	62.02	6.77	31.21		85
Glidpol-1001-A	37.0	1,280	6816	1	3	51.03	5.83	43.14		106
Interchemical-401	54.6	400	7079	3	4	62.39	7.51	30.10		41
Pleogen-1150	36.0	1,680	6918	1	3	69.03	7.76	23.21		0
Aropol-7120	54.4	1,080	6933	1	2	68.80	4.53	26.67		8
Polylite-8001	56.0	4,080	6952	1	3	66.56	5.08	28.36		8
Interchemical-937	53.4	1,960	6854	1	1	64.34	5.49	30.17		0
Polylite-8007	53.7	1,360	7168	1	2	69.38	5.61	25.01		8
4116-85%; 4134-15%	36.0	1,000	7086	1	1	60.85	5.37	33.78		8
Aropol-7300	62.6	1,120	6686	2	3	62.14	7.95	29.91		148
Pleogen-1006	39.0	2,040	6830	1	1	66.29	2.30	31.41		0
ED-199	60.4	720	6868	1	3	64.16	6.38	29.46		58
PLL-4262	60.5	1,400	6824	–	4	63.38	6.53	30.09		0
Vibrin-1088-B	57.9	3,040	8149	2	4	72.40	8.01	19.59		41
Paraplex-49	41.5	3,750	6879	3	3	63.46	5.11	31.43		109
Laminac-4134	38.0	560	6709	0	1	45.56	5.58	48.86		57
Vibrin-117	60.3	1,360	6816	1	2	65.38	5.86	28.76		0
Interchemical-312	58.4	5,240	6659	1	1	66.71	5.96	27.33		0
Celanese-MX-314	60.7	1,960	6783	–	4	65.19	5.87	28.94		49
Interchemical-1191	59.5	too viscous	6664	1	1	65.55	6.82	27.63		0
Interchemical-730	56.8	5,200	6837	1	2	64.45	6.08	29.47		8
Interchemical-1154	56.3	2,240	6484	1	3	62.04	5.71	32.25		16
Stypol-4051	37.5	2,340	6750	2	1	65.02	6.24	28.74		151
Stypol-405	38.4	1,020	6888	2	4	67.10	5.85	27.05		100
Aropol-7110	65.4	10,960	6494	1	2	67.07	8.21	24.72		8
Selectron-5027	55.6	23,750	6440	1	3	65.35	5.65	29.00		245
Celanese-MR 28-C	59.5	3,140	6853	–	1	67.01	6.37	26.62		0
Epoxy Resin										
Bakelite ERL-2795	65.9	2,840	7629	–	4	72.31	6.74	20.95		0

TABLE 5

Effect of Additives on Gel Time of Resins

Polyester Resins	Resin Alone, minutes	With Magnesium, minutes	With Sodium Nitrate, minutes	With Magnesium/ Sodium Nitrate, minutes
Hetron-92	11	31	20	13
Paraplex-43	80	*dng 154	150	dng 125
Paraplex-444	>1440	dng 168	dng 160	dng 393
Laminac-4116	13	47	28	25
Paraplex-13	37	113	110	dng 180
Paraplex-47	13	13	10	15
Glidpol-1001-A	14	64	33	72
Interchemical-401		188	114	116
Pleogen-1150	27	dng 188	85	dng 332
Aropol-7120	11	17	4	6
Polylite-8001	25	23	31	30
Interchemical-937	12	12	11	11
Polylite-8007	21	60	31	37
4116-85%; 4134-15%	9	24	19	50
Aropol-7300	23	24	19	20
Pleogen-1006	30	166	57	dng 128
ED-199	16	18	16	16
PLL-4262	15	19	13	14
Vibrin-1088-B	24	38	26	39
Paraplex-49	5	16	15	17
Laminac-4134	17	64	79	
Vibrin-117	12	11	8	9
Interchemical-312	7	13	9	11
Celanese-MX-314	38	53	52	53
Interchemical-1191	8	16	11	14
Interchemical-730	11	15	10	12
Interchemical-1154	16	23	18	18
Stypol-4051	26	dng 96	50	dng 120
Stypol-405	6	40	19	dng 108
Aropol-7110	7	8	6	7
Selectron-5027	6	12	7	17
Celanese MR 28-C	27	22	16	17
Epoxy Resin				
Bakelite ERL-2795	17	11	25	17

* dng = did not gel after -- minutes

TABLE 6

Effects of 76°C Storage on Resins

Resin	Source	Initial Data Cp* 1000 cdle	Initial Data BR in/min	Initial Data TIL 10^6 cs	2 Weeks Cp 1000 cdle	2 Weeks BR in/min	2 Weeks TIL 10^6 cs	1 Month Cp 1000 cdle	1 Month BR in/min	1 Month TIL 10^6 cs	3 Months Cp 1000 cdle	3 Months BR in/min	3 Months TIL 10^6 cs	6 Months Cp 1000 cdle	6 Months BR in/min	6 Months TIL 10^6 cs	12 Months Cp 1000 cdle	12 Months BR in/min	12 Months TIL 10^6 cs
$Mg/NaNO_3$, 60/40	–	209	18.6	3.0	282	18.6	4.1	263	18.9	3.8	293	20.5	3.9	381	21.8	4.7	309	20.3	4.1
Paraplex-13	Rohm-Haas	131	4.2	7.3	182	5.2	8.1	136	5.1	6.2	163	5.0	7.6	145	4.9	6.9	193	4.7	9.7
Hetron-92	Hooker Electro	145	5.2	6.7	157	5.7	6.6	126	5.8	5.2	165	6.0	6.6	164	5.7	6.9	181	5.8	7.5
Laminac-4116**	American Cyana.	133	3.8	8.3	151	4.5	7.8	134	4.5	7.0	157	4.7	7.9	161	4.6	8.2	178	4.4	9.4
Paraplex-43	Rohm-Haas	108	4.7	5.5	132	5.6	5.7	143	5.9	5.8	178	5.6	7.7	141	5.5	6.1	161	6.1	6.3
Stypol-4051	HH Robertson	120	4.8	6.0	135	6.2	5.2	142	5.9	5.7	163	5.7	6.9	157	5.8	6.5	169	6.4	6.4
Laminac-4116***	American Cyana.	112	4.6	5.9	169	6.2	6.5	201	6.0	8.1	158	5.2	7.3	192	6.3	7.3	160	5.9	6.5
Pleogen-1150	American Petro	97	5.2	4.7	142	5.9	6.1	117	6.4	4.6	153	6.1	6.4	137	6.2	5.6	154	6.3	6.2
Vibrin-1088B	Naugatuck Chem	116	4.8	6.1	201	6.6	7.7	192	7.6	6.3	180	7.2	6.3	214	6.4	8.4	165	6.5	6.3
I.C.-401	Interchemical	144	4.5	7.3	208	7.3	6.5	214	7.6	6.4	198	7.9	5.7	207	6.5	7.2	182	6.2	6.7
Polylite-8001	Reichhold Chem	141	5.4	6.2	238	6.8	8.2	232	7.4	7.3	195	7.0	6.5	225	7.0	7.6	157	6.0	6.1
MX-314	Celanese Corp.	159	5.3	7.0	229	7.4	7.3	241	8.2	6.9	240	7.8	7.2	239	7.1	7.8	173	6.6	6.1
Selectron-5027	Pittsburgh Plate	118	5.1	5.5	204	6.5	7.6	224	7.1	7.6	192	6.6	7.0	213	6.5	7.7	183	6.5	6.8
PLL-4262	Bakelite Co.	135	5.1	6.5	166	5.8	7.1	182	6.8	6.6	159	6.2	6.4	187	6.4	7.2	140	5.7	6.1
Aropol-7120	Archer Daniels	123	5.2	5.7	205	6.0	8.2	217	7.3	7.1	183	6.7	6.6	199	6.3	7.5	176	6.1	6.9
Glidpol-1001-A	Glidden Co.	135	4.9	6.4	219	6.4	8.0	213	7.1	7.0	181	6.9	6.2	186	6.4	6.8	157	6.0	6.1
ERL-2795	Bakelite Co.	137	5.0	6.9	161	4.9	8.2	190	6.2	7.8	166	5.8	7.1	167	5.4	7.8	188	5.7	8.3

*Cp - Candlepower
BR - Burning Rate
TIL - Total Integral Light

**Control for Paraplex-13 and Hetron-92

***Control for all resins except Paraplex-13 and Hetron-92

TABLE 7

Effects of Ambient Storage on Resins

Resin	Source	Initial Date Cp* 1000 cdle	Initial Date BR in/min	Initial Date TIL 10^6 cs	2 Weeks Cp 1000 cdle	2 Weeks BR in/min	2 Weeks TIL 10^6 cs	1 Month Cp 1000 cdle	1 Month BR in/min	1 Month TIL 10^6 cs	3 Months Cp 1000 cdle	3 Months BR in/min	3 Months TIL 10^6 cs	6 Months Cp 1000 cdle	6 Months BR in/min	6 Months TIL 10^6 cs	12 Months Cp 1000 cdle	12 Months BR in/min	12 Months TIL 10^6 cs
$Mg/NaNO_3$ 60/40	–	209	18.6	3.0	250	21.1	3.2	274	19.1	4.0	238	20.6	3.1	337	20.3	4.5	281	20.2	3.8
Paraplex-13	Rohm-Haas	131	4.2	7.3	124	4.6	6.7	159	4.8	7.8	145	5.3	6.4	170	5.1	7.8	196	5.3	8.6
Hetron-92	Hooker Electro	145	5.2	6.7	149	5.2	6.8	151	5.3	6.9	156	5.1	7.3	157	5.1	7.4	156	5.2	7.3
Laminac-4116**	American Cyana.	133	3.8	8.3	134	3.7	8.4	131	3.8	8.0	135	4.0	8.0	134	4.1	7.6	155	4.1	8.9
Paraplex-43	Rohm-Haas	108	4.7	5.5	122	5.1	5.8	147	5.1	7.0	144	5.1	6.8	155	5.1	7.3	155	5.3	7.0
Stypol-4051	HH Robertson	120	4.8	6.0	121	5.4	5.4	111	5.3	5.1	145	5.4	6.5	136	5.5	5.9	162	5.3	7.4
Laminac-4116***	American Cyana.	112	4.6	5.9	117	4.9	5.8	114	4.8	5.7	142	5.2	6.7	151	5.2	7.0	131	5.0	6.3
Pleogen-1150	American Petro	97	5.2	4.7	135	5.9	5.8	123	5.8	5.4	142	5.8	6.2	140	5.6	6.2	152	5.6	6.8
Vibrin-1088B	Naugatuck Chem	116	4.8	6.1	130	5.6	5.8	121	5.2	5.9	132	5.4	6.2	135	5.2	6.6	123	4.9	6.3
IC-401	Interchemical	14[illegible]	4.5	7.3	169	4.9	7.9	144	4.8	6.8	160	4.9	7.4	150	4.7	7.5	181	5.1	8.0
Polylite-8001	Reichhold Chem.	141	5.4	6.2	154	5.4	6.7	158	5.5	6.7	149	5.6	6.3	162	5.4	7.1	163	5.4	7.1
MX-314	Celanese Corp.	159	5.3	7.0	161	5.4	7.0	161	5.6	6.7	157	5.6	6.5	170	5.4	7.5	170	5.3	7.5
Selectron-5027	Pittsburgh Plate	118	5.1	5.5	150	5.4	6.7	155	5.9	6.3	131	5.4	5.9	155	5.3	7.0	164	5.3	7.5
PLL-4262	Bakelite Co.	135	5.1	6.5	153	5.2	7.3	139	5.3	6.4	168	5.5	7.5	156	5.2	7.3	167	5.2	7.9
Aropol-7120	Archer Daniels	123	5.2	5.7	133	5.0	6.4	125	5.1	5.9	155	5.1	7.3	150	5.2	6.9	146	4.9	7.1
Glidpol-1001-A	Glidden Co.	135	4.9	6.4	131	5.3	5.8	152	5.3	6.7	160	5.3	7.1	163	5.2	7.2	171	5.2	7.7
ERL-2795	Bakelite Co.	137	5.0	6.9	143	4.8	7.5	129	5.0	6.6	158	4.4	8.9	141	4.5	7.9	166	4.6	9.0

*Cp - Candlepower
BR - Burning Rate
TIL - Total Integral Light

**Control for Paraplex-13 and Hetron-92

***Control for all resins except Paraplex-13 and Hetron-92

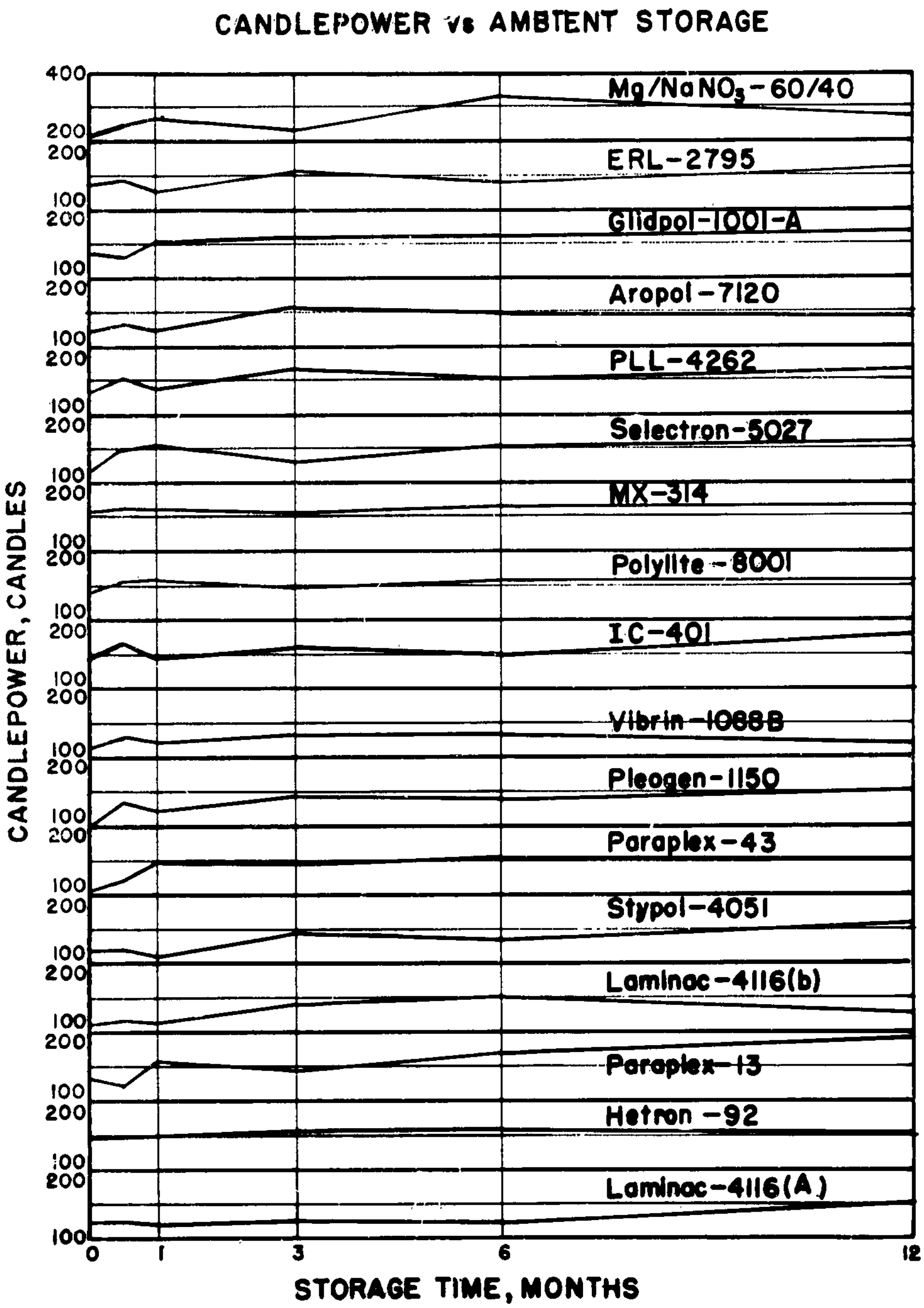

Fig 1 Effect of 76°C Storage on Candlepower of Flare Compositions Containing Various Resins

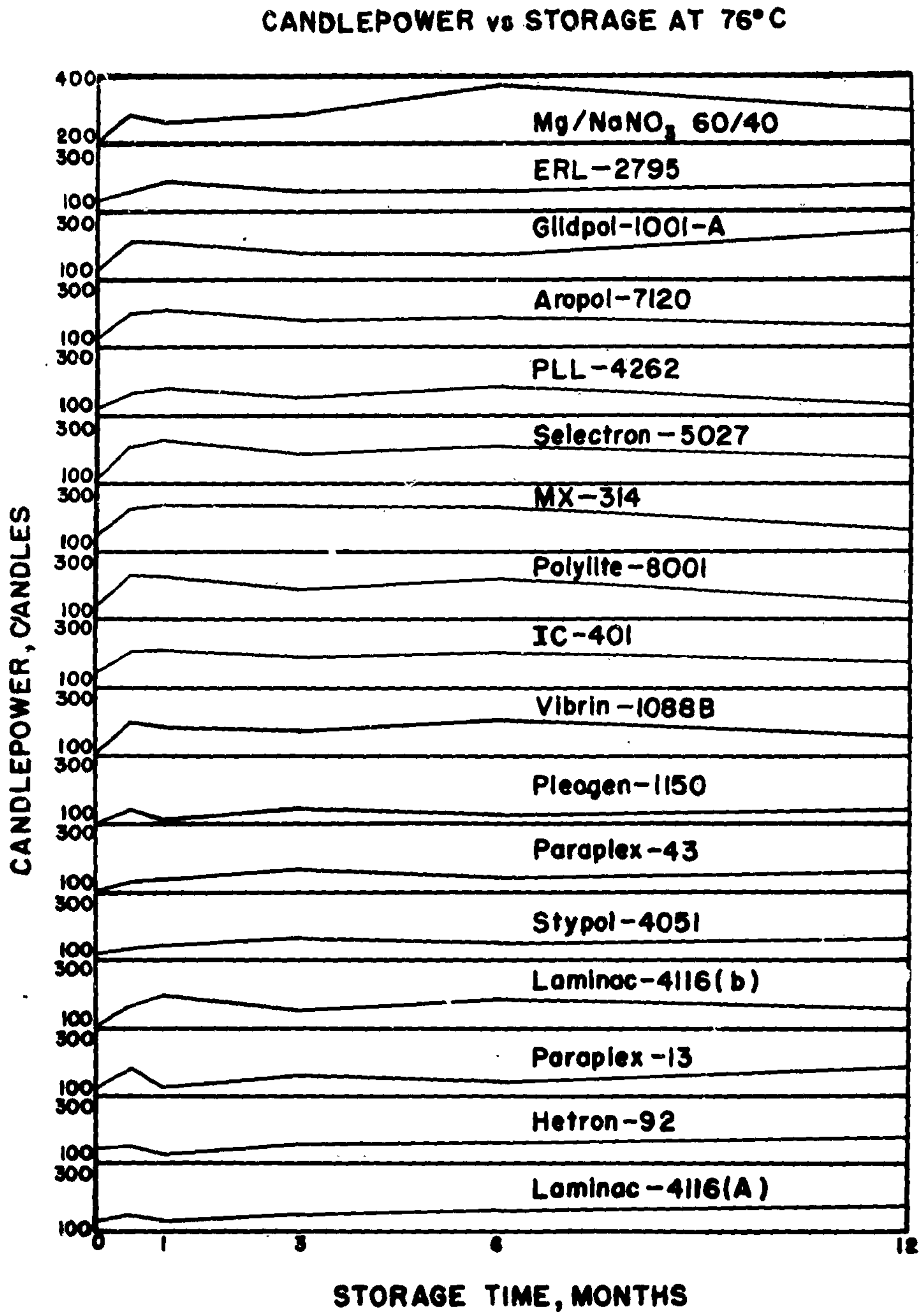

Fig 2 Effect of Ambient Storage on Candlepower of Flare Compositions Containing Various Resins

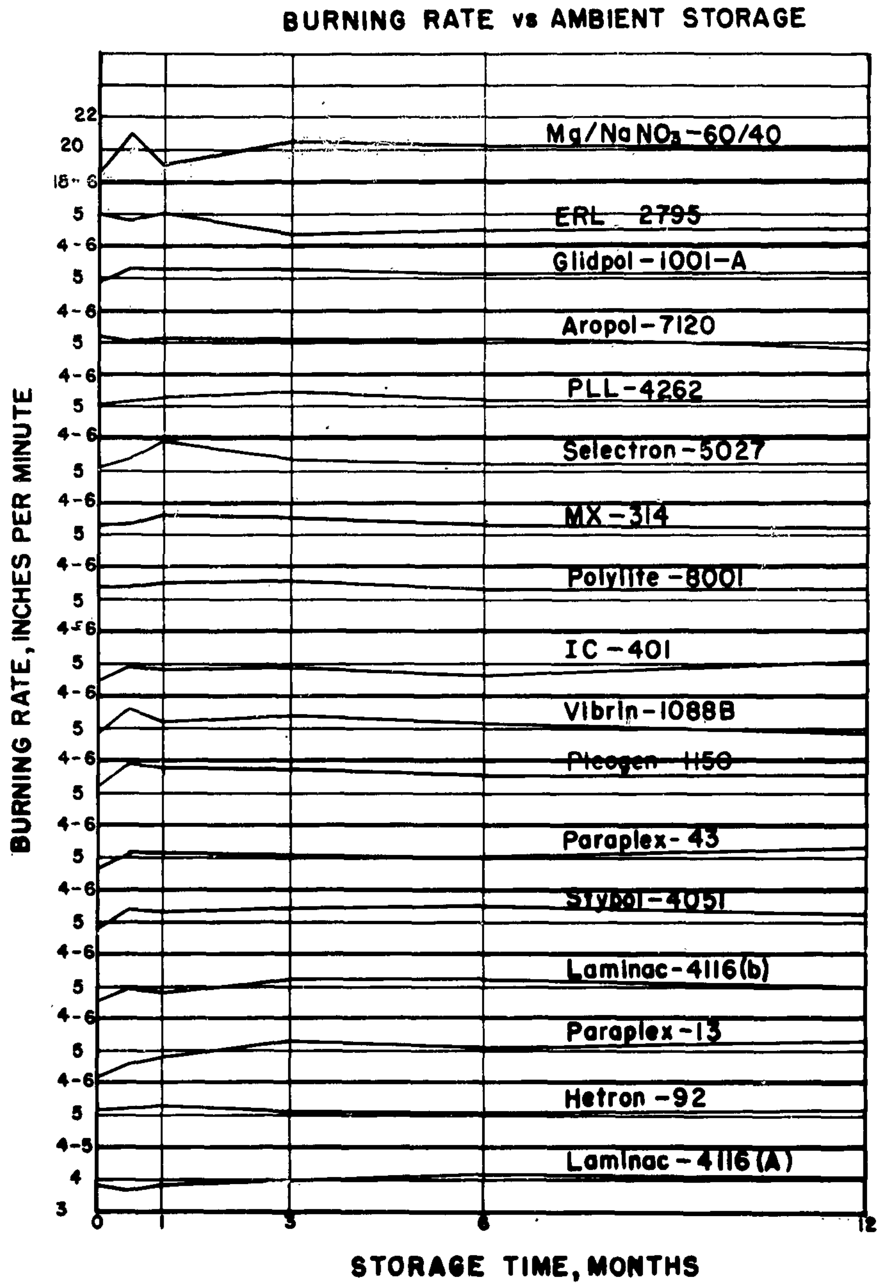

Fig 3 Effect of 76°C Storage on Burning Rate of Flare Compositions Containing Various Resins

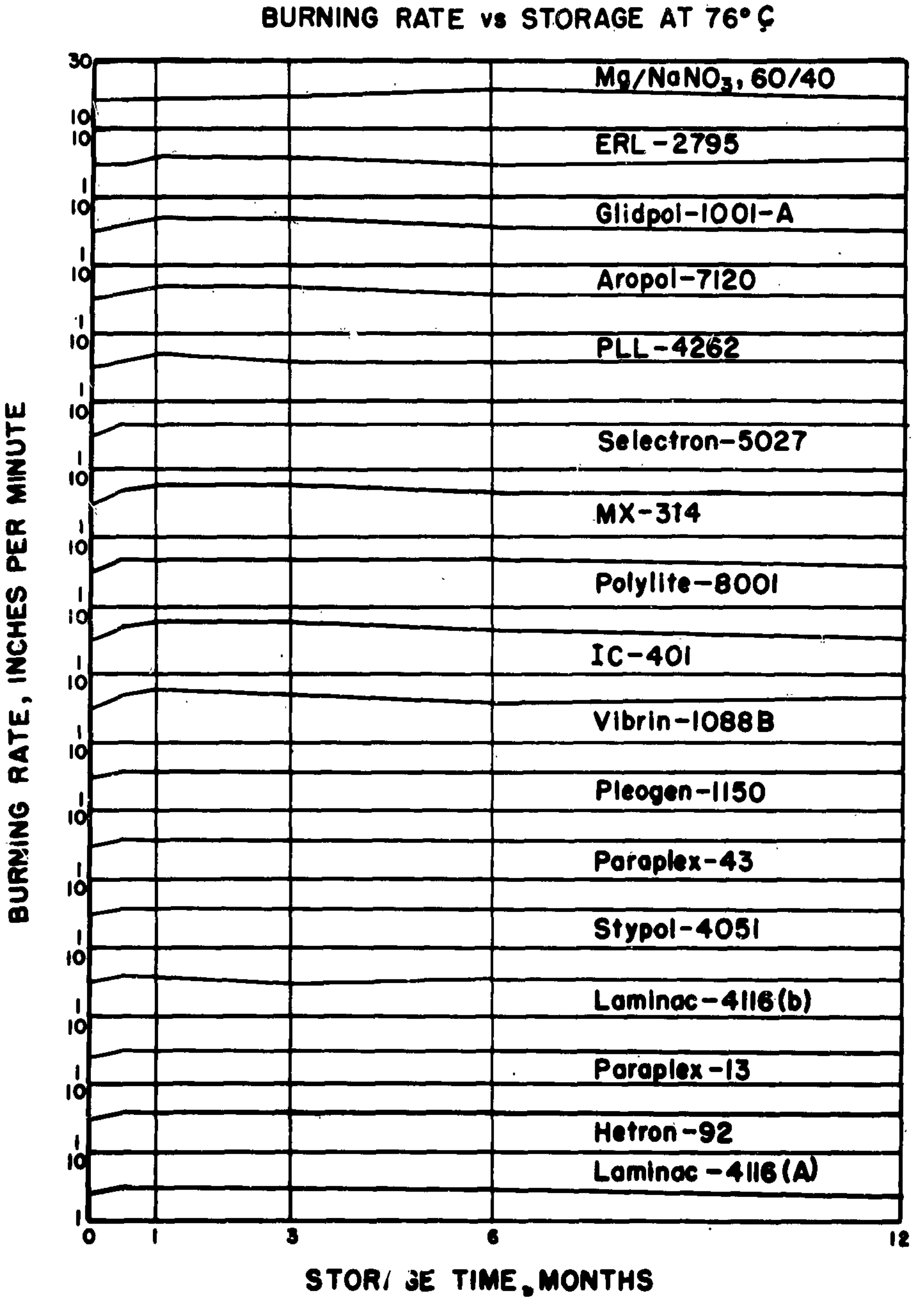

Fig 4 Effect of Ambient Storage on Burning Rate of Flare Compositions Containing Various Resins

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